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Comprehensive Wealth, Intangible Capital, and Development

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Abstract

Existing wealth estimates show that in most countries intangible capital is the largest share of total wealth. Intangible capital is calculated as the difference between total wealth and tangible (produced and natural) capital. This paper uses new estimates of total wealth, natural capital, and physical capital for a panel of countries to shed light on the constituents of the intangible capital residual. In a development-accounting framework, the authors show that factors of production are very successful in explaining the variation in output per worker when they use intangible capital instead of human capital as a factor of production. This suggests that intangible capital captures a broad range of assets typically included in the total factor productivity residual. Human capital is an important factor, both in statistical and economic terms, in regressions decomposing intangible capital.

This paper—a product of the Environment and Energy Team, Development Research Group—is part of a larger effort in the department to extend the national accounts to include more comprehensive measures of the wealth of nations. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at khamilton@worldbank.org.

Comprehensive Wealth, Intangible Capital, and Development

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Comprehensive Wealth, Intangible Capital, and Development

1. Introduction

It has been understood since at least the time of Irving Fisher (Fisher 1906) that income is the return on wealth. But if we scale this idea up to the level of the national economy, we arrive at a puzzle. If we measure wealth only as produced capital, we see from the national balance sheet accounts of countries such as Canada that wealth is only a small multiple of gross national income, implying unrealistically high rates of return on wealth.

Table 1 shows Canadian figures for 2009. The value of produced capital is less than three times GNI, while net worth (the sum of produced capital, commercial land and net financial assets) is a bit less than four times GNI – the implicit rates of return on wealth are correspondingly high, 35.9% and 25.4%, respectively. Canadians appear to be very productive.

The 'solution' to this puzzle, of course, is that the national balance sheets of the system of national accounts (SNA) exclude many intangible[1] asset values, such as human capital and the value of social / institutional capital. Moreover, the Canadian balance sheets highlighted in Table 1 exclude the value of commercial natural resources.[2] Since a 'normal' rate of return on assets should be on the order of 5%, a comprehensive measure of national wealth should be on the order of 20 times national income.

Hamilton and Hartwick (2005) show how to estimate a comprehensive measure of national wealth for a competitive economy with constant returns to scale. For production $F = F(K, L, R)$ with production factors K (produced capital), labor L, natural resource flow R, and interest rate r (equal to the marginal product of capital), comprehensive wealth is given by

$$W = K + H + S = \int_t^\infty C(s) \cdot e^{-\int_t^s r(z)dz} ds \qquad (1)$$

That is, comprehensive wealth can be measured either by adding up asset values K, H (human capital) and S (natural resource stock)[3] or by measuring the present value of consumption C along the competitive development path. The intuition behind expression (1) is that in the long run a country must consume within its possibilities, which are given by the sum of all its assets.

[1] The SNA has precise definitions for intangible fixed and intangible non-produced assets, which include items such as mineral exploration expenditures and the value of patents. In this paper we use the term 'intangible' to include all non-physical, non-financial assets.

[2] While SNA 1993 (United Nations 1993) requires the inclusion of the value of commercial natural resources in the balance sheet accounts, to date only Australia has published such accounts.

[3] Note that L and R are flows of inputs, measured in worker-hours or barrels of oil, whereas H and S are asset values measured in dollars.

It is then possible to derive the following result from Hamilton and Hartwick (2005): if interest rate r is constant, δ is the depreciation rate for produced capital, and $F_R R$ is the value of resource depletion, then net income is just equal to the return on total wealth, i.e.

$$C + \dot{K} - \delta K - F_R R = rW = r\int_t^{\infty} C(s) \cdot e^{-r(s-t)} ds \, . \qquad (2)$$

Given the difficulty in obtaining monetary estimates for intangible assets, in this paper we compute intangible capital (IC) as a residual by subtracting the values of produced capital, natural capital and net financial assets from the value of comprehensive wealth. Our estimates of comprehensive wealth are calculated according to the RHS of (1) as the present discounted value of future consumption. Human capital is therefore implicitly included in the intangible capital residual along with institutional, social capital and other missing asset values, e.g. diamonds and fisheries, for which data are not widely available.

For most of the countries in our sample, IC is the biggest contributor to total wealth; it represents, on average, more than 60 percent of comprehensive wealth. The finding of a large intangible capital residual is reminiscent of the finding in the development accounting literature of large cross-country differences in total factor productivity (TFP), after controlling for physical and human capital (see e.g. Klenow and Rodriguez Clare, 1997; Hall and Jones, 1999). The conventional wisdom is that "more than half of the variation in income per capita results from differences in TFP. And the same applies to differences in growth rates of income per capita: more than half of the variation results from differences in TFP growth. Students of economic growth have concluded from this evidence that, in order to understand the growth of nations, it is necessary to develop a better understanding of the forces that shape total factor productivity" (Helpman, 2004, p34).

In Section 3, we bridge the growth/development accounting literatures and the wealth accounting literature. First, in the tradition of the development accounting literature, we show that differences in physical capital, natural capital, and human capital per worker explain only between 20 and 43 percent of the variation in output per worker in our sample. However, if we use intangible capital instead of human capital, variation in factors of production explains 97 percent of the variation in output per worker. This is precisely what we would expect if intangible capital is indeed measuring a wide range of assets (human, social, institutional, etc.). The contribution of TFP to explaining the variation of output per worker should be small - zero in the limit. This result confirms what we know from the definition of intangible capital: it encompasses not only human capital but any other assets, such as institutional or social capital, which constitute the residual left when produced and natural capital are subtracted from total wealth. Second, in the tradition of the growth accounting literature, we estimate a production function from which the shares of produced, natural and intangible capital in production can be derived. Although both these approaches shed light on the contribution of intangible capital to explaining output per worker, they do not directly address the question of what constitutes intangible capital.

In Section 4, we directly investigate the composition of intangible capital, by analyzing the relative contributions of human capital and institutional/social capital using regression analysis. As in World Bank (2006), potential correlation between the regressors and the error term (arising, for example, from measurement error or omitted variable bias) is an issue in the empirical estimation. The intangible capital residual includes, by construction, (i) any assets not accounted for in the tangible capital estimates, for example, some minerals (e.g. diamonds, platinum), fisheries and groundwater, not accounted for in the calculation of natural capital, and (ii) any errors in the estimation of tangible capital and/or of total wealth.

