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Human Capital, Tangible Wealth, and the Intangible Capital Residual

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Abstract

Since income is the return on wealth, the total wealth of any given country should be on the order of 20 times its gross domestic product. Instead the average observed ratio from the balance sheet accounts of the System of National Accounts is a factor of 2.6 to 6.6, depending on whether natural resource stocks are included in the balance sheet. The clear implication is that the System of National Accounts wealth accounts are incomplete, with the most obvious omission being human capital. Estimating the value of human capital using the lifetime income approach for a sample of 13 (mostly high-income) countries yields a mean share of human capital in total wealth of 62 percent—four times the value of produced capital and 15 times the value of natural capital. But for selected high-income countries in the sample there is still an average of 25 percent of total wealth that is unaccounted—it is neither produced, nor natural, nor human capital. This residual intangible wealth is arguably the "stock equivalent" of total factor productivity—the value of assets such as institutional quality and social capital that augment the capacity of produced, natural and human capital to support a stream of consumption into the future.

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Human Capital, Tangible Wealth, and the Intangible Capital Residual

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HUMAN CAPITAL, TANGIBLE WEALTH, AND THE INTANGIBLE CAPITAL RESIDUAL

1. Introduction

Both theory and intuition support the idea that income is the economic return on wealth. But this conception of income and wealth is apparently at odds with the figures that we can observe in the national balance sheets of the System of National Accounts (SNA).

Since the 1993 revision of the SNA, the national balance sheet accounts include both produced assets and the value of commercial natural resources, including land. According to wealth estimates published in *The Changing Wealth of Nations* (World Bank, 2011), the ratio of produced wealth to GDP averages a factor of 2.6 across more than 120 countries in 2005. If we expand the asset accounts to include all tangible wealth, both produced and natural, then the ratio of wealth to GDP averages a factor of about 6.6.

The puzzle in all of this is that, if income is understood as the return on wealth, and the rate of return is assumed at 5%, then the total wealth of a nation should be on the order of 20 times GDP. Since there is no reason to believe that average rates of return on assets in these countries should be substantially higher than 5%, the obvious conclusion is that there are 'missing' assets, i.e. assets that are not measured in the SNA balance sheet accounts.

The most obvious missing asset in the SNA is human capital, which was measured indirectly as a component of the residual in the World Bank's comprehensive wealth accounts (World Bank, 2006, 2011). Recent work at the OECD (Liu, 2011) has estimated the monetary value of human capital stocks for sixteen countries[2] over a range of years, which offers an opportunity to include these direct estimates of human capital into the World Bank framework of comprehensive wealth accounting.

The growth accounting literature also suggests that there must be other 'missing' assets in the SNA – when using the growth in production factors such as produced capital and 'raw' labor to explain the growth in output in an economy, there is always a large residual of unexplained growth in output. This residual factor in growth accounting is termed 'total factor productivity' (TFP) and it is generally considered to encompass some combination of knowledge and technology as the missing contributors to growth in output.

The first aim in this paper is to combine the OECD's monetary estimates of human capital and the World Bank's comprehensive wealth accounting to arrive at a better understanding of the contribution of human capital to the wealth of nations, relative to produced and natural capital. The second aim of this paper is to estimate the size of what could be termed the 'stock equivalent' of total factor

2. Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland, Romania, Spain, the United Kingdom and the United States.

productivity (TFP) – i.e. the intangible capital residual remaining in the measure of comprehensive wealth after accounting for human, produced and natural capital. The estimates in this paper suggest that this intangible capital residual is large, on the order of 25% of comprehensive wealth for the sample of the richest countries considered here, indicating that our measures of the component elements of the wealth of nations are still substantially incomplete.[3]

The rest of the paper is organized as follows. Section 2 discusses the possible ways for comprehensive national wealth accounting and provides some of the key findings from the World Bank's work by means of the top-down approach. The detailed theoretical backing for the top-down approach is provided in Annex I. In Section 3, a brief overview is given of the lifetime income approach applied by the OECD project for measuring the value of human capital. The detailed implementation procedure of the lifetime income approach is presented in Annex II. Section 4 presents the adjustments made in this paper to align the OECD human capital estimates with the World Bank total wealth estimates. Section 5 presents the results of the wealth decomposition with human capital included and discusses the findings. Section 6 concludes.

2. Estimating total wealth

As noted in the Introduction, two of the main motivations for the analysis in this paper are to estimate the share of human capital in a comprehensive measure of total wealth, and to estimate the 'residual of the residual' – i.e. the unmeasured portion of total wealth which includes institutional, social and other forms of intangible capital. Combined, these estimates can provide a deeper insight into the composition of wealth than has been available to date in the separate work of the OECD and of the World Bank.

There are two broad ways to measure total wealth for a country – from the bottom up, i.e. asset by asset, and from the top down, i.e. relying on guidance from economic theory. If the accounting for assets from the bottom up is complete (no omitted assets), then the two measures of wealth will coincide. A recent example of bottom-up estimation is provided by Arrow *et al.* (2012), a study which is commendably comprehensive in its approach, but the approach raises important questions[4] about the measurement of intangible wealth, in particular 'health capital'. *The Changing Wealth of Nations* (World Bank 2011) builds on the top-down approach, with total wealth measured as the present value of future consumption, as theory would suggest under the assumption of constant returns to scale. In this work, as in World Bank (2006), there is a gap between total wealth and the sum of produced capital, natural capital and net foreign assets owing to the necessarily incomplete measurement of assets; as noted above, this gap is labeled the intangible capital residual.

