Variable Factor Shares, Units of Measurement and Growth Accounting: an Empirical Exercise

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Abstract

The global decline of labor shares has been extensively documented in the last years. Additionally, the shares of natural resources and raw labor seem to be negatively correlated with income per capita while the share of human and physical capital is positively correlated with income per capita. The variability of factor shares implies that growth accounting exercises rely on false assumptions. First, the standard assumption of constant shares generates a bias in the estimation of the contribution of factors to economic growth. Second, the effect that changes in factor shares have on output depends on the relative abundance of factors and, for this reason, it is necessary to have correct units of measurement for all the factors. We propose a growth accounting methodology that incorporates the variability of factor shares and solves the measurement issue. We also build a database for 34, 62 and 58 countries for 1995, 2000 and 2005, respectively, disentangling physical capital's share from natural capital's share and human capital's share from unskilled labor's share. With this database we apply the methodology proposed and perform a growth accounting regression. Our results suggest that (i) the correct units of measurement are significantly lower than standard ones for both the stock of physical capital per worker and the stock of natural capital per worker, (ii) the contribution of changes in factor shares to the growth rate of income is important for several countries (iii) the marginal productivity of all the factors is positively correlated with per worker income.

JEL Codes: O11, O30, O41

Keyword: Factor Shares, Production Function, Measurement.

1. INTRODUCTION

Empirical works show that the labor income share has globally declined in the last decades. Blanchard (1997) observes the share of labor decreases in continental Europe after the 80s and suggests that the reason for such decline may be technological bias. Recently, several authors have highlighted the downward trend in labor shares and provide different explanations for this fact.[1] Similarly, Kahn and Lim (1997) show that the shares of equipment, production workers and non-production workers have clear trends which are consistent with the biased innovations explanation.[2]

Other authors calculate the income share of reproducible factors (human and physical capital) and non-reproducible factors (natural capital and raw labor) and it turns out that the former is positively correlated with the income level (see Krueger (1999), Acemoglu (2002), Caselli and Feyrer (2007), Zuleta (2008a), Sturgill (2012) and Zuleta, Parada, García and Campo (2010)).

The variability of factor shares can be explained by: i) changes in the bargaining power of different agents[3]; ii) an aggregate production function where the elasticity of substitution between factors is different from one; iii) an increase in the relative size of the sectors where factor shares are different from the average; or iv) biased technological change. Of course, in the first case the functional distribution of income (the distribution between owners of different factors) has no relation with aggregate output so, if this is the correct explanation then there are no problems regarding units of measurement.[4] However, if any of the other explanations is correct then any change in the functional distribution of income is the result of a fundamental change that also affects aggregate output.

According to Zuleta (2012), changes in the factor shares have different effects on output depending on the factor abundance of the economy. If the income share of abundant factors is growing then the effect of this change on the income level is positive but if the share of abundant factors decreases then the effect of the change is negative. To illustrate the importance of correct

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[1] See Young (2010), Sachs and Kotlikoff (2012), Elsby, Hobijn, and Sahin (2013), Karabarbounis and Neiman (2013) and Rodriguez and Jayadef (2013) among others.

[2] In the last decades some authors revisited the theory of biased innovations and challenged the Cobb-Douglas-Kaldor paradigm (see Zeira (1998, 2005), Seater (2005), Peretto and Seater (2013), Zuleta (2008b) and Zuleta and Young (2013), among others).

[3] According to this line of research, the decrease in labor shares is due to a decrease in the bargaining power of workers generated by the institutional setting (see Bentolila and Saint Paul (2003), Giammarrioli et al. (2002), Berthold et, al. (2002) and Bental and Demouguin (2010), among others).

[4] According to Aghion and Howitt (2009) the attempt to attribute changes in human capital and raw labor shares to deunionization fails on the basis of time considerations.

measures for the factors Zuleta considers a Cobb-Douglas technology with two factors: capital (*K*) and labor (*L*). Output per worker $\left(y = {}^{Y}/_{L}\right)$ can be expressed as a function of capital per worker $\left(k = {}^{K}/_{L}\right)$: $y = Ak^{\alpha}$. If there is an increase in the share of capital, then the effect on output per worker depends on the relative abundance of capital,

$$\frac{\partial y}{\partial k} = Ak^{\alpha} lnk \ \ .$$

Therefore, if $k > 1$ then the effect is positive and if $k < 1$ the effect is negative.

We apply the method developed by Zuleta (2012) in order to identify the correct measures of factors per worker and propose a growth accounting methodology that incorporates the variability of factor shares and solves the measurement issue. We also build a database for 34, 62 and 58 countries for 1995, 2000 and 2005, respectively, disentangling physical capital's share from natural capital's share and human capital's share from unskilled labor's share. With this database we apply the methodology proposed and estimate a growth accounting regression.[5]

Our results suggest that (i) the correct units of measurement for factors per worker are significantly lower than the standard units, (ii) the contribution of the change in factor shares is significant in economic terms, (iii) the marginal productivity of all factors is positively correlated to income per worker.

The rest of the paper is organized as follows. In section 2 we present the methodology. In section 3 we present data. In section 4 we present the main results. In section 5 we present some empirical implications of our results. Finally we conclude in section 6.

2. HOW TO SOLVE THE PROBLEM?

2.1 The Methodology assuming away factor augmenting technological change.

Consider a Cobb-Douglas production function with four factors:

(1) $$Y_t = A_t(\phi_K K_t)^{\alpha_t}(\phi_H H)^{\beta_t}(\phi_N N_t)^{\gamma_t}(\phi_L L_t)^{1-\alpha_t-\beta_t-\gamma_t}$$

where Y is total income, K is physical capital, H is human capital, N is natural capital, L is raw labor, α is the elasticity of output with respect to physical capital, β is the elasticity of output with

[5] We present the complete list of countries and available years in Appendix 1.

respect to human capital, γ is the elasticity of output with respect to natural capital and $(1-\alpha-\beta-\gamma)$ is the elasticity of output with respect to raw labor.

Expressing equation (1) in per worker terms we get,

$$(2) \qquad y_t = \frac{Y_t}{L_t} = A_t \left(\frac{\phi_K K_t}{\phi_L L_t}\right)^{\alpha_t} \left(\frac{\phi_H H}{\phi_L L_t}\right)^{\beta_t} \left(\frac{\phi_N N_t}{\phi_L L_t}\right)^{\gamma_t}$$

From equation (2) it is clear that a change in the units of measurement ϕ do not remove or alter any information about factors per worker. However, these changes do alter the magnitude of the response of output per worker to a change in shares. For this reason it is necessary to control for the impact of the choice of units on the response of output to a change in factor shares. In other words, given that factor shares vary, the relative abundance of factors becomes very important and, for this reason, it is necessary to have correct units of measurement for the factors of production per worker. The parameters $\frac{\phi_K}{\phi_L}$, $\frac{\phi_H}{\phi_L}$ and $\frac{\phi_N}{\phi_L}$ play this role.

Taking logs and differences to equation (2) yields

$$(3) \quad lny_t - lny_{t-1} = \begin{Bmatrix} lnA_t - lnA_{t-1} + \alpha_t ln\left(\frac{K}{L}\right)_t - \alpha_{t-1} ln\left(\frac{K}{L}\right)_{t-1} + \beta_t ln\left(\frac{H}{L}\right)_t - \beta_{t-1} ln\left(\frac{H}{L}\right)_{t-1} \\ +\gamma_t ln\left(\frac{N}{L}\right)_t - \gamma_{t-1} ln\left(\frac{N}{L}\right)_{t-1} + \Delta\alpha \ln\left(\frac{\phi_K}{\phi_L}\right) + \Delta\beta \ln\left(\frac{\phi_H}{\phi_L}\right) + \Delta\gamma \ln\left(\frac{\phi_N}{\phi_L}\right) \end{Bmatrix}.$$

Now define

$$(4) \qquad S_t = lny_t - lny_{t-1} - \begin{Bmatrix} \alpha_t ln\left(\frac{K}{L}\right)_t - \alpha_{t-1} ln\left(\frac{K}{L}\right)_{t-1} + \beta_t ln\left(\frac{H}{L}\right)_t \\ -\beta_{t-1} ln\left(\frac{H}{L}\right)_{t-1} + \gamma_t ln\left(\frac{N}{L}\right)_t - \gamma_{t-1} ln\left(\frac{N}{L}\right)_{t-1} \end{Bmatrix}.$$

From equations (3) and (4) it follows that

$$(5) \qquad S_t = lnA_t - lnA_{t-1} + \left\{\Delta\alpha_t \ln\left(\frac{\phi_K}{\phi_L}\right) + \Delta\beta_t \ln\left(\frac{\phi_H}{\phi_L}\right) + \Delta\gamma_t \ln\left(\frac{\phi_N}{\phi_L}\right)\right\}.$$

Note that the variable S is TFP growth plus biased technological change. According to biased innovation models, biased technological change manifests as a change in output elasticities with respect to factors and, with competitive factor markets, such elasticities are equal to factor shares. In other words, changes in factor shares ($\Delta\alpha_t$, $\Delta\beta_t$ $\Delta\gamma_t$) occur because of biased technological changes.