Unlike World Bank (2006), we have a panel dataset with observations for 115 countries for the years 1995, 2000 and 2005. The use of country and time fixed effects helps us to mitigate omitted variables bias as long as the unobserved variables are constant over time and/or across countries. In addition, we take a number of steps to reduce measurement error in the variables used in the analysis. Our indicator of intangible wealth accounts for net foreign financial assets; we use several indicators of human capital that are a function of health status in addition to years of schooling; we analyze the robustness of the results to alternative measures of institutional capital and to the exclusion of outliers. Finally, we estimate an instrumental variables regression in which differences in European settler mortality rates (from Acemoglu, Johnson and Robinson, 2001), distance from the equator, and the percentage of the population speaking a Western European language as their first language today (from Hall and Jones, 1999), are used as instruments for current institutions and human capital. Overall, our results show that human capital is an important factor, in both statistical and economic terms, in explaining intangible capital.

2. Data

2.1 Intangible capital

We compute intangible capital for over 100 countries for the years 1995, 2000 and 2005 by subtracting produced capital, natural capital and net foreign financial assets from total (comprehensive) wealth. Our estimates of comprehensive wealth and its "tangible" components are from World Bank (forthcoming).

Applying expression (1), World Bank (forthcoming) calculates comprehensive wealth as the present discounted value of future consumption.[4] To test whether these comprehensive wealth

[4] The computation is performed for a time horizon of 25 years, which roughly corresponds to a generation. Assuming that the elasticity of utility with respect to consumption is one and that consumption grows at a constant

estimates make sense, we use data from World Bank (2010) to calculate net income, and then apply expression (2) in order to derive the implicit rate of return on comprehensive wealth in each country. The distribution of rates of return is plotted in Figure 1, which shows that 80% of the rates lie between 4% and 6%.

Produced capital stocks are derived from historical investment data using a perpetual inventory model. Most natural resources are valued by taking the present value of resource rents—the economic profit on exploitation—over their assumed lifetime. Resources considered include energy, mineral, timber and non-timber forest resources, cropland, pastureland and protected areas.

Finally, the wealth estimates in World Bank (forthcoming) account for ownership of capital. The interest payments derived from foreign financial assets or obligations will affect future levels of consumption of the country's residents and, by construction, total wealth. The adjustment to the wealth estimates to account for ownership is particularly important in the light of the acceleration in cross border asset trade observed in the last decades.[5]

By definition intangible capital includes any asset other than physical capital, natural resources and net foreign assets. It thus includes human capital—the sum of knowledge, skills, and know-how possessed by the population. It includes the institutional and social infrastructure of the country. It also includes resources omitted in the natural capital calculations such as subsoil water, diamonds, and fisheries.[6]

Table 2 presents descriptive statistics of total wealth and its components. Our sample includes an unbalanced panel of 115 developed and developing countries for years 1995, 2000 and 2005 (total of 315 observations). All the numbers in Table 2 are expressed in per capita terms in constant 2005 US$. For most countries in our sample, intangible capital is the largest component of total wealth; on average it constitutes 64 percent of total wealth, although it varies from a minimum of 5 percent in Uganda to a maximum of 90 percent in St. Lucia. Figure 2a shows that intangible capital is positively correlated with income. This is not surprising. As shown in Panel B of Table 2, except for net foreign assets, richer countries have, on average, more capital than

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rate, the expression for total wealth can be simplified to $W = \int_t^\infty C(t) \cdot e^{-\rho(s-t)} ds$, where ρ, the pure rate of time preference, is assumed to equal 1.5 percent. For more details please see World Bank (forthcoming).

[5] An indicator of financial integration used by Lane and Milesi-Ferretti (2007), the sum of external assets and liabilities over GDP, has risen steadily in both developing and developed countries, more markedly in the latter, where it increased by a factor of 7, from 45% in 1970 to over 300% in 2004, with a clear acceleration in the mid 1990s.

[6] Owing to data limitations no explicit value for ecosystem services is estimated. However, the services provided by ecosystems, such as the hydrological functions of forests and the pollination services of insects and birds, are indirectly captured in the natural wealth estimates through the values of cropland and pastureland.

poorer countries for each capital category.[7] The share of intangible capital in total wealth is also positively correlated with income, as shown in Figure 2b. For the OECD countries, this share is on average 78 percent and always larger than 60 percent. Panel B in Table 2 also shows IC increasing over time, in absolute value and as a percentage of total wealth. The *z*-statistic for a test of a difference between the means in the IC shares in years 2005 and 1995 is 1.12.

2.2 Human capital

The analysis in World Bank (2006) suggests that the value of the stock of human capital is a large component of a country's wealth. This fits well with the intuition that an important asset of a country is its people. Not surprisingly, the statistical agencies in some developed countries are starting to systematically compile human capital accounts to monitor the evolution of the stock of human capital. A method typically employed to value the stock of human capital in dollars is the lifetime income approach of Jorgenson and Fraumeni (1989, 1992a, 1992b). Under this approach, human capital is valued as the net present value of the income flow it produces over an assumed lifetime. In practice, the application of the method requires information on survival, enrollment and employment probabilities as well as earnings, by sex, age and educational attainment. Although these are relatively modest informational requirements, applying this method to a cross section of countries is impracticable.

Most of the empirical studies studying the role of human capital on growth and development accounting have focused instead on a cost-based approach to measure human capital. In order to increase future labor productivity and future income, people forgo consumption and invest in education. The human capital embodied in the labor force can then be seen as a function of education. Even accepting education as a valid proxy for investment in human capital, the relationship between education and human capital needs to be correctly specified.[8] The current consensus relies on a log-linear specification between earnings and years of schooling first formulated by Mincer (1974), to express the human capital per worker as an exponential function of the years of schooling, $h = e^{\phi(N)}$, where the function $\phi(N)$ represents the efficiency of a unit of labor with N years of schooling relative to one with no schooling (for reviews see Krueger and Lindahl, 2001; Woessman, 2003). We follow common practice and use $\phi(N) = r_e N$, where r_e is the rate of return to education.

We made different assumptions regarding the returns to education. Our benchmark is r_e=8.5 percent return on years of schooling as in Arrow et al. (2010) and Klenow and Rodriguez-Clare

[7] This is also true for aggregate natural resource stocks; the simple correlation between GNI per capita and the natural resource stock per capita for the countries in our sample is 0.44.

[8] For example, Klenow and Rodriguez-Clare (1997) show that using secondary school enrolment rates as proxies for human capital in Mankiw, Romer and Weil (1992) exaggerates the role of human capital in explaining differences in output per worker, as secondary enrolment varies more than other (preferable) measures of human capital. The results of Mankiw Romer and Weil (1992) are not robust to expanding the human capital estimator to include primary and terciary education or to using an alternative human capital estimator based on Mincerian regressions.