This paper takes the World Bank (2011) estimates of total wealth as the point of departure. Annex I provides the theoretical backing for this approach. The intuition behind measuring total wealth as the present value of future consumption can be provided by thinking of the household level: if a household suddenly and permanently lost all capacity to earn income, then its future consumption would be

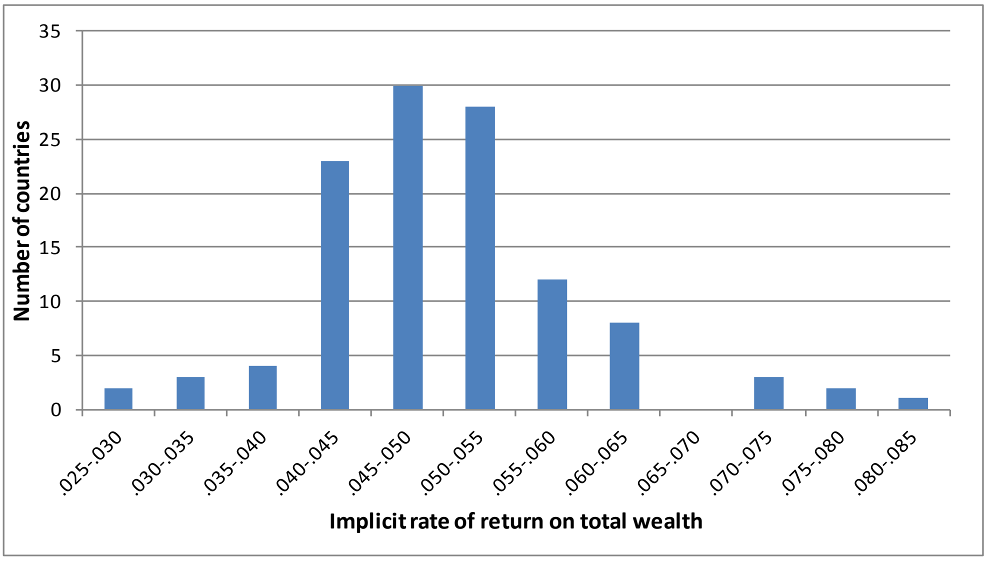
3 . Note that, in common with World Bank (2006, 2011), we refer to the 'intangible capital residual' or 'intangible wealth residual' in this paper. This usage differs from the definitions of intangible fixed assets and intangible non-produced assets in the SNA. Intangible fixed assets in the SNA (and in the work of the OECD) include the value of knowledge.

4 . These questions are explored in the *Environment and Development Economics* symposium for which the Arrow *et al.* paper is the centrepiece.

constrained by the current total value of its assets. Arrow *et al.* (2012) argue that this may not be the most comprehensive measure of total wealth, but it is arguably a comprehensive measure of the wealth which underpins the consumption of produced goods and services.

As Annex I makes clear, estimating total wealth from the top down depends crucially upon a number of assumptions and parameter choices. World Bank (2011, Chapter 5) and Ferreira and Hamilton (2010) provide some tests of the extent to which the total wealth estimates are reasonable. Figure 1 below shows the distribution of estimated rates of return on total wealth across countries – this builds on a result in Hamilton and Hartwick (2005) and Asheim (2000), which shows that net national income is the return on total wealth. As can be seen, 80% of the implicit rates of return on total wealth across countries fall between 4% and 6% – a reasonable result.

Figure 1. Distribution of the implicit rate of return on total wealth, 2005



Source: World Bank (2011)

Ferreira and Hamilton (2010) carry out panel regressions with intangible wealth as the dependent variable to show that human capital, based on the Barro and Lee (2001) data set on educational attainment is a statistically significant component of intangible wealth. They also perform a development accounting test to show that intangible capital includes what might be termed the ‘stock equivalent of TFP’ (total factor productivity).

Table 1 displays one of the key findings from the World Bank wealth accounts. At least in cross section, there is a clear tendency for natural capital to shrink as a share of total wealth as countries become wealthier, while there is a corresponding increase in the share of intangible capital. However, because the World Bank does not have estimates of human capital by country, the result is that intangible capital – the sum of human capital and the stock equivalent of TFP – constitutes 50% to 80% of total wealth. Pulling this intangible capital residual apart, and using the values of human capital in selected countries estimated by the OECD, is one of the primary contributions of this paper.

Table 1. Shares of wealth by income aggregate, 2005

	Intangible	Produced	Natural
Low income	50%	14%	36%
Lower middle income	50%	24%	25%
Upper middle income	67%	17%	17%
High income: OECD	81%	17%	2%

Source: World Bank (2011).

3. Measuring human capital

As mentioned above, one of the key findings from the World Bank's national wealth accounting is that intangible capital – the unexplained residual – constitutes a large share of total wealth, an estimated 60% to 80%, in most countries covered. In particular, the share is around 80 % for high income OECD countries (World Bank, 2011).

To better understand the composition of this residual, accounting for the main components within it is a natural way forward. Ferreira and Hamilton (2010) find that, by treating human capital as a function of years of schooling (adjusted by survival rates), human capital is the most important component of intangible capital for all countries and especially so for high income countries.

Many different approaches to measuring human capital currently exist.[5] One approach, common in the economics literature, is to use single indicators as proxies for human capital, such as educational attainment in the form of average years of schooling (e.g. Barro and Lee, 2001, 2010). However, these single indicators, though simple and based upon available data, do not on their own adequately measure the stock value of human capital (OECD, 2001); and they may even poorly specify the relationship between education and the stock of human capital (Wößmann, 2003; Kokkinen, 2010).

Moreover, applying a single indicator as a proxy for human capital is in any case not equivalent to accounting as practiced in the SNA and the World Bank wealth accounts. In the SNA, produced capital (e.g. machinery, equipment, and structures) is accounted using the perpetual inventory method (PIM), in which the stock of capital is measured as the sum of depreciated flows of investment; and commercial natural resources (e.g. energy and mineral resources, timber resources) are valued as the present value of resource rents – both methods are consistent with standard economic theory. Therefore, to serve the purpose of directly accounting for human capital within the World Bank's wealth accounting framework, a monetary measure based on sound economic theory is needed.

To this end, the results from the recently launched OECD human capital project are employed in this paper. The methodology applied by the OECD for measuring human capital is the lifetime income approach, developed by Jorgenson and Fraumeni (1989, 1992a, 1992b). This approach measures the stock value of human capital embodied in individuals as the total present value of the expected future labor income that could be generated over the lifetime of people currently living – it therefore produces values of human capital that are consistent with the SNA and World Bank asset accounts.

As outlined in Annex II, the implementation of the lifetime income approach usually requires three steps: first, a database for each country is constructed, containing information on the number of people, their earnings, school enrolment rates, employment rates, and survival rates, all cross-

5 . For discussions on the pros and cons of these various approaches for measuring human capital, please refer to Liu (2011) and Boarini *et al.* (2012).

classified by several characteristics of individuals, such as age, gender and education; then, the lifetime income of the representative individual within each cross-classified group is simulated; finally, aggregating across these groups yields an estimate of the monetary value of the human capital stock for each country.