It is a broader representation of productivity growth than what is usually discussed.

From equation (5), we can estimate the following equation:

$$(6) \qquad S_t = C_0 + C_1\Delta\alpha_t + C_2\Delta\beta_t + C_3\Delta\gamma_t + \rho_t$$

where $C_0 + \rho_t = lnA_t - lnA_{t-1}$, $C_1 = \ln\left(\frac{\phi_K}{\phi_L}\right)$, $C_2 = \ln\left(\frac{\phi_H}{\phi_L}\right)$, $C_3 = \ln\left(\frac{\phi_N}{\phi_L}\right)$. Therefore, this methodology allows us to identify the correct measures of factors per worker $\frac{\phi_K}{\phi_L}$, $\frac{\phi_H}{\phi_L}$ and $\frac{\phi_N}{\phi_L}$, and the growth rate of TFP.

2.2 Factor augmenting technological change

If there is factor augmenting technological change and the rate of technological change is constant then equation (3) becomes

$$(3A) \qquad lny_t - lny_{t-1} = \left\{\begin{matrix} lnA_t - lnA_{t-1} + lnA_{L.t} - lnA_{L,t-1} + \alpha_t lnA_{K.t} - \alpha_{t-1} lnA_{K,t-1} \\ +\beta_t lnA_{H.t} - \beta_{t-1} lnA_{H,t-1} + \gamma_t lnA_{N.t} - \gamma_{t-1} lnA_{N,t-1} \\ +\alpha_t ln\left(\frac{K}{L}\right)_t - \alpha_{t-1} ln\left(\frac{K}{L}\right)_{t-1} + \beta_t ln\left(\frac{H}{L}\right)_t - \beta_{t-1} ln\left(\frac{H}{L}\right)_{t-1} \\ +\gamma_t ln\left(\frac{N}{L}\right)_t - \gamma_{t-1} ln\left(\frac{N}{L}\right)_{t-1} + \Delta\alpha \ln\left(\frac{\phi_K}{\phi_L}\right) + \Delta\beta \ln\left(\frac{\phi_H}{\phi_L}\right) + \Delta\gamma \ln\left(\frac{\phi_N}{\phi_L}\right) \end{matrix}\right\}.$$

Equation (3A) can be combined with equation (4) to yield

$$(5A) \qquad \tilde{S}_t = \left(\begin{matrix} ln\left(\frac{A_t}{A_{t-1}}\right) + ln\left(\frac{A_{L,t}}{AL_{,t-1}}\right) + \alpha_t\left[ln\left(\frac{A_{K.t}}{A_{L.t}}\right) - ln\left(\frac{A_{K.t-1}}{A_{L.t-1}}\right)\right] + \beta_t\left[ln\left(\frac{A_{H.t}}{A_{L.t}}\right) - ln\left(\frac{A_{H.t-1}}{A_{L.t-1}}\right)\right] \\ +\gamma_t\left[ln\left(\frac{A_{N.t}}{A_{L.t}}\right) - ln\left(\frac{A_{N.t-1}}{A_{L.t-1}}\right)\right] + \Delta\alpha\left[\ln\left(\frac{\phi_K}{\phi_L}\right) + ln\left(\frac{A_{K.t-1}}{A_{L.t-1}}\right)\right] \\ +\Delta\beta\left[\ln\left(\frac{\phi_H}{\phi_L}\right) + ln\left(\frac{A_{H.t-1}}{A_{L.t-1}}\right)\right] + \Delta\gamma\left[\ln\left(\frac{\phi_N}{\phi_L}\right) + ln\left(\frac{A_{N.t-1}}{A_{L.t-1}}\right)\right] \end{matrix}\right).$$

Finally, we can estimate the following equation:

$$(6A) \qquad \tilde{S}_t = C_0 + C_1\Delta\alpha_t + C_2\alpha_t + C_3\Delta\beta_t + C_4\beta_t + C_5\Delta\gamma_t + C_6\gamma_t + \rho_t$$

where $C_0 + \rho_t = ln\left(\frac{A_t}{A_{t-1}}\right) + ln\left(\frac{A_{L,t}}{AL_{,t-1}}\right)$, $C_1 = \ln\left(\frac{\phi_K}{\phi_L}\frac{A_{K.t-1}}{A_{L.t-1}}\right)$, $C_2 = ln\left(\frac{A_{K.t}}{A_{L.t}}\right) - ln\left(\frac{A_{K.t-1}}{A_{L.t-1}}\right)$, $C_3 = \ln\left(\frac{\phi_H}{\phi_L}\frac{A_{H.t-1}}{A_{L.t-1}}\right)$, $C_4 = ln\left(\frac{A_{H.t}}{A_{L.t}}\right) - ln\left(\frac{A_{H.t-1}}{A_{L.t-1}}\right)$, $C_5 = \ln\left(\frac{\phi_N}{\phi_L}\frac{A_{N.t-1}}{A_{L.t-1}}\right)$ and $C_6 = ln\left(\frac{A_{N.t}}{A_{L.t}}\right) - ln\left(\frac{A_{N.t-1}}{A_{L.t-1}}\right)$.

Therefore, we can identify the correct measures of factors per worker, the differences between physical, human and natural capital augmenting and labor augmenting technological change, which are given by $\frac{\Delta A_{K,t}}{A_{K,t}} - \frac{\Delta A_{L,t}}{A_{L,t}}$, $\frac{\Delta A_{H,t}}{A_{H,t}} - \frac{\Delta A_{L,t}}{A_{L,t}}$,and $\frac{\Delta A_{N,t}}{A_{N,t}} - \frac{\Delta A_{N,t}}{A_{N,t}}$, respectively, and the sum of neutral plus labor augmenting technological change $\frac{\Delta A_{t}}{A_{t}} + \frac{\Delta A_{L,t}}{A_{L,t}}$.

Note that if there is factor augmenting technological change then the coefficients C_1, C_3 and C_5 change with time. In particular, $C_{1,t} = C_{1,t-1} + C_2$, $C_{3,t} = C_{3,t-1} + C_4$,and $C_{5,t} = C_{5,t-1} + C_6$. Therefore, for the empirical strategy we need to include these restrictions.

3. DATA

Data availability and the methodology used to collect and construct all necessary variables yield a panel of 154 observations consisting of 34, 62 and 58 countries for 1995, 2000 and 2005, respectively. Given our reliance on growth rates and differences, only countries that have complete data for two consecutive periods are included in the data set. A country with data for all three periods yields two growth rates, one for 1995-2000 and one for 2000-2005. A country with data for only two periods yields only one growth rate, either 1995-2000 or 2000-2005. The distribution of data over time and across countries yields 92 growth rate observations.

3.1 Output, raw labor and output per worker

Aggregate income (*Y*) is measured as real GDP, and estimates of this variable for the years 1995, 2000, and 2005, reported in 2005 international dollars (PPP converted), are generated using data obtained from version 7.1 of the Penn World Tables (PWT71 – Heston et al., 2012). These tables report values for real GDP per capita (*rgdpch*) and population (*POP*). Estimates of real GDP are computed as the product $rgdpch \cdot POP$. *Total Employment* for the population aged 15 years and over, which we obtain from version 7 of the International Labor Organization's (ILO) Key Indicators of the Labor Market (KILM) database (KILMnet, 2013), is used as the measure of raw labor (*L*) for most countries. *Total Employment* includes *Wage and Salaried Workers, Total Self-Employed Workers* and *Not Classified*.[6] There are a few countries for which KILM data is unavailable or for which the employment age and/or geographic coverage varies across 1995, 2000 and 2005 within the KILM database. For these countries raw labor is measured as the product of the *employment to population ratio* and *population* reported in the World Bank's World Development

[6] The ILO defines *Not classified* workers as "those for whom insufficient relevant information is available, and/or who cannot be included in any of the preceding categories" (KILMnet, 2013).

Indicators (WDI) database.[7] Output per worker (*Y/L*) is formed by dividing the estimate of real GDP by the estimate of raw labor.

Note that the *rgdpwok* variable provided in PWT71 is an estimate of real GDP per worker, but it is unappealing for the growth accounting exercise because "worker" in this variable corresponds to a census definition based on the economically active population. The economically active population includes employed and unemployed persons. Unemployed persons do not contribute to the production of a good or service and therefore do not represent raw labor inputs into aggregate production.

3.2 Physical and natural capital

We generate estimates of physical and natural capital using data reported in the World Bank's Wealth of Nation's database. The data are available only for the years 1995, 2000 and 2005. The World Bank builds its estimate of aggregate natural capital using data on stocks of natural resources and estimates of resource rents.[8] Aggregate stocks of physical capital are computed from historical investment data using the perpetual inventory method.