(1997, 2005) -this is the average of returns to education in Psacharopoulos and Patrinos (2004). The results did not change when we adjusted the returns to education to account for differences in educational quality across countries. In this case, $\phi(N) = r_e QN$, where *Q* is a country-specific educational quality index, as in Hanushek and Kimko (2000).[9]

We also used two alternative data sources for years of schooling, *s*, as an indicator of the level of educational attainment in the labor force: Barro and Lee (2001) and Cohen and Soto (2007).[10] In this paper we present the results for the human capital indicator based on Barro and Lee's years of schooling. This reduces our sample to 112 countries and 309 observations. When the human capital indicator was based in Cohen and Soto's *N*, the estimates were robust, if a bit less precise, but the sample size further dropped, by 20 percent (from 112 to 88 countries, or from 309 to 253 observations).

Finally, we augment our indicator of human capital to account for the health of the population and of the working force;

$$h = A_h e^{\phi(N)} \qquad (3)$$

A_h can be expressed as $A_h = e^{\rho_{ASR} ASR}$ as in Caselli (2005), where *ASR* is the adult survival rate. Shastry and Weil (2003) argue that differences in health status proxied by adult mortality rates map into substantial differences in energy and capacity for effort. Caselli (2005) finds that correcting the standard human capital measures to account for health, proxied, as in our case, by adult survival rates (*ASR*), increases the percentage of cross-country income variance attributed to physical and human capital by almost one third. In Weil (2007) accounting for health differences reduces the variance of log GDP per worker by 9.9 percent.

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[9] Hanushek and Kimko (2000) combine the results of cognitive achievement tests in mathematics and science into two educational quality indexes. We take an average of the two indexes and, as Woessman (2003), normalize the educational quality index for each country relative to the US. Woessman argues that the US is a good reference country as the returns to schooling should be relatively undistorted in the competitive US labor market. Data are available for 80 countries in our sample.

[10] From both data sets we take the years of schooling in the population aged 15 and over because this age group corresponds better to the labor force for most developing countries (the majority in our sample) than the population aged 25 and over (Woessman 2003, p.256). The Barro and Lee dataset contains the average years of schooling in 5-year intervals from 1960 to 1995 and projections for 2000. Values for 2005 were predicted by using a linear trend fitted from the observations between 1960 and 2000. When a country-specific growth rate in the years of schooling could not be calculated, the regional average growth rate was used. A visual inspection of the data suggests that a linear trend is a good approximation. A caveat, however, is that educational attainment is asymptotically a constant, and by fitting a linear trend we may overstate the educational attainment for the countries that have reached the asymptote. This would affect mainly OECD countries. Our second source for schooling data (Cohen and Soto, 2007) suggests that this may not be a problem. Virtually all the developed countries with the exception of Norway and Sweden exhibit more years of schooling in this second dataset for all the years considered, including 2005. For Norway and Sweden, the largest difference between the two datasets is 0.52 years of schooling. Cohen and Soto (2007) report educational attainment for the years 1990, 2000, and a projection for 2010. Since we are interested in the years 1995 and 2005, averages of 1990 and 2000 values were taken for 1995 and of 2000 and 2010 for 2005.

Adult survival rates are available in consistent form for a large cross-section of countries from the WDI.[11] The ASR has the advantage of measuring survival during working years (15-60), and thus seems likely to be a good measure of health during working years, which is what should be most relevant for determining the level of output per worker (Weil 2007). Weil (2007) estimates a value of ρ_{ASR} =0.653.

Table 2 reports descriptive statistics for years of schooling and human capital for all the countries in the sample (Panel A) and subsamples according to level of economic development and year (Panel B). Notice that while other capital assets in Table 2 are expressed in dollars, human capital is the 'physical' human capital embodied in a worker as expressed in (3).

2.3 Institutional capital

As in World Bank (2006) our indicator for institutional capital is a rule of law index from Kaufmann, Kraay and Mastruzzi (2009). It measures the extent to which agents have confidence in and abide by the rules of society. In particular, it measures the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.[12]

In their Worldwide Governance Indicators (WGI) research project, Kaufmann, Kraay and Mastruzzi, provide data on five additional dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality and control of corruption. These indicators are highly correlated -the lowest pair-wise correlation coefficient in our sample is 0.76 between political stability and regulatory quality.

An argument employed in World Bank (2006) to use the rule of law indicator, is that it captures well some of the features of a country's social capital, in particular trust. The correlation between a generalized trust indicator in Paldam and Svendsen (2006) and rule of law, 0.51, is larger than for other indicators of governance.

As an alternative, we averaged the six governance indicators. Many previous studies have averaged or summed governance indicators, with the rationale being that averaging reduces measurement error if the indicators pertain to similar underlying concepts of governance and have independent errors (e.g. Wheeler and Mody, 1992; Mauro, 1995; Chong and Calderon, 2000). In Section 4 we report results for the rule of law index but the results were robust to the use of an aggregate indicator.

[11] Adult mortality rates (AMR) are calculated as the weighted average of male and female adult mortality rates (series SP.DYN.AMRT.MA and SP.DYN.AMRT.FE, respectively) available from the WDI (2008). For Australia, Canada, Germany, Italy and the US, 2005 rates are missing so 2004 values are used instead. ASR=1-AMR.

[12] In the original dataset, the rule of law index ranges between -2.69 and 2.12; we rescaled it between 1 and 100.

3. Bridging the development accounting and wealth accounting literatures

There is an obvious parallel between our finding of a large intangible wealth residual and the finding in the growth and development accounting literatures that a residual, TFP, accounts for more than 50 percent of the variation in income per capita.

Development accounting tries to identify the basic determinants of income levels. Conceptually, it can be thought of as quantifying the contributions of factor inputs and productivity to economic performance:

Y=F(Factors, Productivity).

More specifically, development accounting calculates the relative contributions of measurable input quantities –physical and human capital- and the total factor productivity (TFP) residual in explaining cross-country differences in income levels.

In performing a development accounting exercise, the starting point is a Cobb-Douglas production function, in which we include natural resources, *S*, as a factor of production, in addition to physical capital, *K*, and human capital (*H*=*hL*). If we assume Hicks-neutral productivity, total output can be expressed as:

$$Y = AK^{\alpha} S^{\beta} (hL)^{(1-\alpha-\beta)}, \qquad (4)$$

and output per worker, $y \equiv Y/L$, as:

$$y = Ak^{\alpha} s^{\beta} h^{(1-\alpha-\beta)} \qquad (5)$$

where $s \equiv S/L$ is the natural resources to labor ratio, $k \equiv K/L$ is the physical capital to labor ratio, *h* is the 'physical' human capital per worker, and *L* is the number of workers.