In addition to strengthening the theoretical consistency within the wealth accounting framework, the lifetime income approach, by bringing together the influence of a broad range of factors (demography, mortality, education and labor market aspects), allows comparison of the relative importance of these factors, which can lead to useful policy implications. For instance, information drawn from the estimates could be used to answer questions such as to what extent investment in higher education could offset the negative impact on human capital accumulation due to population aging.

The OECD human capital project has required the creation of a database for the participating countries over a range of observed years, including all the elements needed for human capital estimation based on the lifetime income approach. The estimated results and analyses based on these results are presented in Liu (2011).

To the purpose of this paper, the relevant data for thirteen countries (Canada (CAN), France (FRA), Israel (ISR), Italy (ITA), Korea (KOR), the Netherlands (NLD), New Zealand (NZL), Norway (NOR), Poland (POL), Romania (ROU), Spain (ESP), the United Kingdom (GBR) and the United States (USA))[6] for the year 2005 or closest available year are drawn from the OECD database; these data are combined with the World Bank (2011) estimates of the total wealth for these same countries in 2005.

4. The wealth decomposition with human capital included

Since the wealth decomposition with human capital included is based on two different sources, Liu (2011) and World Bank (2011), the assumptions used by each should be compared and, if appropriate, aligned. This section describes the type of alignment that was implemented.

4.1. The scope of population

The first issue concerns the scope of the population covered in both sets of estimates. Subject to certain conditions,[7] wealth in per capita terms is the correct measure of social welfare (Dasgupta, 2001). This motivates the comparison of national wealth in per capita terms. The OECD project focuses on the working age population (15 to 64), while the whole population is used in the World Bank wealth accounting.

As the OECD estimates of human capital refer to the working age population rather than to the whole population (i.e. they exclude the human capital embodied in children and in elderly people who are assumed to have fully withdrawn from the labor market), the human capital per capita (denoted as HCP_{real}), defined as total human capital of the whole population divided by the corresponding whole population, could only be approximated as total human capital of working age population

6. Except Romania, all chosen countries are OECD members.

7. These conditions are: population grows at a constant rate; per capita consumption is independent of population size; and production exhibits constant returns to scale.

divided either by the corresponding working age population (denoted as $HCP_{working}$), or by the whole population (denoted as HCP_{whole}).

Let the sub-population of youth (0-14), working age (15-64) and the elderly (65 and above) be denoted respectively as POP_{young}, $POP_{working}$, and POP_{elder}; and the corresponding average lifetime income as LIN_{young}, $LIN_{working}$ and LIN_{elder}. As defined,

$$HCP_{real} = \frac{LIN_{young} * POP_{young} + LIN_{working} * POP_{working} + LIN_{elder} * POP_{elder}}{POP_{young} + POP_{working} + POP_{elder}}$$

$$= \frac{LIN_{young} * POP_{young} + LIN_{working} * POP_{working}}{POP_{young} + POP_{working} + POP_{elder}},$$

The last identity holds because LIN_{elder} is assumed to be zero in the OECD project due to the assumption made there that people with age 65 and above will have withdrawn from the labor market. It follows that:

$$HCP_{working} = \frac{LIN_{working} * POP_{working}}{POP_{working}} = LIN_{working},$$

$$HCP_{whole} = \frac{LIN_{working} * POP_{working}}{POP_{young} + POP_{working} + POP_{elder}}.$$

Clearly, we know that $HCP_{whole} < HCP_{real}$, but uncertain about the relationship between $HCP_{working}$ and HCP_{real} .

In general, $LIN_{young} > LIN_{working}$, simply because younger people will have longer remaining working years and thus more lifetime incomes than their elder counterparts. If the sub-population of the elderly people POP_{elder} is very small, then it may lead to $HCP_{working} < HCP_{real}$. However, if POP_{elder} is large enough, we may expect that $HCP_{working} > HCP_{real}$.

Therefore, depending on a country's demographic structure, the use of $HCP_{working}$ could overestimate or underestimate the real human capital per capita, while the use of HCP_{whole} will surely underestimate it. To align the OECD and World Bank assumptions, this paper calculates the human capital per capita as HCP_{whole} instead of $HCP_{working}$; this measure is an approximation and represents an underestimation of human capital per capita.

4.2. The choice of real discount rates

The second issue is the choice of two key parameters in the OECD project, i.e. the annual real income growth rate and the real discount rate, compared with the assumptions about growth and discounting used in the World Bank estimates.

As displayed in Table 2, country-specific annual real income growth rates are applied in the OECD project. These numbers are derived from the OECD *Medium-term Baseline*, which is prepared by the OECD Economics Directorate, based on historical data and short-term projections, and extended to the medium term based on assumptions about the growth of potential output in each country.[8]

Table 2. Annual real income growth rate, discount rate and remaining working years in OECD project

	CAN	FRA	ISR	ITA	KOR	NLD	NZL	NOR	POL	ROU	ESP	GBR	USA
Annual real income growth rate (%)	1.39	2.18	1.32	2.29	3.98	1.23	0.77	1.82	3.04	1.32	2.78	2.14	1.30
Annual real discount rate (%)	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58
Remaining working years	26.1	26.1	28.9	25.1	27.5	25.2	26.8	25.8	27.1	27.5	26.4	26.0	26.6

Source: Liu (2011).

As illustrated in Annex II, the effective discount rate used in the calculation of human capital depends on the ratio of (1+ annual real income growth rate) to (1+ annual real discount rate). Owing to a lack of either theoretical or empirical evidence, the OECD work for human capital estimation uses a uniform rate of 4.58% for all countries to discount expected future earnings.[9] This implies that the effective discount rate differs across countries, reflecting the different pace of growth of future labor income.

While a high income growth rate substantially raises the present value of future earnings, resulting in much higher estimates of human capital, the opposite is true for a high discount rate. A number of studies that have applied the lifetime income approach to measuring human capital have found that the estimated stock values are very sensitive to the choice of these rates (e.g. Wei, 2004; Gu and Wong, 2008; Liu and Greaker, 2009; Liu, 2011; World Bank, 2011 Chapter 6). Some national studies have simply chosen the same parameters as used by the original Jorgenson and Fraumeni study for the United States (e.g. Ahlroth *et. al*. (1997) for Sweden; Wei (2004) for Australia). And the discount rate used can be as low as 3.5% in the case of Norway (Ervik et al, 2003; Liu and Greaker, 2009) and as high as 8.26% in the case of China (World Bank, 2011 Chapter 6).