The World Bank's measure of physical capital includes the value of urban land. Following Kunte et. al (1998), The World Bank assumes for each country a value of urban land equal to 24 percent of the value of the aggregate stock of physical capital. The measure reported by the World Bank is an estimate of $K+.24K$. Land, regardless of how it is used in production, is a non-reproducible input and, in the context of this paper, should be categorized as natural capital. We divide the World Bank estimate by 1.24 to derive our estimate of *K*. The difference between the World Bank's reported sum and the aforementioned estimate of *K* is the estimate of urban land's value. The estimate of urban land's value is added to The World Bank's estimate of natural capital to obtain an appropriate estimate of *N*.

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[7] Specifically, the WDI reports the *employment to population ratio (15+), percentage of the total population (15+)* and *population (total)*. The number of employed workers is backed out as the product $(\textit{employment to population ratio (15+)})(\textit{percentage of the total population (15+)})(\textit{population (total)})$. The WDI definition of *employment* encompasses wage and salaried workers and self-employed workers.

[8] The World Bank's natural capital data encompasses the following resources: energy resources including oil, natural gas, hard coal and lignite; mineral resources including bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin and zinc; timber resources; nontimber forest resources; cropland; pastureland; and protected areas.

One final adjustment is necessary before the physical and natural capital stock estimates can be implemented in a growth accounting exercise. The cross-country data provided by The World Bank rely on nominal exchange rates and are reported in constant 2005 US dollars. In order to be consistent with the real GDP data described above, estimates of *K* and *N* should be PPP converted and reported in 2005 international dollars. To that end, we multiply the U.S. dollar estimates of *K* and *N* by the exchange rate (local currency unit/U.S. dollar), which we obtain from the WDI database. This converts the data into local currency units. We then divide the local currency value by the PPP exchange rate (local currency unit/international dollar), also obtained from the WDI database, to express the estimates of *K* and *N* in 2005 international dollars. The per worker estimates, *K/L* and *N/L*, are constructed by dividing these international dollar estimates by our estimates of raw labor.

Our categorization of urban land as natural capital is debatable as is the World Bank's assumption that the value of urban land equals 24 percent of the value of the physical capital stock. By assuming that urban land is a constant proportion of physical capital, we may be inflating the value of natural capital. For this reason we build an alternative series for physical and natural capital. This alternative series is discussed in Appendix 5. The forthcoming analysis in section 4 is based on the data that categorize urban land as natural capital, but the analysis was also performed using this alternative series. The results are robust and provided in Appendix 5.

3.3 Human capital

Let human capital augmented labor be defined as $J = jL$. where *j* is effective labor per worker and encompasses the level of education. Specifically, we follow Hall and Jones (1999) and define $j = e^{\phi(E)}$ where *E* is average years of schooling, which we obtain for the population aged 15 and over from Barro and Lee (2013), and $\varphi(E)$ is piecewise linear with slope 0.117 for $E \leq 4$, 0.097 for $4<E\leq 8$ and 0.075 for $E>8$. The slope coefficients represent rates of return for education as reported by Psacharopoulos and Patrinos (2004). Human capital (*H*) is given by $H = J - L$ and can be thought of as the difference between the effective workforce, which is the workforce augmented by education, and the basic workforce, which is not augmented.

Note that effective labor per worker (*j*) takes on a value of 1 when there is no schooling. Thus human capital per worker (*H/L*), which equals *j-1*, can be interpreted as the difference between the efficiency of a unit of labor with *E* years of schooling and the efficiency of a unit of labor with no schooling.

3.4 Factor Shares

Recall from Section 2.1 that α, β, γ and $1-\alpha-\beta-\gamma$ are the elasticities of output with respect to physical capital, human capital, natural capital and raw labor, respectively. Theoretically, factor shares and output elasticities are equivalent only in a perfectly competitive environment. However, estimates of factor shares are generally accepted as reasonable estimates of aggregate output elasticities and are routinely inserted for output elasticities in growth accounting analyses and other empirical work.

We start by estimating *total* labor's share and *total* capital's share in accordance with Bernanke and Gurkaynak (2001) and Gollin (2002). Total labor's share (*TLS*) is computed as

$$TLS = \frac{Employee\ Compensation}{GDP - TPILS - Gross\ Mixed\ Income}, \tag{8}$$

and *total* capital's share (*TCS*) is computed as the perfect competition counterpart and given by

$$TCS = \left(1 - \frac{Employee\ Compensation}{GDP - TPILS - Gross\ Mixed\ Income}\right). \tag{9}$$

Note that *TLS* encompasses the fractions of income accruing to both human capital and raw labor and can be thought of as an estimate of $1-\alpha-\beta-\gamma$, the sum of human capital and raw labor shares. *TCS* encompasses the fractions of income accruing to both physical and natural capital and can be thought of as an estimate $\alpha+\gamma$, the sum of physical and natural capital shares.

Gross Mixed Income refers to self-employed income and is defined by the United Nations' Statistics Division as "the surplus or deficit accruing from production by unincorporated enterprises owned by households." Subtracting *Gross Mixed Income* from *GDP* in equations (8) and (9) implies the share of labor income in *Gross Mixed Income* is assumed to be the same as the share of labor income generated in the corporate sector.

Taxes on production and imports less subsidies (*TPILS*) include but are not limited to taxes payable on goods when they are produced, taxes on imports, taxes on fixed assets and taxes on the total wage bill.[9] *TPILS* should be allocated to either capital or labor compensation depending on the

[9] The United Nation's Statistics Division defines taxes on production and imports as "taxes payable on goods and services when they are produced, delivered, sold, transferred or otherwise disposed of by their producers

tax type. However, most countries report only the aggregate tax value without any detailed breakdown of the various taxes. It is impossible to know exactly how *TPILS* should be dispersed. By subtracting *TPILS*, the implicit assumption is that the fraction of *TPILS* attributable to capital compensation is equivalent to *total* capital's share, and the fraction of *TPILS* attributable to labor compensation is equivalent to total labor's share.

Data for *Employee Compensation, GDP* and *TPILS* are obtained from table 4.1 of the United Nation's online national accounts database (UN data).[10] Data for *Gross Mixed Income*, when it is available, is also obtained from table 4.1.[11] For some countries, the value of *Gross Mixed Income* is included in the reported value of *Gross Operating Surplus*. In these cases *total* shares are estimated using equations (8) and (9) with *Imputed Gross Mixed Income* (*IGMI*) substituted for actual *Gross Mixed Income*. *Imputed Gross Mixed Income* is constructed by multiplying the share of self-employed persons in total employment by private sector income as follows:

$$IGMI = \left(\frac{Total\ Self-Employed\ Workers}{Total\ Employment-Not\ Clasified}\right)\begin{pmatrix} Gross\ Operating\ Surplus\ + \\ Employee\ Compensation \end{pmatrix} \quad (10)$$

This computation assumes that self-employed income as a fraction of total income is equivalent to the share of self-employed workers in total employment.

A person that is *Not Classified* could be employed in the corporate sector or self-employed. By subtracting *Not Classified* from *Total Employment* in equation (10) we are assuming that the

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plus taxes and duties on imports that become payable when goods enter the economic territory by crossing the frontier or when services are delivered to resident units by non-resident units; they also include other taxes on production, which consist mainly of taxes on the ownership or use of land, buildings or other assets used in production or on the labor employed, or compensation of employees paid."

[10] In some cases, multiple values of each variable are reported for multiple "Series" within the 1968 and 1993 systems of national accounts (SNA) methodologies. For each country, we use the values from the most recent "Series" for which data are reported for each variable across 1995, 2000 and 2005.

[11] In a few cases, *net* rather than *gross mixed income* is reported in the UN database. *Net mixed income* does not encompass the *consumption of fixed capital* pertaining to unincorporated enterprises. *Consumption of fixed capital* "represents the reduction in the value of the fixed assets used in production during the accounting period resulting from physical deterioration, normal obsolescence or normal accidental damage." Since *consumption of fixed capital* is reported only for the aggregate economy, we construct *imputed consumption of fixed capital for unincorporated enterprises* (ICFCUE) as

$$ICFCUE = \left(\frac{Total\ Self-Employed\ Workers}{Total\ Employment-Not\ Clasified}\right)(Consumption\ of\ Fixed\ Capital).$$

This computation assumes that consumption of fixed capital for unincorporated enterprises as a fraction of consumption of fixed capital for the aggregate economy is equivalent to the share of self-employed workers in total employment. The estimate of *ICFCUE* is added to *net mixed income* to obtain an estimate of *gross mixed income*.

fraction of *Not Classified* that is self-employed is equivalent to the fraction of *Total Employment* that is self-employed. Without this subtraction, the implicit assumption in equation (10) would be that all workers that are *Not Classified* are *Wage and Salaried Workers*.

Data for *Total Employment* and all of its components, including *Wage and Salaried Workers*, *Total Self-Employed Workers* and *Not Classified* are obtained from version 7 of the KILM database (KILMnet, 2013). If *Gross Mixed Income* must be imputed, only countries for which self-employment as a fraction of total employment is less than 0.6 are included.[12] If the self-employed comprise more than 60% of total employment, then some of the resulting total labor share estimates are unrealistic and often greater than 1. Bernanke and Gurkaynak (2001), who use a similar cutoff of 50%, state that such results are not unexpected since data quality tends to be relatively poor in countries with large informal sectors.