3.1 Explaining variation in output per worker with factors of production

The typical question in the literature is how much of the variation in *y* can be explained by variation in the observables *k*, *s* and *h*, and how much is attributed to differences in *A*. As in Caselli (2005), if we define $y_{factors} = k^{\alpha} s^{\beta} h^{(1-\alpha-\beta)}$, we can rewrite (5) as

$$y = Ay_{factors}. \qquad (6)$$

We can measure the "success" of the factors-only model at explaining cross-country income differences using two standard indicators based on the tradition of variance decompositions:

$$Success_C = \frac{\text{var}[\log(y_{factors})]}{\text{var}[\log(y)]}, \text{ and } Success_{KR} = \frac{\text{var}[\log(y_{factors})] + \text{cov}[\log(A), \log(y_{factors})]}{\text{var}[\log(y)]}.$$

The first expression, assumes that all the countries have the same level of TFP, so that *A* is a constant. The second expression, proposed by Klenow and Rodriguez-Clare (1997), allows countries to have different levels of efficiency, and splits the contribution from the covariance term evenly between *A* and $y_{factors}$.

We have data on *k*, *s*, and *h*.[13] We use the WDI GNI series to compute output per worker. For the factor shares, most of the previous empirical studies take α=1/3 and ignore natural resources as a factor of production (i.e. β=0). A notable exception is the study of Tzouvelekas, Vouvaki and Xepapadeas (2007). They introduce the environment, proxied by CO_2 emissions, into their computations of TFP. The implicit shares of the environment in output in their analysis can be as high as 14%. For our analysis we take a more conservative value of β=10%, but the results in Table 3 are robust to taking β=0.

The first column of Table 3 shows the results of the estimation of the two measures of success, and their components. The fraction of the variance of income explained by observed endowments (*k,s, h*) is 0.20 if we use the first standard measure of success, and 0.43 if we use Klenow and Rodriguez-Clare's. The Klenow and Rodriguez-Clare measure assigns a greater role to factors of production, but their contribution is still under 50 percent.

Compare equation (5), with equation (7):

$$y = Ak^{\alpha} s^{\beta} ic^{(1-\alpha-\beta)} \qquad (7)$$

Equation (5), even including natural resources, is more or less conventional. Only produced, natural and human capital are represented in the equation, so that the TFP factor *A* picks up the contribution to income of all 'missing' assets.

For equation (7) we have included intangible wealth as the third production factor. If *ic* actually is measuring a wide range of assets (human, social, institutional, etc.), then the contribution of *A* to explaining the variation of output per worker should be small – zero in the limit.

So one way to bring together the wealth accounting and growth accounting literatures would be to estimate the two success indicators and examine the estimated contributions of $y_{factors}$, (with *ic* instead of *h*), and *A* to see if the contribution of *A* is indeed small. The second column of Table 3 shows that to be case. When *ic* is the third factor of production instead of *h*, both measures of success of the factors-only model are 97 percent.[14]

[13] We take the estimates of total physical capital and natural capital wealth and divide them by the labor force series, (SL.TLF.TOTL.IN), to obtain estimates of *k* and *s*.

[14] We repeated the calculations in Table 3 for each of the years, 1995, 2000, and 2005, independently, and for the subsamples of OECD and non-OECD countries. The results, not reported, are available from the authors. The relative contributions of *A* and $y_{factors}$ are constant over time and similar to those in Table 3. The differences between OECD and non-OECD countries are minimal when factors of production are conventionally defined, but if *ic* is used

These measures of success are certainly large, but it must be recalled that intangible capital includes, by construction, all missing factors of production. The result therefore makes sense. By comparison, the traditional development accounting literature *invokes* TFP as the factor which explains all of the residual variation in output across countries after capital and labor factors have been taken into account.

3.2. Explaining output per worker

By taking logarithms of (5), we obtain:

$$\ln(y) = \ln(A) + \alpha \ln(k) + \beta \ln(s) + (1 - \alpha - \beta) \ln(h)\,. \quad (8)$$

In the tradition of the development accounting literature, equation (8) can be estimated econometrically.

$$\ln(y_{it}) = \gamma_i + \lambda_t + \delta_k \ln(k_{it}) + \delta_s \ln(s_{it}) + \delta_h \ln(h_{it}) + \varepsilon_{it}\,. \quad (9)$$

The parameters δ_k, δ_s and δ_h represent the contributions of physical capital, natural capital and human capital to aggregate productivity, gamma allows for differences in total factor productivity across countries and lambda for differences in TFP over time. Notice that unlike the approach in the previous section, equation (9) treats δ_k, δ_s and δ_h as free parameters, which adds a layer of testability to the theory. Equation (9) is similar to equation (7) in Topel (1999).

We estimate (9) using country and time fixed effects. Thus, we do not need to assume that capital intensities are orthogonal to productivity differences across countries or over time. A widespread criticism to the estimation of (9) with cross-section data (as is done in Mankiw, Romer and Weil, 1992) is that if more productive (higher *A*) countries are also more intense users of capital, the causal contribution of observed inputs will be overstated. By using country-specific fixed effects, we avoid this potential bias.

Tzouvelekas, Vouvaki and Xepapadeas (2007) also estimate a function similar to (9). They note that an additional problem when estimating a production function is the potential endogeneity of the inputs which results in inconsistent estimators. However, they also note that, as shown by Mundlak (1996), under constant returns to scale, OLS estimates of a *k*-input Cobb-Douglas production function in average productivity form, with regressors in input-labor ratio form (as we have in equation 9), are consistent.

The estimated elasticities from the estimation of equation (9) are reported in the first column of Table 4. The share of physical capital is 0.4 and statistically significant. However, the shares for

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instead of human capital, the measures of success are larger in non-OECD countries than in OECD countries (0.94 and 0.82, respectively, for $Success_C$).

human capital and natural resources are not statistically significant. In column (2) of Table 4, we use intangible capital as the third factor of production instead of human capital. The estimate for the share of physical capital, 0.32, is similar to that reported in Tzouvelekas, Vouvaki and Xepapadeas (2007). Our estimate for the share of natural capital, 0.07, is larger than theirs (0.04). An explanation could be that their indicator of natural capital, which only refers to CO_2 emissions, is narrower than ours. Finally, our estimated share of intangible capital, 0.18, is also larger than their estimated share for human capital, 0.07. This is what we would expect. Our intangible capital variable is broader and arguably encompasses their indicator of human capital.