Questions can also be raised about whether or not these parameters should be set the same across countries and/or over time. As noted, the OECD project applied a uniform discount rate (Liu, 2011), and Arrow *et al*. (2012) apply a discount rate of 8.5% for measuring human capital for the United States, China, Brazil, India and Venezuela that are apparently heterogeneous in many aspects.

Within the World Bank's wealth accounting framework, a uniform discount rate of 4% is used to estimate the stock value of natural resources across countries and across resource types. As outlined in Annex I, the World Bank measures total wealth as the present value of future consumption, with the discount rate *r* derived from the Ramsey formula:

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8. To be precise, the country-specific value of annual real income growth rate that is assumed to prevail over the future working life of working age people is calculated as the geometric mean of the real growth rate of wages and salaries per employee over the period of 1960 – 2017.

9. The discount rate of 4.58% was originally used by Jorgenson and Fraumeni (1992a) and corresponded to their estimates of the long-run rate of return for the private sector of the economy in the United States.

$$r = \delta + \eta \cdot g$$

for pure rate of time preference δ, elasticity of the marginal utility of consumption η, and consumption growth rate g.

Strictly speaking, the discount rate used in the World Bank's work (i.e. the social rate of return to investment) differs from that in the OECD project. The former is a kind of social discount rate from a social planner's point of view, while the latter is a long-term private return from an individual perspective (Fraumeni, 2011). The difference can be illustrated by the following example.

Consider an individual deciding to undertake formal education. Since the risk that he or she faces cannot be easily diversified, a relatively high rate of return may be needed to induce this person to remain in school. On the other hand, from the perspective of the society as a whole, investment in formal education is diversified across individuals and thus considerably less risky, meaning that future returns to this investment should be discounted at a lower rate (Abraham, 2010). The question of whether there are positive externalities from human capital accumulation (so that social returns exceed private returns) is contested in the recent literature[10] and is not further considered in what follows.

More discussion on the choice of real rates in general, and the income growth rates and the discount rate in particular, are beyond the scope of this paper. For our purpose, we take the total wealth estimates from the World Bank wealth accounts as given, and run a sensitivity analysis with respect to the discount rates applied for calculating both human and natural capital. Our central discount rate is 4.58%, while variants of 4% and 5% are reported in Annex III (note that discount rates of 4.58% and 5% result in slightly different values of natural capital compared with the figures published in World Bank (2011)).

4.3. The choice of time horizon

The third issue involved in aligning the OECD and World Bank capital estimates concerns the choice of time horizon over which future consumption, resource rents and labor income are discounted. The World Bank accounting sets the time horizon to 25 years, roughly corresponding to a generation, for the calculation of both total wealth and natural resource wealth (World Bank, 2011).

In the OECD project, the lifetime for working is truncated at age 15 as lower bound and age 64 as upper bound beyond which the labor income is assumed to be zero. Thus, the remaining working years for an individual at age $x \geq 15$ is just (64-x), and the remaining working years for the whole population is calculated as the weighted average of the remaining working years of each individual, with the weight being the number of people in the corresponding (5-year) age groups.

As shown in Table 2, the weighted average remaining working time for all countries selected is slightly above 25 years, roughly in line with the assumptions made by the World Bank wealth accounting. Note that for simplicity, the calculation of remaining working years as shown in Table 2 does not take into account the labor force participation, employment and mortality rates. If these adjustments were made, the results would be slightly smaller.

10 . See Lange and Topel (2006).

4.4. The choice of deflators

The fourth issue in aligning the capital estimates from the OECD and World Bank works is related to the choice of exchange rates to ensure the comparisons being made based on a common metric (currency).

The World Bank applied the market exchange rates (MER, in constant 2005 U.S. dollar prices) for this purpose, because the World Bank estimates are primarily aimed at making comparisons across broad income groups and to analyze a country's wealth over time – its volume and composition – but with less focus on making comparisons between individual countries (World Bank, 2011). On the contrary, the OECD project used the purchasing power parities (PPPs) for private consumption to serve this purpose, as its focus is made on comparisons across countries.

Since this paper is primarily concerned with showing the pattern of wealth distribution within a country when human capital is included, we therefore estimate human capital using the MERs instead of the PPPs, to be consistent with the estimates for other assets in the World Bank's accounts.

5. The wealth decomposition with human capital included

Estimates of the composition of national wealth with human capital included, for the thirteen selected countries in 2005, are presented in Table 3. The estimates of the total wealth and net foreign assets are directly drawn from the World Bank wealth accounts, while the estimates for human capital are the OECD ones, as included in Liu (2011) after the adjustments described above. The value of the 'intangible residual' is calculated as the difference between total wealth and the sum of all of the other asset values.[11]

Table 3. Wealth decomposition, 2005 (level in nominal US$ per capita by MER and share in percentage), Discount rate = 4.58% for both natural and human capital

US$ (%)	Produced capital	Natural capital	Net foreign assets	Human capital	Intangible residual	Total wealth
CAN	89,811 (16.7)	34,761 (6.5)	-2,977 (-0.6)	349,838 (64.9)	67,263 (12.5)	538,697 (100)
FRA	93,619 (16.0)	8,105 (1.4)	2,561 (0.4)	339,261 (57.9)	142,901 (24.4)	586,448 (100)
ISR	47,232 (14.4)	4,559 (1.4)	-3,495 (-1.1)	197,238 (60.2)	81,937 (25.0)	327,471 (100)
ITA	89,860 (18.0)	7,063 (1.4)	-4,533 (-0.9)	269,241 (54.0)	136,647 (27.4)	498,277 (100)
KOR	58,636 (23.6)	2,487 (1.0)	-3,252 (-1.3)	288,887 (116.4)	-98,578 (-39.7)	248,180 (100)
NLD	109,658 (18.5)	12,421 (2.1)	-1,676 (-0.3)	332,930 (56.1)	140,214 (23.6)	593,547 (100)
NZL	76,281 (18.4)	49,875 (12.0)	-21,271 (-5.1)	305,094 (73.7)	4,133 (1.0)	414,113 (100)
NOR	183,078 (21.2)	103,708 (12.0)	36,436 (4.2)	503,204 (58.4)	35,371 (4.1)	861,797 (100)
POL	20,526 (15.1)	8,373 (6.2)	-3,414 (-2.5)	98,268 (72.3)	12,188 (9.0)	135,941 (100)

11. Tables 4 and 5 in Annex III present a sensitivity analysis of the wealth decomposition using 4% and 5% as the discount rate for both natural and human capital.. Given the narrow range of discount rates used, the results are very similar to what is presented in Table 3.