Sturgill (2012), which builds on Caselli and Feyrer (2007), shows that, under the assumption that physical and natural capital pay the same return, physical capital's share is proportional to the ratio of physical capital to *total* capital and can be computed as

$$\alpha = \frac{K}{C} TCS \tag{11}$$

where $C = K+N$ is the value of the *total* capital stock. Given our estimates of K, N and TCS, estimates of α are obtained in accordance with equation (11). In like manner, natural capital's share is computed as

$$\gamma = \frac{N}{C} TCS \tag{12}$$

Human capital's share is estimated using returns to education and the percentage of the population in various educational attainment categories. As with the specification of human capital in section 3.3, a year of schooling in each country is assumed to yield an 11.7% rate of return per

[12] Forty three of the 154 observations in the sample require *Imputed Gross Mixed Income*. They include Bahrain (2000 and 2005); Bolivia (1995 and 2000); Costa Rica (1995, 2000 and 2005); Denmark (1995, 2000 and 2005); Hong Kong (1995, 2000 and 2005); Israel (1995, 2000 and 2005); Jamaica (2000 and 2005); South Korea (1995, 2000 and 2005); Macao (2000 and 2005); Malta (2000 and 2005); New Zealand (1995, 2000 and 2005); Panama (1995); Philippines (1995, 2000 and 2005); Romania (2000 and 2005); Russia (2000 and 2005); Sri Lanka (2000 and 2005); Trinidad and Tobago (2000 and 2005); Ukraine (2000 and 2005); and Venezuela (1995).

year for the first four years, a 9.7% rate of return per year for the next four years, and a 7.5% rate of return per year for schooling beyond eight years. The percentage of the population aged 15 and over in seven educational attainment categories is obtained for each country from Barro and Lee (2013). The categories include *No Schooling*, *Incomplete primary*, *Complete Primary*, *Incomplete Secondary*, *Complete Secondary*, *Incomplete Higher* and *Complete Higher*. These categories correspond to 0, 4, 8, 10, 12, 14 and 16 years of schooling, respectively. The returns to education imply a wage relative to no schooling for each educational attainment category. For example, workers with *Incomplete Higher* education would earn $1.117^4 \times 1.097^4 \times 1.075^6 = 3.48$ times as much as workers with *No Schooling*.

As in Sturgill (2012), who follows Pritchett (2001), the fraction of wages accruing to human capital is computed as

$$Human\ Capital's\ Share\ of\ Wages = \frac{\sum_{g=0}^{6}(w_g - w_0)\tau_g}{100 + \sum_{g=0}^{6}(w_g - w_0)\tau_g} \tag{13}$$

where g indexes the seven educational attainment categories, w_g is the wage relative to no schooling, and τ_g is the percentage of a country's population in each educational attainment category. The numerator in equation (13) represents total wages paid to human capital and the denominator represents total wages paid in the economy. The 100 in the denominator is the normalized value of total wages paid to raw labor; 100% of workers receive the relative wage of 1 for remuneration of raw labor.

Estimates of human capital's share of income (β) are computed by multiplying total labor's share of income (*TLS*) by *Human Capital's Share of Wages*. Given estimates of *TLS* and β, raw labor's share of income ($1 - \alpha - \beta - \gamma$) can be computed as a residual.

The factor share estimates for our pooled sample (1995, 2000 and 2005) are plotted against real GDP per worker in Figures 1-4. The formal regression results in Appendix 2.1 reveal that physical capital's share and human capital's share are each positively correlated with output per worker at the1% level. Natural capital's share and raw labor's share are negatively correlated with output per worker at 1% and 5% levels, respectively. This systematic variation in factor shares is consistent with the empirical literature and the theory of factor saving innovations. Appendix 2.2 provides plots and regression results for each year.

An alternative method for constructing physical and natural capital shares is discussed in Appendix 3. Among the countries for which both methods can be computed, the correlation between the Sturgill (2012) method and the alternative method is 0.63 for physical capital's share and 0.84 for natural capital's share. The main appeal of the alternative methodology is that, unlike the Sturgill (2012) methodology, the assumption that physical and natural capital pay equal returns is not required nor is data for *K* and *N*. We claim that the units of measurement for *K* and *N* may be wrong so if the share estimates are functions of *K* and *N*, then such share estimates, which are required for estimating correct measurement units, are plagued by the very units bias that we are trying to remedy.

The fact that the alternative share methodology is computed independently of the *K* and *N* data described in section 3.2 and used in the rest of the analysis is also its main drawback; the Sturgill (2012) methodology relies explicitly on capital stock data, so there is a clear relationship between each factor and the construction of its share. Furthermore, the alternative approach generates fewer observations. For these reasons, and given that the qualitative results pertaining to the systematic variation of shares is robust to the choice of methodology, we perform and discuss the regression estimations that follow in section 4 using share data based on the Sturgill (2012) approach. However, these same regressions are also performed using the alternative share data. Results are robust. See Appendix 5.