The results in column (2) seem to be driven by non-OECD countries. In column (3) we report estimates for the subsample of non-OECD countries. The results are similar to those in column (2) for the whole sample. The results for the subsample of OECD countries, reported in column (4), are strikingly different. The share of physical capital is 0.21 and statistically insignificant, suggesting that physical capital plays a smaller role than in non-OECD countries, while the share of intangible capital increases to 0.5. The estimated share of natural capital is reduced and is statistically insignificant. These results are consistent with the poor performance of savings measures that exclude human capital (or other intangible assets) accumulation in OECD countries reported in Ferreira and Vincent (2005).

4. Investigating the composition of intangible capital

The previous section suggests that intangible capital is indeed measuring a wide range of assets: human capital and other forms of intangible capital grouped under the heading of total factor productivity. In this section, we estimate the relationship between intangible capital and our proxies of human and institutional capital econometrically to analyze their relative contributions. We assume that

$$ic = f(h, g), \qquad (10)$$

where *ic* is intangible capital per capita, *h* is our indicator of 'physical' human capital per worker, and *g* is an indicator of institutional capital (a rule of law index).

Compared to World Bank (2006), we do not consider foreign remittances. Workers' remittances received by a country represent compensation to its human capital residing abroad, but they are a flow (yearly payments) rather than a stock.[15]

By definition, intangible wealth is the sum of sources of wealth other than physical and natural capital. We thus estimate a linear specification,

[15] It could be argued that even though they are a flow, remittances are correlated with the stock of human capital of a country. We repeated all the regressions including remittances per capita as an additional explanatory variable and the results we report below did not change; remittances were not significant in any specification and the coefficients on the other variables were robust to its inclusion.

$$ic_{it} = \alpha_i + \delta_t + \lambda h_{it} + \gamma g_{it} + \varepsilon_{it}, \qquad (11)$$

in which λ is the price of a unit of *h*, γ is the price of one point in the rule of law index, *g*, α_i is a country-specific intercept and δ_t is a time dummy for *t*=2000 and 2005. We also estimated the relationship in (10) using a log linear model, and a log-log model, but (11) was our preferred specification.

4.1 Econometric issues with the estimation of equation (11)

Intangible capital is, by definition, a broad concept, and our specification in (11) is very parsimonious with only two regressors, *h* and *g*. If *h* and *g* are correlated with the regression error term, then our estimators would be inconsistent. This potential correlation between regressors and error term can stem from various sources including omitted variables, errors in variables (measurement errors in the regressors) and simultaneous causality.

In order to deal with the first issue, omitted variable bias, we introduce (country- and time-) fixed effects in the regression. The combined time and country fixed effects regression model eliminates omitted variable bias arising from both unobserved variables that are constant over time, and from unobserved variables that are constant across countries. The country dummies (α_i) capture time-invariant country-specific traits while the time dummies (δ_t) capture common shocks to the intangible capital across countries.

Measurement error, on the other hand, typically results in attenuation bias, so, provided this were the only source of correlation, we can interpret our coefficients for *h* and *g* as lower-bound estimates of their true effects.

The third source of correlation, simultaneous causality, is causality running from our dependent variable, intangible capital, to *h* and *g* as well as from *h* and *g* to intangible capital. An advantage of our analysis is that intangible capital, by construction, is forward looking. Total wealth is calculated as the present discounted value of future consumption flows (see Section 2.1 for details on its derivation) and by definition cannot determine past educational and institutional outcomes.

The discussion above should go some way to allaying endogeneity concerns. Alternatively, we could use instrumental variables (IV). In practice, finding good instruments, i.e. exogenous sources of variation that affect intangible capital only through their effect on *h* and *g* and not directly, is difficult.

Acemoglu, Johnson and Robinson (2001) use differences in European settler mortality rates as an instrument for current institutions. We can use this variable as an instrument for the rule of law index, but we need at least an additional instrument for human capital. Hall and Jones

(1999) propose using the geographical and linguistic characteristics of an economy as instrumental variables for their social infrastructure. We focused on distance from the equator and the percentage of the population speaking a Western European language as their first language today.

Another problem with the IV strategy is that it limits the analysis to a cross-section as the instrumental variables are available only at a point in time. We chose the year 1995 since the data for years of schooling for 1995 are arguable measured with less error than for 2000 and 2005, where extrapolations were used. The first instrumental variable, logarithm of settler mortality rates, further limits the analysis to 59 countries that are ex-colonies. Thus, the results from the IV analysis should be interpreted with caution and considered only tentative.

4.2 Panel estimation results

Table 5 shows the results from the estimation of equation (11). The columns differ in terms of the estimation technique and the variable measuring human capital per worker. For column (1) we replicate the results in World Bank (2006); that is, we just pool the observations over the years 1995, 2000, and 2005 and use OLS so that $\alpha_i = \alpha \;\; \forall i$ and $\delta_t = 0 \; \forall t$. The indicator of human capital is simply years of schooling from Barro and Lee (2001). In column (2) we also use OLS on the pooled sample, but the indicator of human capital is given by equation (3). Both the coefficients on our indicator of institutional quality and years of schooling exhibit positive signs and are highly significant. An additional point in the rule of law index is associated with an increase in intangible wealth per capita of around $3,000. An additional year of schooling is associated with an increase in intangible wealth per capita of over $11,000 and a unit increase in human capital per worker with an increase in intangible wealth per capita of around $45,000.

The regressions in columns (1) and (2) also include income dummies relative to high income countries. All of them are negative and statistically significant. This means that countries in each income group have a lower level of intangible capital than high income countries which is consistent with the positive relationship between income and intangible capital shown in Figure 2. The coefficients are large in magnitude; around $100,000 for all income categories.

In columns (3) and (4) we introduce country fixed effects in the model. The null hypothesis of country-specific intercepts equal to zero is rejected for both regressions. Compared to columns (1) and (2) the coefficients on rule of law are reduced and, although still positive, they are no longer statistically significant. The estimated coefficients of human capital in both columns increase in size and remain highly significant. Note that of the three components of h in (3)–years of schooling, returns to education and adult survival rates, returns to education does not vary over time or across countries. Thus, estimation of (11) using country fixed effects relies on the within-country variation of years of schooling and adult survival rates.