US$ (%)	Produced capital	Natural capital	Net foreign assets	Human capital	Intangible residual	Total wealth
ROU	14,292 (17.7)	8,527 (10.5)	-1,403 (-1.7)	45,078 (55.7)	14,411 (17.8)	80,906 (100)
ESP	82,194 (20.1)	7,033 (1.7)	-11,999 (-2.9)	289,929 (71.0)	41,227 (10.1)	408,385 (100)
GBR	84,861 (12.8)	5,896 (0.9)	-7,290 (-1.1)	404,239 (61.0)	174,919 (26.4)	662,624 (100)
USA	100,075 (13.6)	13,012 (1.8)	-6,947 (-0.9)	409,524 (55.8)	218,532 (29.8)	734,195 (100)

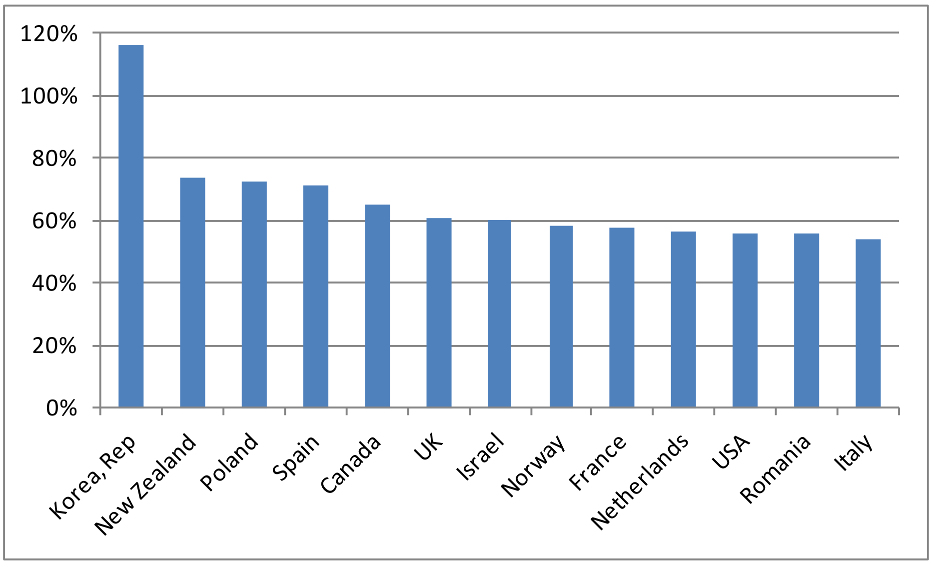
Source: Author's calculations.

As indicated in the table, human capital accounts for more than half of total national wealth for all the selected countries. This finding is consistent with the results found by both Ferreira and Hamilton, (2010) and national studies for Canada (Gu and Wong, 2008) and Norway (Greaker, 2008).

5.1. Discussion

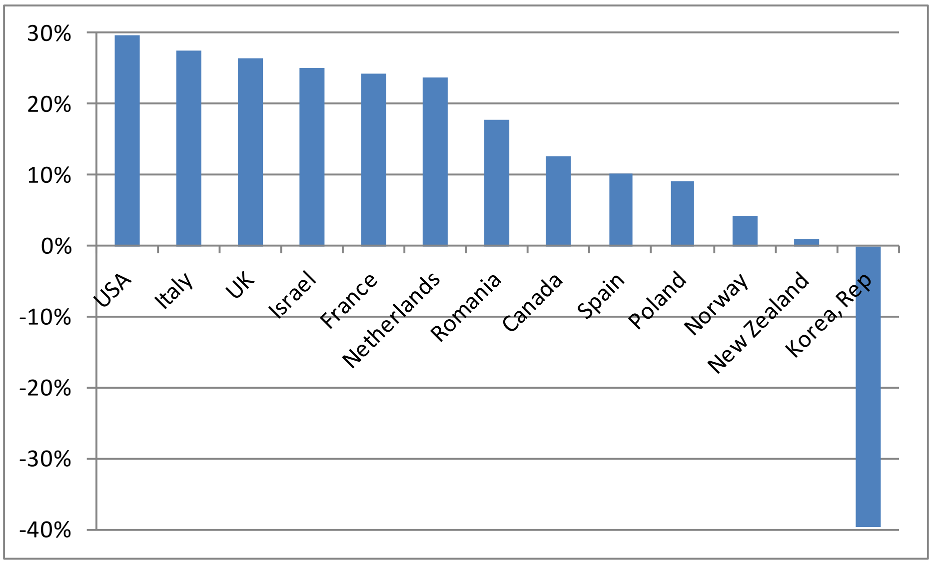
Figures 2 and 3 summarize the key results from the wealth decomposition, with the focus being put on the shares of human capital and of the intangible residual in the total wealth of each country.

Figure 2. Human capital share of total wealth, 2005



Source: Authors' calculations

Figure 3. Intangible residual share of total wealth, 2005



Source: Authors' calculations

For the countries analyzed, the unweighted average share of human capital in total wealth (excluding Korea, which is clearly an outlier) is nearly 62%, and, as Figure 2 shows, the shares fall in the range of 54% to 74%. These shares can be compared with those for produced capital, which average roughly 17% across the countries in our sample,[12] and those for natural capital, which average 4.5% of total wealth (compared to 2% for high income countries in total as seen in Table 1).

Turning to the intangible residual, this is in effect computed as a 'residual of a residual.' Intangible capital, as measured in World Bank (2011), is measured as the difference between total wealth and tangible capital, both produced and natural. The estimate of the intangible residual shown in this paper is instead computed as the difference between the World Bank measure of intangible capital and the OECD human capital measured using the lifetime income approach.

Since estimated total wealth depends upon the assumption of constant returns to scale (CRS), the calculated intangible residual implicitly includes intangible assets such as institutional quality and social capital, missing tangible assets (e.g. fish stocks, owing to a lack of data), as well as any deviations from CRS and measurement errors.