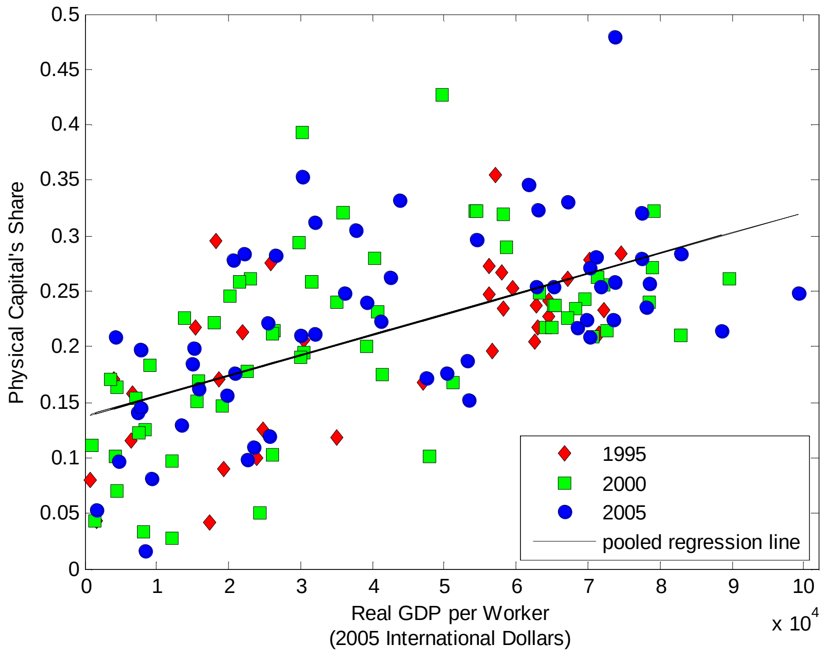


Fig. 1 Physical Capital's Share vs. Real GDP per Worker

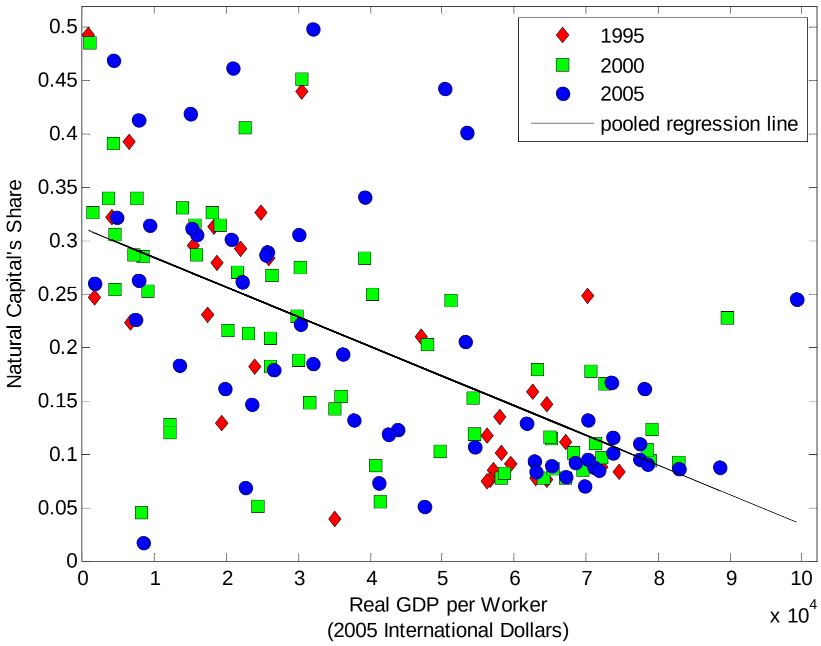


Fig. 2 Natural Capital's Share vs. Real GDP per Worker

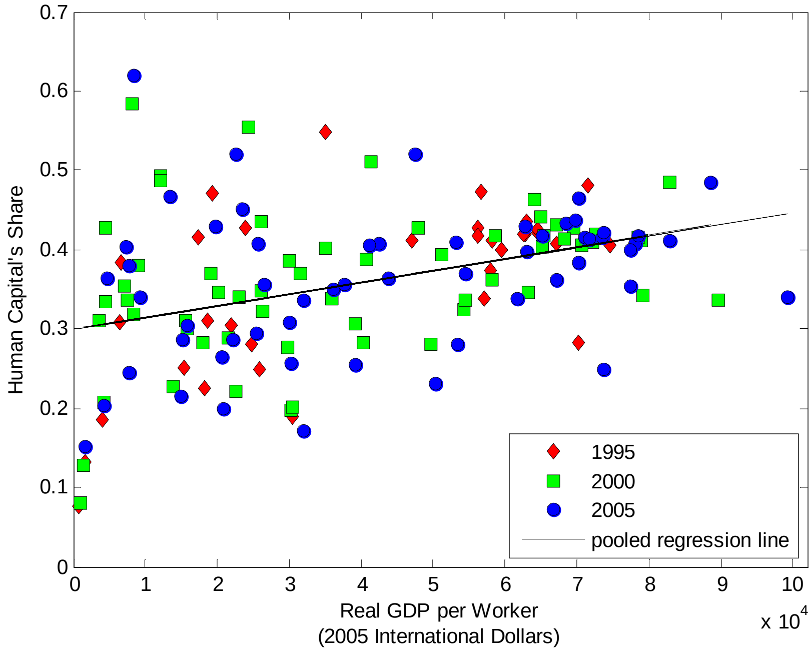


Fig. 3 Human Capital's Share vs. Real GDP per Worker

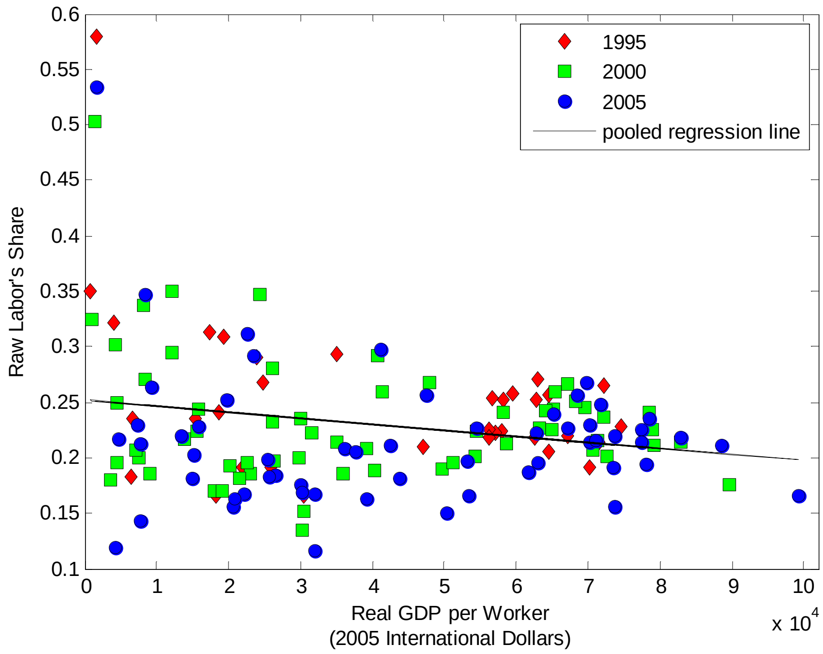


Fig. 4 Raw Labor's Share vs. Real GDP per Worker

4. RESULTS

In this section we estimate growth regressions using panel data. We use the data described in the previous section and consider an aggregate production function, which combines two reproducible factors, human and physical capital (*H* and *K*), and two non-reproducible factors, natural capital and raw labor (*N* and *L*), in a Cobb–Douglas form. We observe GDP, factor values and factor shares so we can estimate equation (6).

Results are presented in Table 1. Column 1 shows the results of the panel regression using robust errors, column 2 shows the results including country fixed effects and column 3 includes country and time fixed effects.

Regarding equation 6, results seem to be robust. Coefficients C_1 and C_3 are significantly different from zero and their values are similar for all the specifications. Therefore, the results suggest that the correct units of measurement are significantly lower than the standard ones for both the stock of physical capital per worker and the stock of natural capital per worker. Coefficient C_2 is not significantly different form zero so we cannot claim that the units of measurement of human capital are incorrect. We also run regressions that include a data quality control and that consider an OECD subsample of countries. Again, results are robust.

Table 1. Estimation of equation 6.

Variables	(1) $\tilde{S}$	(2) $\tilde{S}$	(3) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-11.36***	-11.00***	-10.84***
	[1.546]	[1.031]	[1.025]
$\Delta\beta_t$ (C_2)	-3.707	-1.408	-1.398
	[2.470]	[1.523]	[1.504]
$\Delta\gamma_t$ (C_3)	-14.09***	-12.13***	-12.26***
	[1.335]	[0.906]	[0.900]
Constant	0.0709***	-0.144**	-0.122**
	[0.0221]	[0.0550]	[0.0568]
Observations	92	92	92
R-squared	0.960	0.997	0.997
Year fixed effects	NO	NO	YES
Country fixed effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

In order to find the correct units of measurement for the factors we need to transform the coefficients, $C_1 = \ln\left(\frac{\phi_K}{\phi_L}\right)$, $C_2 = \ln\left(\frac{\phi_H}{\phi_L}\right)$, $C_3 = \ln\left(\frac{\phi_N}{\phi_L}\right)$. Table 2 shows the implied values for the parameters, $\frac{\phi_K}{\phi_L}$, $\frac{\phi_H}{\phi_L}$ and $\frac{\phi_N}{\phi_L}$ according to specification (3).

Table 2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.00001963
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.00000475

From Table 2 it follows that the correct units of measurement are significantly lower than standard ones for both the stock of physical capital per worker and the stock of natural capital per worker. Regarding human capital per worker, the implied correct units are closer to the standard one and, as we stated above, given the lack of statistical significance we cannot claim that the original units are incorrect.

Now, as we stated in section 2, if there is factor augmenting technological change then we need to take it into account. In Table 3, we present estimations of equation 6A. The first column presents the estimation without country fixed effects. The results suggest that there is no evidence of factor augmenting technological change and that the units of measurement of all factors are incorrect. However, the significance of coefficient C_3 is 10% so the result is not strong. In the second column we repeat the exercise including country effects. In this case, all coefficients but C_3 are significantly different from zero suggesting that the units of measurement of human capital per worker are correct and that there is no factor augmenting technological change. In both cases, the results suggest that units of measurement of physical and natural capital per worker are incorrect.

Note also that coefficients C_1 and C_2 from specification 2 are very similar to the ones reported in Table 1 (column 3).

Again, in order to find the correct units of measurement for the factors we need to transform the coefficients. Table 4 shows the implied values for the parameters according to specification 2.

Similar to Table 2, Table 4 implies that the correct units of measurement are significantly lower than standard ones.

Table 3. Estimation of equation 6A.

VARIABLES		(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$	(C_1)	-11.60***	-11.49***
		[1.482]	[1.071]
α_t	(C_2)	0.0700	0.171
		[0.246]	[0.633]
$\Delta\beta_t$	(C_3)	-4.237*	-2.866
		[2.210]	[1.723]
β_t	(C_4)	0.110	1.473
		[0.336]	[1.084]
$\Delta\gamma_t$	(C_5)	-15.05***	-12.93***

	[1.411]	[1.131]
γ_t (C6)	0.397	0.813
	[0.280]	[0.883]
$\Delta\alpha_t * D_{2005}$	0.0700	0.171
	[0.246]	[0.633]
$\Delta\beta_t * D_{2005}$	0.110	1.473
	[0.336]	[1.084]
$\Delta\gamma_t * D_{2005}$	0.397	0.813
	[0.280]	[0.883]
Constant	-0.0472	1.725**
	[0.231]	[0.700]
Observations	92	92
Country effects	NO	YES

Table 4
Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.0000102
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.0000092

Given that we do not find evidence of factor augmenting technological change we use the values reported in Table 2 in order to build the new series of factors per worker. In order to do that, we take series of production factors and transform them according to the following equations: $\tilde{k}_t = \frac{\phi_K}{\phi_L}\frac{K_t}{L_t}$, $\tilde{n}_t = \frac{\phi_N}{\phi_L}\frac{N_t}{L_t}$, $\tilde{h}_t = \frac{\phi_H}{\phi_L}\frac{H_t}{L_t}$. The values of these variables are presented in Appendix 4. With these series we can perform growth accounting exercises and compute the marginal productivity of each factor.

5. EMPIRICAL IMPLICATIONS

5.1 The Marginal Product of Factors

Using the data reported in Appendix 4 we can compute the marginal productivity of physical capital, human capital, natural capital and raw labor:

$$MPK = \alpha_t \frac{y_t}{\tilde{k}_t},\ MPH = \beta_t \frac{y_t}{h_t},\ MPN = \gamma_t \frac{y_t}{\tilde{n}_t},\ MPL = (1 - \alpha_t - \beta_t - \gamma_t) y_t \qquad (14)$$

In figures 5, 6, 7 and 8 we plot the marginal productivity of these factors against income per worker. The positive correlation between GDP per worker and the marginal productivity of all factors is apparent.