In columns (5) and (6), we introduce time fixed-effects in addition to country fixed effects in the regression, as we also reject the joint null hypothesis that the time dummies are equal to zero, in this case at a 2 percent significance level or better. This is our preferred specification, since, as discussed, time and country fixed effects address omitted variable bias arising from both unobserved variables that are constant over time, and from unobserved variables that are constant across countries. Compared to column (3), in column (5) years of schooling becomes insignificant, suggesting that the time dummies capture the variation of years of schooling over time. This is not surprising; a linear trend fits years of schooling well for most countries (see footnote 8). *h*, which accounts for adult survival rates, remains significant when we include both types of fixed effects.

The estimated coefficient on human capital in column (6) is large; a one-point increase in the human capital indicator is associated with an increase in intangible wealth of over $92,000. This implies a difference of intangible wealth of over $320,000 per capita between the country with the lowest human capital (Mozambique with an average value of 1.54 over the sample period) and the country with the highest human capital (Norway with an average value of 5.08). Finally, the estimates for the time dummies are positive and statistically significant indicating that intangible capital per capita has increased over time, as shown in Table 2 Panel B.

The results in Table 5 are robust to a number of changes. First, we repeated the regressions using alternative measures of human capital. In particular, we considered an indicator that accounted for differences in the quality of schooling across countries (see footnote 7). We also repeated the regressions with human capital measures based on Cohen and Soto's (2007) years of schooling. Second, we used an average index of governance instead of the rule of law index as indicator of institutional capital. Third, we excluded outliers and influential observations as identified by Cook's distance. Fourth, we introduced interaction terms between the indicator of institutional capital and human capital.

We used the estimates in column (6) to compare actual intangible capital with the in-sample predictions from the model. Results of the calculations are available upon request. The positive and large contributions to intangible wealth from human capital and from common shocks to all the countries (from the time dummy coefficients) contrasted with the negative (and statistically significant for non-OECD countries) country-specific intercepts.

4.3 IV estimation results

Table 6 reports the results of the IV analysis. The first panel in Table 6 shows the association between the three instruments (log of settler mortality rates, distance from the equator and fraction of a country's population whose first language is Western European) and the two independent variables, *h* and *g*. Distance from the equator and the percentage of the population whose first language is a Western European language have the expected positive signs in both regressions and are highly statistically significant in the human capital regression. Settler mortality rate has the expected negative sign and is statistically significant at a 1 percent level in both regressions. Overall, the instruments are strongly associated with the rule of law and human capital variables. Together the three instruments explain approximately 52 percent of the variation in our institutions variable and 62 percent of the variation in our human capital variable.

A second desirable property in the instruments is that they affect the dependent variable, in our case, intangible capital, only through their impact on the rule of law index and human capital; i.e. the instruments are not correlated with the error term in the equation explaining intangible capital. By employing three instruments, we can test this assumption.[16] Panel B in Table 6 reports the results from two tests, the Sargan and Basman tests. In both cases we cannot reject the null that the instruments are exogenous.

Both rule of law and human capital have positive coefficients in the second stage regressions in Panel C Table 6. For rule of law, its magnitude, around $2,300, is similar to that in the OLS regressions in Table 5, while for human capital, at around $80,000, it is between the OLS and fixed effect estimates in Table 5. They are estimated less precisely, however, and neither is statistically significant at conventional levels; human capital is significant at a 32 percent significance level.

5. Conclusions

For most countries the sources of wealth reported in the standard system of national accounts (SNA) are just a small percentage of their comprehensive wealth. Based on economic theory, in this paper we use a measure of comprehensive wealth computed as the present discounted value of future consumption to analyze what conventional accounting systems are leaving out. Our estimates of comprehensive wealth are on the order of 20 times net national income; the implicit rate of return on comprehensive wealth for 80 percent of the countries in our sample lies between 4 and 6 percent.

We calculate intangible capital as a residual, by subtracting the values of assets that the SNA measures (produced capital and net financial assets), and estimates of the value of the stock of natural capital, from the value of comprehensive wealth. For most of the countries in our sample,

[16] This assumption, known as the exclusion restriction, is not testable in exactly identified models (i.e. models in which the number of instruments is equal to the number of endogenous covariates). If the model is overidentified (so that there are more instruments than endogenous covariates, as in our case with 3 instruments and 2 endogenous covariates), there is information available which may be used to test this assumption.

and especially for OECD countries, intangible capital is the largest constituent of total wealth. For the whole sample, it represents on average more than 60 percent of total wealth.

Our measure of intangible capital therefore captures a broad range of assets – not only human capital, but also social/institutional and other forms of capital. Intuitively, we would expect intangible capital to be related to total factor productivity (TFP), and part of the analysis in this paper is concerned with verifying this intuition. Using a development accounting framework, we applied variance decomposition techniques to measure the extent to which factors of production explain the variation in output per worker. When the factors of production are physical capital, natural capital, and (physical) human capital per worker, they explain only between 20 and 43 percent of the total variation in output per worker in our sample – the balance of the variation is assumed to be explained by TFP. When the factors of production are physical capital, natural capital, and the intangible capital residual (instead of human capital), the variation in factors of production explains 97 percent of the total variation in output per worker – the balance of the variation explained by TFP must therefore be extremely small.

There is strong evidence, therefore, for a link between the non-human capital portion of intangible capital and TFP. This is important given the emphasis given to TFP growth, versus increases in factor inputs, in the growth literature. Ultimately, growth in factor inputs will be subject to diminishing returns. But this can be overcome through growth in TFP, which economists have generally equated with knowledge – more efficient technologies, more effective management, and increased quality of institutions. Our analysis suggests that wealth accounting can begin to put an asset value on this knowledge.

To better understand the role played by intangible capital in production, we also estimated a Cobb-Douglas production function where produced, natural and intangible capital are the factors of production. Using fixed effects estimation for all countries in our sample (115 countries over the years 1995, 2000 and 2005), we find that the shares of produced, natural and intangible capital in production are 32%, 7% and 18% respectively; if we limit our sample to developing countries the shares are quite similar. However, when we limit the sample to OECD countries, we find the striking result that the only statistically significant factor of production is intangible capital, with a 50% share. This finding supports the conjecture in Ferreira and Vincent (2005) that intangible factors, rather than produced or natural capital, are the principal sources of consumption growth in high-income countries.