As Figure 3 shows, the share of the intangible residual in total wealth exhibits considerable variation across countries. For a cluster of the highest income countries (the United States, Italy, the United Kingdom, France, the Netherlands), however, the share stands close to 25%. Excluding Korea, the unweighted average share of the intangible residual in total wealth is nearly 18%.

12. One reviewer has pointed out that there is a high correlation between the value of human capital and the value of produced capital in Table 3. This is consistent with a constant elasticity of substitution (CES) production function. Since the cross partial derivatives with respect to factors are positive for a CES production function, employing an additional marginal quantity of produced capital will increase the marginal return to human capital.

A striking result in these figures is the very large share of human capital (more than 100% of total wealth) and the negative intangible residual wealth for Korea. There could be several explanations for this. First, Korea has historically enjoyed relatively high annual real income growth, which is reflected in the 3.98% forecast growth rate shown in Table 2.[13] A similar argument may hold for Poland and Spain as well, since their projected income growth rates are also relatively high. Second, and in contrast to all the other countries covered in the OECD project, the educational attainment data for Korea combine educational Level 4 (post-secondary, non-tertiary education) with Level 5B (first stage of tertiary education), while earnings' data for Level 5B are applied to this combined group, which results in an upward bias to the human capital estimates for Korea.

The intangible wealth residual is small but positive in New Zealand and Norway, 1% and 4% of total wealth respectively. There are no obvious explanations for this low share – both countries have a high proportion of natural capital (which will decrease calculated intangible capital in total, given the wealth accounting methodology), but other countries such as Romania, Canada and Poland also have considerably high shares of natural capital. New Zealand stands out in Figure 2 as having the highest share of human capital after Korea, in spite of a projected real income growth of only 0.77% as shown in Table 2. The other notable feature for New Zealand is the large negative figure for net foreign assets, more than 5% of total wealth. In contrast, Norway's share of human capital in total wealth is near the sample mean, while it enjoys a positive 5% share of net foreign assets in total wealth. [14]

6. Concluding remarks

We began this analysis by presenting evidence that the SNA balance sheet accounts are substantially incomplete and hypothesizing that human capital makes up the bulk of the missing wealth. By aligning the assumptions underlying the OECD measurement of human capital in Liu (2011) and the measurement of comprehensive wealth published in World Bank (2011), we conclude that this hypothesis is true. At the mean for our sample of selected countries, human capital is nearly four times the value of produced capital, and 15 times the value of natural capital.

By measuring human capital directly, we also greatly enrich the comprehensive wealth accounts of the World Bank, as seen in Table 3. Instead of a high income country average of 81% of total wealth consisting of an intangible capital residual, as seen in Table 1, we have narrowed this residual value to an average of 18% in our sample of countries (excluding Korea). In other terms, we have narrowed the bounds of our ignorance about where is the wealth of nations.

But it would be incorrect to view our new estimate of the intangible wealth of nations as purely a measure of our ignorance. The needed insight comes from the growth accounting literature (which builds upon Solow (1957)), where large percentages of the growth in economic output are ascribed to total factor productivity growth. As measured, TFP growth is another residual quantity, i.e. the difference between real GDP growth and the weighted growth of production factors such as capital and labor. But TFP itself has a clear interpretation as a measure of the efficiency with which

13 . As mentioned in subsection 4.2, the annual income growth rate of 3.98% is calculated as a geometric mean over the period of 1960 – 2017. By using a growth rate of 1.84%, Korea's growth rate calculated over 1997 -2017, the estimated value of Korean human capital stock would be 27% lower.

14. The low intangible residual for Norway supports Greaker's (2008) assumption that human capital in Norway can be measured in the same manner as the World Bank's intangible capital, i.e. as total wealth minus tangible wealth. Liu and Greaker (2009) showed that using the lifetime income approach in Norway produces a similar estimate of human capital.

productive factors are converted into economic output, while TFP growth is generally interpreted as a measure of technological change.

In this light, it is plausible to suggest, as we do in the Introduction, that our new estimate of the intangible residual is the 'stock equivalent' of TFP. It is an asset which augments the ability of other assets – produced, natural and human capital – to support a stream of consumption. Institutional quality, and other forms of social capital, can clearly play this role.

From this perspective, the significant residual share of intangible wealth that we estimate for our sample of countries, and the variation that we observe in the sample, have inherent analytical interest. Before viewing the empirical question as settled, however, at least two additional pieces of research are needed.

First, our methodological discussion has raised the question of the use of social versus private discount rates for estimating human capital. This requires further consideration.

Second, the results for Korea merit reflection on the choice of the growth rate of real income used in human capital estimation. As Romer and Sala-I-Martin (1995) show, for a relatively homogeneous group of countries, both theory and empirical evidence suggest that there should be convergence of growth rates of per capita income as countries grow richer. Particularly for initially poor, rapidly growing economies such as Korea, expected future growth rates of per capita income may be considerably lower than what has been observed historically. This would lower the estimate of human capital for these economies.

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Annex I. Measuring total wealth: bottom-up and top-down

We present a simplified version of a model for wealth accounting developed by Hamilton and Hartwick (2005). Assume a simple economy producing a homogeneous good which may be either consumed C or invested $\dot{K}$. The production factors are produced capital K, natural resource input R, and a fixed labor force L. GDP for this economy is therefore measured as,

$$GDP = F(K, R, L) = C + \dot{K}$$

There is a finite stock S of the natural resource, measured as,

$$S = \int_t^\infty R\, ds$$

Production is assumed to exhibit constant returns to scale (CRS), so that,

$$F = F_K K + F_R R + F_L L$$

Here F_K is the marginal product of capital (i.e. the interest rate, assumed to be constant for simplicity), F_R is the resource price (equal to the marginal resource rent), and F_L is the wage rate.

The value of the natural resource stock N is measured as the present value of resource rents, while the value of the human capital stock H is the present value of returns to labor,

$$N = \int_t^\infty F_R R\, e^{-F_K(s-t)} ds$$

$$H = \int_t^\infty F_L L\, e^{-F_K(s-t)} ds$$

This in turn implies that instantaneous changes in natural and human capital are given by,

$$\dot{N} = F_K N - F_R R$$

$$\dot{H} = F_K H - F_L L$$

Total wealth W can simply be measured from the bottom up in this formulation,

$$W = K + N + H$$

The change in total wealth $\dot{W} = \dot{K} + \dot{N} + \dot{H}$ is derived as follows,

$$\begin{aligned} \dot{W} &= F - C + F_K N - F_R R + F_K H - F_L L \\ &= F_K(K + N + H) - C \end{aligned}$$

The latter expression follows from the assumption of CRS, and a specific solution to this equation is,

$$W = K + N + H = \int_t^\infty C e^{-F_K(s-t)}\, ds$$

Total wealth, measured as the sum of its constituent assets, is just equal to the present value of future consumption.