The only difference between our estimates based on the transformed data and the estimates based on the original series is the scale. In other words, the positive correlation between income and marginal productivity of factors does not depend on the units of measurement.

Fig. 5 Marginal Productivity of Physical Capital vs. Real GDP per worker

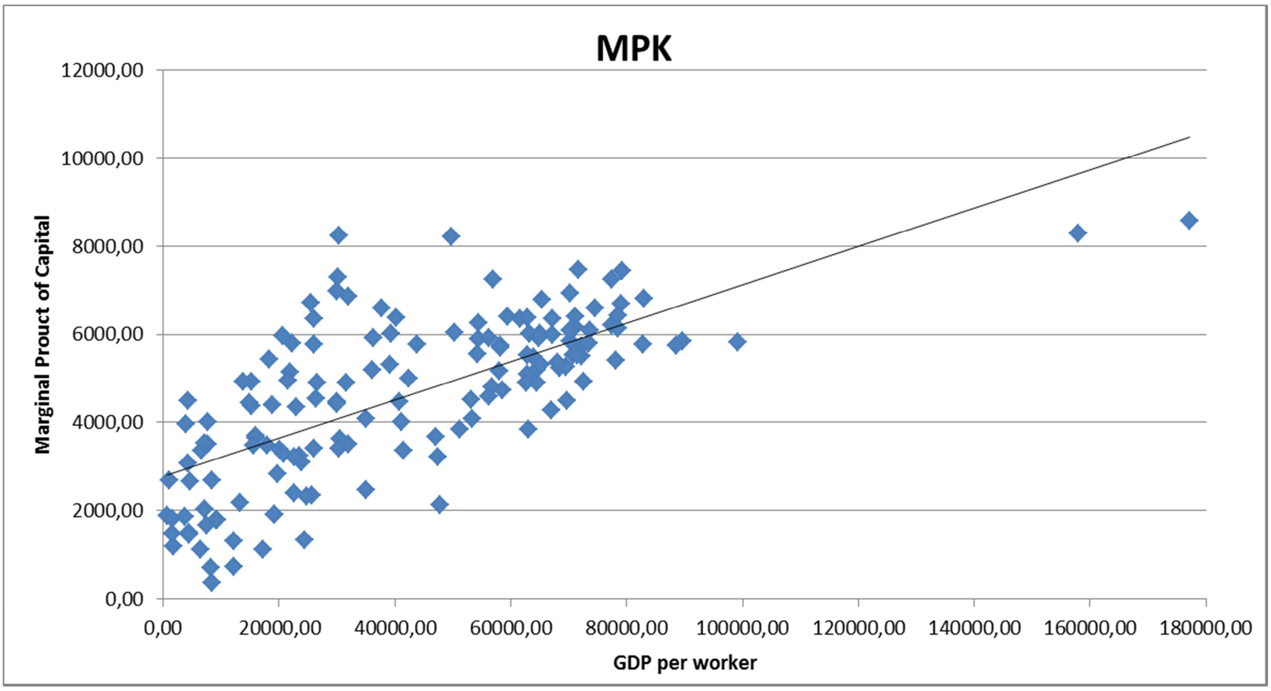


Fig. 6 Marginal Productivity of Human Capital vs. Real GDP per worker

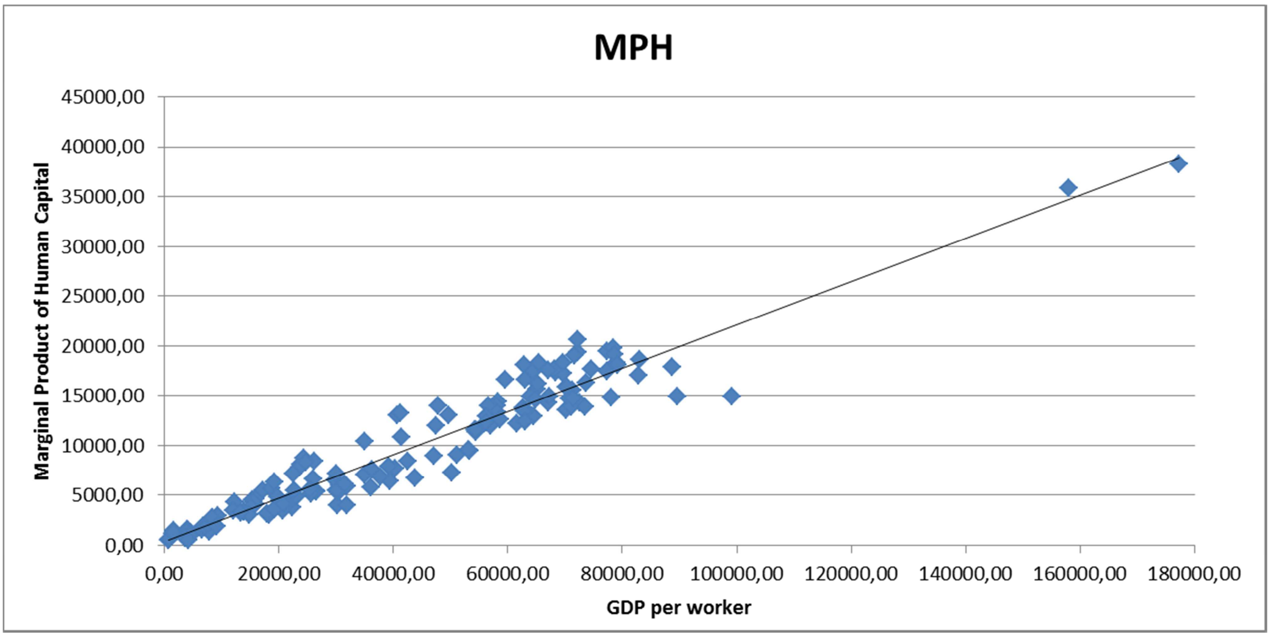


Fig. 7 Marginal Productivity of Natural Capital vs. Real GDP per worker

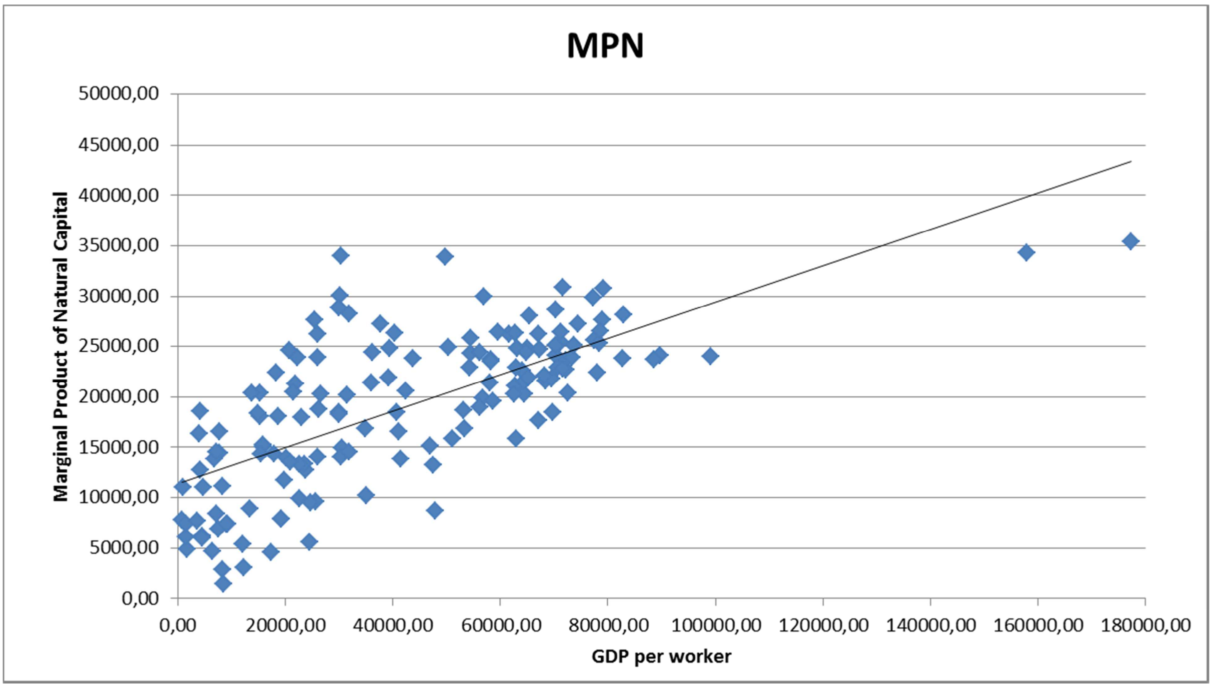
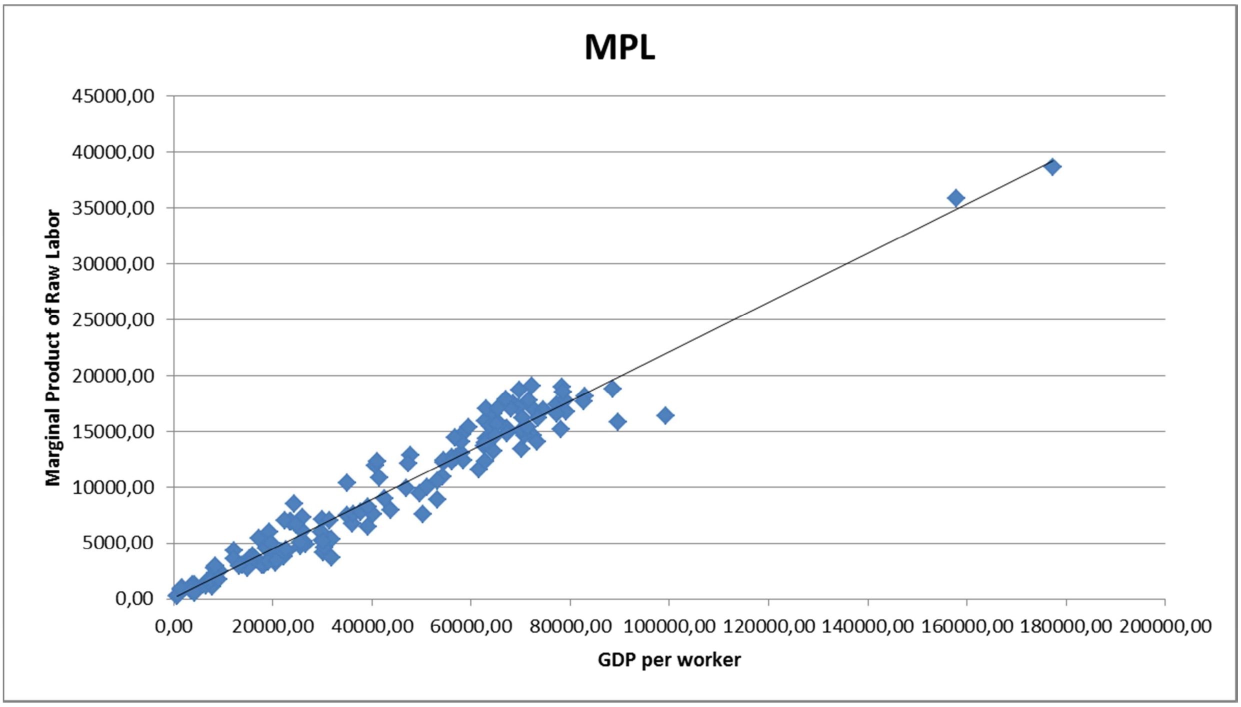