We also attempted to decompose the constituents of intangible capital using data on institutional quality (as measured by a rule of law index) and human capital. Panel regression analysis suggests that the contribution of human capital is indeed important. A one-point increase in our human capital indicator is associated with an increase in intangible wealth of over $92,000 for the average country in our sample. This implies a difference in intangible capital of over

$320,000 per capita between the country with the lowest human capital (Mozambique with an average value of 1.54 over the sample period) and the country with the highest human capital (Norway with an average value of 5.08). In contrast, we find that the rule of law index is not a significant contributor to intangible capital. When we decompose the predicted levels of intangible capital using our estimated model we observe large negative (and statistically significant) fixed effects for all developing countries. It is certainly conceivable that the quality of institutions, captured only imperfectly with our rule of law index, and the legacy of geography and history for developing countries can explain these large negative fixed effects.

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Table 1: National wealth and income in Canada, 2009 ($bn CDN)

Net financial assets	-109,452	
Land assets	1,846,753	
Produced capital (K)	4,191,919	
Net worth	5,929,220	
GNI	1,505,817	
		Implicit rate of return
K / GNI	2.78	35.9%
Net worth / GNI	3.94	25.4%

Table 2: Descriptive statistics

Panel A	Full Sample			
	Mean	Std. Dev.	Min	Max
Total wealth	163,582	215,857	2,152	902,960
Produced capital	30,625	40,887	132	183,078
Natural capital	11,925	20,730	2	169,150
Net foreign assets	-24	12,515	-49,818	74,280
Intangible capital	121,056	170,061	278	799,123
Intangible capital/ total wealth	0.64	0.18	0.05	0.90
Years of schooling	6.52	2.87	0.76	12.59
Human capital	3.06	0.91	1.46	5.34
Rule of law	56.17	23.19	6.96	100.00

Panel B	**OECD**	**Non-OECD**	**Year 1995**	**Year 2000**	**Year 2005**
	Means (standard deviations in parentheses)				
Total wealth	486,177	61,000	157,722	162,365	169,751
	(183,435)	(84,088)	(204,314)	(213,149)	(229,400)
Produced capital	90,562	11,566	30,153	30,237	31,410
	(34,932)	(17,580)	(40,364)	(40,081)	(42,447)
Natural capital	17,656	10,102	12,050	12,947	10,806
	(19,540)	(20,805)	(21,709)	(22,212)	(18,360)
Net foreign assets	-3,469	1,072	273	-165	-135
	(15,814)	(11,083)	(11,537)	(12,799)	(13,120)
Intangible capital	381,427	38,260	115,246	119,347	127,669
	(147,274)	(52,810)	(158,600)	(167,351)	(182,924)
Intangible capital/	0.78	0.59	0.63	0.63	0.66
total wealth	(0.06)	(0.18)	(0.17)	(0.19)	(0.19)
Years of schooling	9.64	5.53	5.99	6.61	6.88
	(1.59)	(2.44)	(2.83)	(2.84)	(2.88)
Human capital	4.14	2.71	2.92	3.08	3.16
	(0.57)	(0.71)	(0.88)	(0.90)	(0.95)
Rule of law	86.64	46.48	57.74	56.04	54.96
	(10.12)	(16.92)	(24.25)	(22.52)	(23.06)

Notes: Panel A: full sample includes an unbalanced panel of 115 developed and developing countries for years 1995, 2000 and 2005 (total of 315 observations), except for human capital for which sample is 112 countries and 309 observations. All variables except years of schooling, human capital and rule of law are expressed in per capita terms in constant 2005 US$. Years of schooling in population aged 15 and over from Barro and Lee (2001); human capital $h = A_h e^{\phi(s)}$ (see text for details); rule of law index (1-100 scale) from Kaufmann, Kraay and Mastruzzi

(2009). Panel B: repots means with standard deviations in parentheses for subsamples of OECD countries (76 observations); non-OECD countries (239 observations); year 1995 (94 observations); year 2000 (110 observations); year 2005 (111 observations).

Table 3: Fraction of output variance explained by factors of production

	Factors considered	
	k,s,h	*k,s,ic*
var (log(y))	2.80	2.80
var (log($y_{factors}$))	0.56	2.71
cov(log(A), log($y_{factors}$))	0.65	0.003
$Success_C$	0.20	0.97
$Success_{KR}$	0.43	0.97

Notes: sample includes an unbalanced panel of 112 developed and developing countries for years 1995, 2000 and 2005 (total of 309 observations).

Table 4: Development accounting regression; implicit shares

	Implicit shares			
	(1)	(2)	(3)	(4)
ln(*k*)	0.398***	0.320***	0.313***	0.205
	(0.073)	(0.058)	(0.062)	(0.128)
ln(*s*)	-0.022	0.068**	0.072*	0.030
	(0.037)	(0.033)	(0.039)	(0.037)
ln(*h*)	0.356			
	(0.348)			
ln(*ic*)		0.176***	0.169***	0.502***
		(0.054)	(0.055)	(0.010)
Country Fixed Effects	Yes	Yes	Yes	Yes
(p-value F.E =0)	(0.00)	(0.00)	(0.00)	(0.00)
Time Fixed Effects	Yes	Yes	Yes	Yes
(p-value F.E =0)	(0.01)	(0.00)	(0.00)	(0.00)
Sample	All	All	Non-OECD	OECD
N	311	311	234	76
n	112	112	86	26

Notes: Dependent variable is ln(output per worker). Independent variables are ln(capital-labor ratio), ln(natural resources-labor ratio), ln(intangible capital-labor ratio), ln(human capital per worker) ***,**,* denote significance at 1% , 5% , and 10 percent levels, respectively.