Measuring top-down total wealth, the present value of future consumption, requires assumptions about the discount rate, the path of future consumption, and the choice of the period over which the present value will be taken. We assume the Ramsey formula,

$$F_K = \delta + \eta \cdot g$$

for pure rate of time preference δ, elasticity of the marginal utility of consumption η, and consumption growth rate g, all assumed to be constant. Choosing $\eta = 1$ and an accounting period of $T - t$ years, then the estimate of total wealth using the Ramsey formula for the discount rate is given by,

$$W = \int_t^T Ce^{-\delta(s-t)}\, ds$$

Here C is held constant at its value at time t.

These parameter choices can be disputed. The choice of the elasticity of the marginal utility of consumption to equal 1 is certainly within the range of empirical estimates in the literature (Beckerman and Hepburn 2007), and this has the effect of cancelling out the assumed growth rate of consumption g in the discount factor. Consumption could be rising or falling at any constant rate, therefore, without affecting the measure of total wealth. World Bank (2011, Appendix A) lays out the further assumptions required to apply this formula for total wealth, including the choice of an accounting period of 25 years (roughly a generation), the choice of a pure rate of time preference δ of 1.5%, and the treatment of unsustainable economies where genuine saving (net saving adjusted for human capital investment and resource depletion – see Hamilton and Clemens 1999) is negative.

While the theory just presented implies an exact equality between top down and bottom up measures of total wealth, in practice there will always be gaps in the value of bottom up total wealth. As a result there is a residual value of wealth, the difference between the two wealth measures, which implicitly includes hard to measure values, such as the value of institutional quality, and all errors and omissions, including any deviations from the assumption of constant returns to scale.

Annex II. Measuring human capital: lifetime income approach

Implementing the lifetime income approach in the OECD human capital project requires three major steps.

First, a database containing the economic value of labor market activities for various categories of people needs to be compiled. This database should include, at minimum, information on the number of people, their earnings, school enrolment rates, employment rates, and survival rates. All these data should, ideally, be cross-classified by some characteristics such as gender, age and levels of educational attainment.

As a second step, an algorithm needs to be constructed for calculating the lifetime income for a representative individual in each classified category in the database. The fundamental assumption applied here is that an individual of a given age, gender and educational level will have in year *t+1* the same labor income (adjusted by real income growth rate and survival rate) and other characteristics (e.g. school enrolment rate, employment rate and survival rate, etc.) as those of a person who, in year *t*, is one year older but has otherwise the same characteristics (e.g. gender and educational level).

The project distinguishes between three stages in the life cycle of an individual of working age (i.e. between 15 and 64 years old): i) 'study-and-work' (15-40); ii) 'work-only' (41-64); and iii) 'retirement' (65 and above). Based on this assumption, the lifetime labor income of an individual can be computed as follows:

- For persons aged 65 and over (i.e. 'retirement' stage), their lifetime labor income is zero since, by assumption, these persons will not receive earnings after withdrawing from the labor market.

- For persons aged 41 to 64 (i.e. 'work-only' stage), their lifetime labor income is estimated as follows:

(1) $$LIN_{age}^{edu} = EMR_{age}^{edu} AIN_{age}^{edu} + SUR_{age+1} LIN_{age+1}^{edu} \{(1+r)/(1+\delta)\},$$

where LIN_{age}^{edu} is the present value of lifetime labor income for a representative individual with educational level of "*edu*" at the age of "*age*"; EMR_{age}^{edu} is the employment rate for this individual; AIN_{age}^{edu} is his/her current annual labor income, if being employed; SUR_{age+1} is the probability of surviving one more year given that this individual is at the age of "*age*"; r is the annual growth rate of the labor income (in real terms) of a person of these characteristics in the future; δ is the annual discount rate.

The lifetime income of a representative individual during the 'work-only' stage is therefore estimated as the sum of two parts: the first part is the current labor income, adjusted by employment rate (the first term in equation (1)); the second part is the lifetime income in the next year, adjusted by the corresponding survival rate, income growth rate and discount rate (the second term in equation (1)).

- For persons aged 15 to 40 (i.e. 'study-and-work' stage), their lifetime labor income is estimated as follows:

$$LIN_{age}^{edu} = EMR_{age}^{edu} AIN_{age}^{edu} + \left\{1 - \sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}\right\} SUR_{age+1} LIN_{age+1}^{edu} \{(1+r)/(1+\delta)\}$$

(2)

$$+ \sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}} \left\{\left(\sum_{t=1}^{t_{edu-\overline{edu}}} SUR_{age+t} LIN_{age+t}^{\overline{edu}} \{(1+r)/(1+\delta)\}^{t}\right) / t_{edu-\overline{edu}}\right\},$$

where $ENR_{age}^{edu-\overline{edu}}$ is the school enrolment rate for a representative individual with educational level of "*edu*" pursuing his/her studies into a higher educational level of "$\overline{edu}$"; $t_{edu-\overline{edu}}$ is the school duration for this individual with educational level of "*edu*" to complete a higher educational level of "$\overline{edu}$".

During the 'study-and-work' stage, a representative individual in the next year will be confronted to two courses of action: the first is to continue his/her work (holding the same educational level as before) and earn income as $SUR_{age+1} LIN_{age+1}^{edu} \{(1+r)/(1+\delta)\}$, with the probability of $\left\{1 - \sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}\right\}$; the second is to enter into school and (after completing study having gained a higher educational level) to receive income as $\left\{\left(\sum_{t=1}^{t_{edu-\overline{edu}}} SUR_{age+t} LIN_{age+t}^{\overline{edu}} \{(1+r)/(1+\delta)\}^{t}\right) / t_{edu-\overline{edu}}\right\}$, with the probability of $\sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}$. Therefore, his/her lifetime income in the next year is the expected value of the outcomes of these two courses of action (i.e. the sum of the second and the third terms in equation (2)).