Fig. 8 Marginal Productivity of Raw Labor vs. Real GDP per worker



To the best of our knowledge, there is only one published article where the marginal productivity of capital is calculated taking into account the variability of capital shares. Caselli and Feyrer (2007) look at the MPK in a framework that also allows shares to vary. Based on the four specifications they consider, Caselli and Feyrer conclude that there is "virtually no difference in MPK between poor and rich countries." However, when they revise their estimates using correct shares and account for differences in prices between capital and consumption goods they find that "rich countries actually have a higher marginal product on average than the poor countries." The positive correlation that we find is consistent with this last statement.

Regarding the marginal productivity of other factors, as far as we know, there is no other estimation in the existing literature. The positive correlation between the marginal productivity of factors and real GDP per worker may help explain why both physical and human factors do not flow to poor countries.

With the results we perform a Lucas-like exercise by computing the difference in TFP needed to have equal marginal productivity of capital given factor shares and factor stocks. We assume a Cobb Douglas and compare USA and Brazil in 2005. First, we take the original data and assume the same factor shares. Then, we use the observed factor shares and the correct units of measurement in order to calculate the required TFP differences.

If we assume that the only factors are physical capital and labor and impose a capital share of 0.33 then the ratio of TFP between USA and Brazil that equalize the marginal productivity of capital is 1.67. When we use all factors, and use the observed factor shares and the correct units of measurement, the ratio of TFP that equalizes the marginal productivity of capital is 2.6.

Now, when we compute the ratio of TFPs using GDP per worker, the observed factor shares and the factors corrected according to Table 4 then the ratio of total factor productivities is 2.78:

$$\frac{A_{US}}{A_{Br.}} = \frac{GDP_{pwUS}}{GDPpw_{Br}} \frac{\left(\frac{\phi_K}{\phi_L}k_{Br}\right)^{\alpha_{Br}}\left(\frac{\phi_H}{\phi_L}h_{Br}\right)^{\beta_{Br}}\left(\frac{\phi_N}{\phi_L}n_{Br}\right)^{\gamma_{Br}}}{\left(\frac{\phi_K}{\phi_L}k_{US}\right)^{\alpha_{US}}\left(\frac{\phi_H}{\phi_L}h_{US}\right)^{\beta_{US}}\left(\frac{\phi_N}{\phi_L}n_{US}\right)^{\gamma_{US}}} = 2.78$$

implying that the marginal productivity of capital is actually higher in USA. This simple exercise illustrates the economic importance of taking into account more than two factors and the observed factor shares.

5.2 Growth Accounting

We have 5 year periods which can be affected by cyclical fluctuations. For this reason we take only the countries for which we have data for 1995 and 2005.[13]

We can use the results presented in the previous sections, and using the database we built we can compute the contribution of each one of the factors to the growth of GDP. Similarly we can decompose the contribution of factors into two elements: (i) the contribution of the factor given a constant factor share and (ii) the contribution of the change in the share of the factor. Table 5 presents this decomposition for the contribution of factors per worker to the growth of GDP per worker.

We present the results according to the units reported in Table 2. According to the results presented in Table 3, there is no evidence of factor augmenting technological change.

[13] We also exclude countries for which TFP values are outliers in the regression. These countries are Argentina, Iran, Mongolia, and Panama.

Additionally, the results are very similar to the ones we get using the units reported in Table 2. Finally, we use the original values for human capital per worker because the coefficient C_2 is not significantly different from zero.

For expositional ease, we use the following notation for the growth accounting tables:

Growth: $\mathrm{lny_t} - \mathrm{lny_{t-1}}$

k: Physical capital per worker, $\alpha_{t-1}\left(\mathrm{ln}\tilde{\mathrm{k}}_t - \mathrm{ln}\tilde{\mathrm{k}}_{t-1}\right)$

h: Human capital per worker, $\beta_{t-1}(lnh_t - lnh_{t-1})$

n: Natural capital per worker, $\gamma_{t-1}(ln\tilde{n}_t - ln\tilde{n}_{t-1})$

α: Physical capital share, $(\alpha_t - \alpha_{t-1})\mathrm{ln}\tilde{\mathrm{k}}_t$

β: Human Capital Share, $(\beta_t - \beta_{t-1})lnh_t$

γ: Natural Capital Share, $(\gamma_t - \gamma_{t-1})ln\tilde{n}_t$

TFP: TFP contribution,

$$\mathrm{lny_t} - \mathrm{lny_{t-1}} - \alpha_{t-1}\left(\mathrm{ln}\tilde{\mathrm{k}}_t - \mathrm{ln}\tilde{\mathrm{k}}_{t-1}\right) - \beta_{t-1}(lnh_t - lnh_{t-1}) - \gamma_{t-1}(ln\tilde{n}_t - ln\tilde{n}_{t-1}) - (\alpha_t - \alpha_{t-1})\mathrm{ln}\tilde{\mathrm{k}}_t - (\beta_t - \beta_{t-1})lnh_t - (\gamma_t - \gamma_{t-1})ln\tilde{n}_t$$

SR: Solow Residual,

$$\mathrm{lny_t} - \mathrm{lny_{t-1}} - \alpha_{t-1}\left(\mathrm{ln}\tilde{\mathrm{k}}_t - \mathrm{ln}\tilde{\mathrm{k}}_{t-1}\right) - \beta_{t-1}(lnh_t - lnh_{t-1}) - \gamma_{t-1}(ln\tilde{n}_t - ln\tilde{n}_{t-1})$$

Table 5 presents the contribution of factors and factor shares and Table 6 presents these contributions as a percentage of GDP per worker growth. We order the countries in the tables according to the effect that the change in physical capital's share has on per worker income.

Note that the last column of Table 6 presents the difference between the contribution of the Solow residual and the contribution of TFP. In other words, this column presents the contribution of biased innovations.

Our results indicate that the variation in physical capital's share, typically ignored in standard growth accounting exercises, explains an important part of the growth in output per worker.

In France, Austria, Germany, Japan and Israel the change in physical capital shares explains more than 20% of the growth in output per worker. On the other hand, in Sweden, Hong Kong, Denmark, Netherlands, Colombia and Costa Rica the effect of changes in capital shares is negative but small in absolute terms.