Table 5: Explaining intangible capital

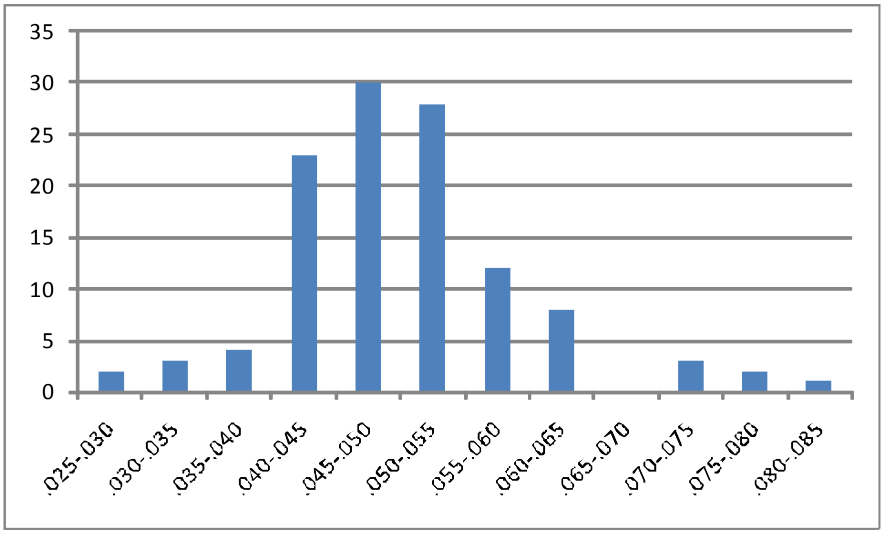
	(1)	(2)	(3)	(4)	(5)	(6)
Rule of law	3,000	2,819	308	37	354	188
	(434)***	(433)***	(383)	(388)	(385)	(380)
Years schooling	11,025		36,568		2,480	
	(2,817)***		(7,877)***		(13,893)	
h		46,178		124,450		92,899
		(10,280)***		(24,078)***		(27,590)***
li	-107,214	-92,272				
	(28,644)***	(29,568)***				
lmi	-153,354	-141,295				
	(22,928)***	(23,375)***				
umi	-163,090	-153,567				
	(18,925)***	(19,352)***				
dy2000					12,954	6,470
					(4,264)***	(2,337)***
dy2005					25,356	10,013
					(8,588)***	(4,137)**
Constant	-22,502	-90,246				
	(42,663)	(50,148)*				
Country FE	No	No	Yes	Yes	Yes	Yes
(F-test p-value)			0.00	0.00	0.00	0.00
Time FE	No	No	No	No	Yes	Yes
(F-test p-value)					0.01	0.02
Observations	315	309	315	309	315	309
Number of id	115	112	115	112	115	112
R-squared[a]	0.77	0.78	0.21	0.30	0.25	0.31

Notes: Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. a. R-squared in fixed-effects regressions corresponds to within-R-squared.

Table 6: IV analysis

Panel A: 1st stage regressions		
	Rule of law	Human capital
Distance	36.57**	1.53***
	(17.48)	(0.58)
Log (settler mortality)	-7.75***	-0.24***
	(2.04)	(0.07)
European language (%)	7.11	0.59***
	(5.37)	(0.18)
Constant	74.18***	3.26***
	(12.20)	(0.40)
R-squared	0.52	0.62
N	59	59
Panel B: Tests of overidentifying restrictions		
	Sargan	Basmann
chi2(1)	0.37	0.34
p-value	(0.55)	(0.56)
Panel C: 2nd stage regression		
	Intangible capital	
Rule of law	2,326	
	(3,190)	
H	77,921	
	(78,161)	
Constant	-266,511***	
	(64,854)	
R-squared	0.58	
N	59	

Figure 1. Distribution of implicit rates of return on comprehensive wealth, 2005



Source: Author's calculations, based on data from World Bank (forthcoming).
Vertical axis is country count, horizontal axis is ranges of rates of return.

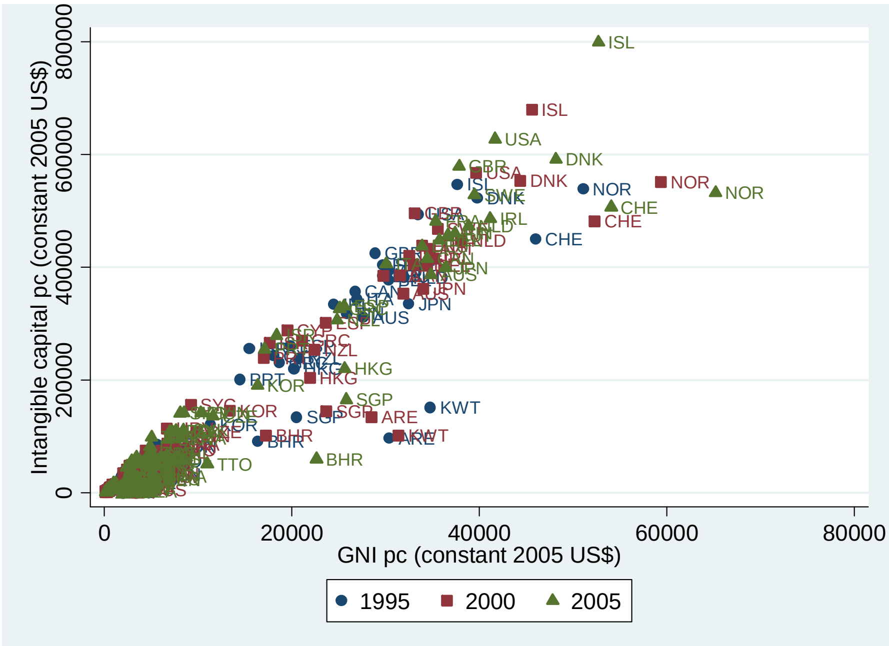


Figure 2a: Intangible capital is positively correlated with income

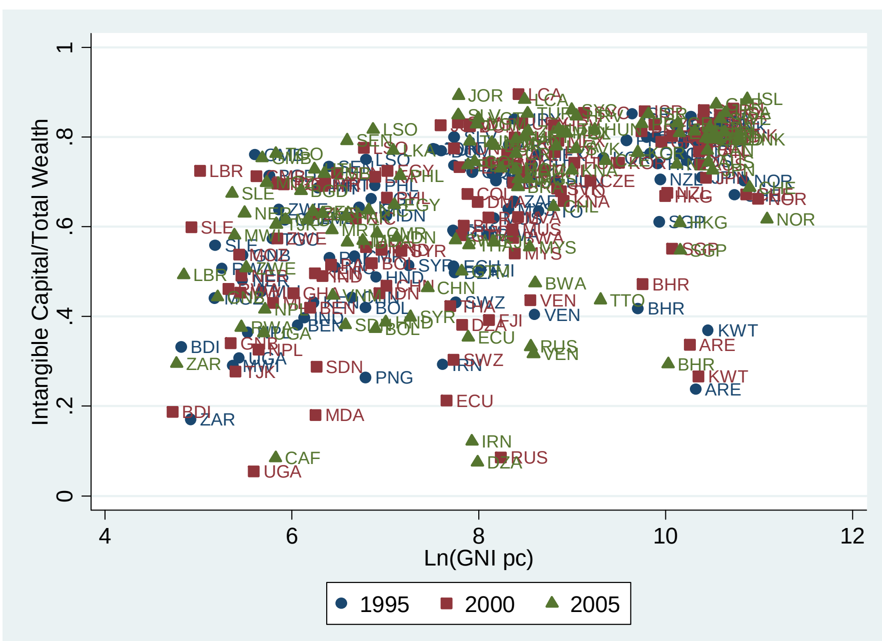


Figure 2b: Share of intangible capital in total wealth is positively correlated with income