The empirical implementation of equations (1) and (2) is based on backwards recursion. By this approach, the lifetime labor income of a person aged 64 (i.e. one year before retirement) is simply his/her current labor income (the first term in equations (1) and (2)) because his/her lifetime labor income at 65 is zero by construction. Similarly, the lifetime labor income of a person aged 63 is equal to his current labor income plus the present value of the lifetime labor income of a person aged 64, and so forth.

In estimating lifetime labor income by using equations (1) and (2), several practical assumptions are made, such as:

- Individuals can only enrol in a higher educational level than the one they have already completed.
- No further enrolment is allowed for people having already achieved the highest educational level.
- Students enrolled in educational institutions requiring more than one year to complete are assumed to be evenly distributed across the total study-period (school duration). This is equivalent to say that, during each school-year, there is the same (equal) proportion of the total students that will complete the study.

- No delaying, quitting or skipping is allowed during the whole period of studying.

As a third and last step, the lifetime labor income measures estimated through equations (1) and (2) are in per capita terms and are then applied to all individuals in each age/educational categories to compute the human capital stock for each category. Summing up the stocks of human capital across all classified categories yields the estimate of the aggregate value of the human capital stock (*HCV*) for each country.

(3) $$HCV = \sum_{age} \sum_{edu} LIN_{age}^{edu} NUM_{age}^{edu} \ ,$$

where NUM_{age}^{edu} is the number of persons in the corresponding age/educational category. It should be noted that equations (1), (2) and (3) are applied separately to both men and women; this allows computing the stock of human capital by gender.

Annex III

Table 4. Wealth decomposition, 2005 (level in nominal US$ per capita by MER and share in percentage), Discount rate = 4% for both natural and human capital

US$ (%)	Produced capital	Natural capital	Net foreign assets	Human capital	Intangible residual	Total wealth
CAN	89,811 (16.7)	36,924 (6.9)	-2,977 (-0.6)	376,606 (69.9)	38,332 (7.1)	538,697 (100)
FRA	93,619 (16.0)	8,609 (1.5)	2,561 (0.4)	367,460 (62.7)	114,198 (19.5)	586,448 (100)
ISR	47,232 (14.4)	4,843 (1.5)	-3,495 (-1.1)	215,165 (65.7)	63,726 (19.5)	327,471 (100)
ITA	89,860 (18.0)	7,502 (1.5)	-4,533 (-0.9)	292,818 (58.8)	112,630 (22.6)	498,277 (100)
KOR	58,636 (23.6)	2,642 (1.1)	-3,252 (-1.3)	316,935 (127.7)	-126,780 (-51.1)	248,180 (100)
NLD	109,658 (18.5)	13,193 (2.2)	-1,676 (-0.3)	357,508 (60.2)	114,863 (19.4)	593,547 (100)
NZL	76,281 (18.4)	52,979 (12.8)	-21,271 (-5.1)	328,722 (79.4)	-22,598 (-5.5)	414,113 (100)
NOR	183,078 (21.2)	110,162 (12.8)	36,436 (4.2)	544,645 (63.2)	-12,523 (-1.5)	861,797 (100)
POL	20,526 (15.1)	8,894 (6.5)	-3,414 (-2.5)	107,671 (79.2)	2,263 (1.7)	135,941 (100)
ROU	14,292 (17.7)	9,058 (11.2)	-1,403 (-1.7)	48,963 (60.5)	9,996 (12.4)	80,906 (100)
ESP	82,194 (20.1)	7,471 (1.8)	-11,999 (-2.9)	316,039 (77.4)	14,679 (3.6)	408,385 (100)
GBR	84,861 (12.8)	6,263 (0.9)	-7,290 (-1.1)	436,613 (65.9)	142,178 (21.5)	662,624 (100)
USA	100,075 (13.6)	13,822 (1.9)	-6,947 (-0.9)	441,827 (60.2)	185,418 (25.3)	734,195 (100)

Source: Author's calculations.

Table 5. Wealth decomposition, 2005 (level in nominal US$ per capita by MER and share in percentage), Discount rate = 5% for both natural and human capital

US$ (%)	Produced capital	Natural capital	Net foreign assets	Human capital	Intangible residual	Total wealth
CAN	89,811 (16.7)	33,312 (6.2)	-2,977 (-0.6)	332,374 (61.7)	86,176 (16.0)	538,697 (100)
FRA	93,619 (16.0)	7,767 (1.3)	2,561 (0.4)	320,976 (54.7)	161,524 (27.5)	586,448 (100)
ISR	47,232 (14.4)	4,369 (1.3)	-3,495 (-1.1)	185,668 (56.7)	93,697 (28.6)	327,471 (100)
ITA	89,860 (18.0)	6,768 (1.4)	-4,533 (-0.9)	253,991 (51.0)	152,191 (30.5)	498,277 (100)
KOR	58,636 (23.6)	2,383 (1.0)	-3,252 (-1.3)	270,867 (109.1)	-80,454 (-32.4)	248,180 (100)
NLD	109,658 (18.5)	11,903 (2.0)	-1,676 (-0.3)	316,870 (53.4)	156,792 (26.4)	593,547 (100)
NZL	76,281 (18.4)	47,797 (11.5)	-21,271 (-5.1)	289,723 (70.0)	21,583 (5.2)	414,113 (100)
NOR	183,078 (21.2)	99,386 (11.5)	36,436 (4.2)	476,348 (55.3)	66,549 (7.7)	861,797 (100)

US$ (%)	Produced capital	Natural capital	Net foreign assets	Human capital	Intangible residual	Total wealth
POL	20,526 (15.1)	8,024 (5.9)	-3,414 (-2.5)	92,213 (67.8)	18,592 (13.7)	135,941 (100)
ROU	14,292 (17.7)	8,172 (10.1)	-1,403 (-1.7)	42,496 (52.5)	17,348 (21.4)	80,906 (100)
ESP	82,194 (20.1)	6,740 (1.7)	-11,999 (-2.9)	273,070 (66.9)	58,379 (14.3)	408,385 (100)
GBR	84,861 (12.8)	5,650 (0.9)	-7,290 (-1.1)	383,194 (57.8)	196,210 (29.6)	662,624 (100)
USA	100,075 (13.6)	12,470 (1.7)	-6,947 (-0.9)	388,510 (52.9)	240,088 (32.7)	734,195 (100)

Source: Author's calculations.