For Latin America, changes in physical capital's share have lower effects on the growth in output per worker, and the effects are often negative. The explanatory power is modest in the USA, only two percent of output per worker growth is explained by variation in physical capital's share.

Regarding the variation in human capital's share the contribution is modest and, in general, it is negatively correlated with the contribution of the variation in physical capital's share. This negative correlation may imply that capital using innovations are not only raw labor saving but also human capital saving.

Changes in natural capital share may have positive or negative effects on income. With the corrected units of measurement, natural capital per worker is smaller than one for almost all the economies in the sample. Therefore, any increase in natural capital's share generates a reduction in GDP per worker. Taking together the contribution of natural capital and natural capital shares it seems that the countries where natural capital grows also experience an increase in natural capital's share and, for this reason, natural capital positively contributes to growth but the contribution of natural capital's share is negative. The analogous argument applies for the countries where natural capital per worker decreases.

Finally, the explanatory power of TFP growth is important for a big set of countries. However, the TFP contribution is often smaller than the Solow Residual implying that the change in factors shares has a non-negligible effect on economic growth. In Brazil, France, Germany, Japan, Mexico and Netherlands contribution of changes in factor shares explain more than 20% of GDP pw growth. On the other hand, in the Philippines, Niger, Colombia and Venezuela the effect of the change in factor shares is negative and it is higher than 30% in absolute terms.

The importance of factor share variation highlights the importance of the units of measurement. The same growth accounting exercise with the original units of measurement would deliver much higher contributions because the original units are significantly higher.

Table 5. Decomposition of output per worker growth

	Growth	k	α	h	β	n	γ	TFP	SR
Sweden	22,3%	0,7%	-3,3%	3,4%	3,5%	-0,2%	3,0%	15,2%	18,4%
Niger	-6,0%	-1,2%	-3,1%	3,3%	-3,3%	-10,5%	-4,0%	12,7%	2,3%
Hong Kong	16,4%	8,0%	-3,0%	2,0%	1,3%	1,9%	0,9%	5,3%	4,5%
Denmark	16,2%	4,2%	-1,8%	0,9%	1,1%	1,7%	1,0%	9,0%	9,4%
Colombia	-20,6%	-2,8%	-1,4%	3,3%	-0,3%	-6,0%	-4,6%	-8,8%	-15,1%
Costa Rica	-1,2%	0,4%	-0,2%	3,3%	0,7%	-5,0%	4,7%	-5,1%	0,1%
Netherlands	9,1%	1,8%	-0,2%	1,6%	0,8%	-0,2%	1,3%	4,1%	6,0%
Chile	31,5%	9,5%	-0,1%	3,4%	0,2%	14,7%	-1,0%	4,8%	3,9%
Belgium	10,7%	2,2%	0,1%	2,8%	0,3%	0,9%	-0,4%	4,9%	4,8%
U. K.	18,6%	0,9%	0,1%	3,3%	0,7%	-0,4%	1,0%	12,9%	14,7%
Finland	19,0%	-2,4%	0,3%	3,2%	0,5%	-1,6%	0,3%	18,7%	19,8%
United States	21,4%	4,0%	0,4%	1,4%	0,4%	1,2%	0,5%	13,5%	14,8%
Venezuela	-17,1%	-2,3%	0,6%	5,1%	-0,1%	-5,7%	-4,6%	-10,1%	-14,2%
Switzerland	10,1%	-0,5%	0,9%	0,5%	0,1%	-1,2%	1,0%	9,2%	11,3%
Australia	19,2%	3,0%	1,1%	0,9%	-1,0%	2,8%	-0,9%	13,1%	12,4%
New Zealand	12,4%	0,4%	1,5%	2,1%	-0,2%	-2,2%	0,2%	10,7%	12,1%
Philippines	13,4%	-2,0%	1,6%	3,5%	-0,2%	2,6%	-8,3%	16,2%	9,2%
Canada	15,9%	1,6%	1,9%	6,3%	-0,2%	0,9%	-0,7%	6,0%	7,1%
Brazil	4,0%	-1,9%	2,0%	8,2%	0,8%	7,1%	-1,2%	-11,1%	-9,4%
Mexico	15,5%	1,5%	2,1%	5,1%	0,2%	-12,5%	10,0%	9,2%	21,4%
France	8,4%	0,6%	2,7%	6,7%	0,1%	-0,2%	-0,5%	-0,9%	1,4%
Germany	9,8%	1,9%	4,7%	13,2%	-0,7%	0,5%	-1,6%	-8,1%	-5,8%
Korea, Rep.	30,2%	4,9%	5,1%	6,0%	-2,1%	1,2%	-2,0%	17,0%	18,1%
Austria	20,8%	4,2%	5,3%	3,6%	-0,9%	0,5%	-0,6%	8,6%	12,4%
Israel	10,2%	1,6%	5,4%	2,2%	-3,1%	0,2%	-2,6%	6,5%	6,2%
Japan	11,3%	2,6%	6,6%	3,4%	-2,1%	0,3%	-1,3%	1,8%	5,0%

Average	**11,6%**	**1,6%**	**1,1%**	**3,8%**	**-0,1%**	**-0,4%**	**-0,4%**	**6,0%**	**6,6%**

Table 6. Contributions as a percentage of output per worker growth

	k	α	h	β	n	γ	TFP	SR	SR-TFP
Sweden	3%	-15%	15%	16%	-1%	13%	68%	83%	**14%**
Niger	20%	51%	-55%	55%	174%	66%	-211%	-39%	**172%**
Hong Kong	49%	-18%	12%	8%	12%	6%	32%	27%	**-5%**
Denmark	26%	-11%	6%	7%	11%	6%	56%	58%	**2%**
Colombia	14%	7%	-16%	1%	29%	23%	43%	74%	**31%**
Costa Rica	-36%	20%	-281%	-63%	427%	-408%	442%	-9%	**-452%**
Netherlands	20%	-2%	18%	9%	-3%	14%	45%	65%	**20%**
Chile	30%	0%	11%	1%	47%	-3%	15%	12%	**-3%**
Belgium	20%	1%	26%	3%	9%	-4%	45%	45%	**0%**
U.K.	5%	1%	18%	4%	-2%	6%	69%	79%	**10%**
Finland	-12%	2%	17%	2%	-8%	1%	98%	104%	**6%**
United States	19%	2%	7%	2%	5%	2%	63%	69%	**6%**
Venezuela	14%	-3%	-30%	0%	33%	27%	59%	83%	**24%**
Switzerland	-5%	9%	5%	1%	-12%	10%	91%	112%	**20%**
Australia	16%	6%	5%	-5%	15%	-5%	69%	65%	**-4%**
New Zealand	3%	12%	17%	-2%	-17%	2%	86%	98%	**12%**
Philippines	-15%	12%	26%	-1%	19%	-62%	121%	69%	**-52%**
Canada	10%	12%	40%	-1%	5%	-4%	38%	45%	**7%**
Brazil	-49%	51%	208%	21%	179%	-29%	-280%	-238%	**43%**
Mexico	9%	13%	33%	1%	-81%	64%	59%	138%	**79%**
France	7%	32%	79%	1%	-3%	-6%	-10%	17%	**27%**
Germany	19%	47%	134%	-7%	5%	-16%	-83%	-59%	**24%**
Korea, Rep.	16%	17%	20%	-7%	4%	-7%	57%	60%	**4%**
Austria	20%	25%	17%	-4%	3%	-3%	41%	60%	**18%**
Israel	15%	53%	22%	-30%	2%	-25%	63%	61%	**-2%**
Japan	23%	58%	30%	-19%	2%	-11%	16%	44%	**28%**
Average	**9,3%**	**14,6%**	**14,8%**	**-0,3%**	**32,8%**	**-13,2%**	**42,0%**	**43,2%**	**1,1%**

6. CONCLUSIONS

The methodology we propose has two main advantages over the standard growth accounting methodology. First, it takes into account the variability of factor shares. Second, it solves the measurement problem that accompanies variable factor shares. If factor shares vary over time, then the response of output to a change in factor shares is sensitive to the relative abundance of the factor, which varies with the choice of measurement units. Using carefully collected factor share data we estimate conversion factors that allow us to identify unit-corrected measures of factors per worker.

We find that the unit-corrected measures of factors per worker are lower than the standard measures. Combining these corrected measures with our factor share data in a growth accounting exercise, the TFP residual is found to explain an average of 42% of the growth in output per worker for countries in the sample. Variation in physical capital's share explains an average of 14.6% of growth in output per worker across the entire sample, variation in human capital's share has a very small effect on average and, finally, movement in natural capital's share has on average a negative contribution of 13%.

Beyond the average contribution of factor shares across the sample, the interesting fact is that for some countries the variation in factor shares explains a big proportion of the Solow residual. In the standard literature, the explanatory power of factor shares is masked and hidden inside the Solow residual because of the assumption of constant shares. Our results show that biased innovations, ignored in most of the growth accounting literature, are important. Allowing for such innovations reduces the unexplained variation in output per worker.

We also estimate the marginal productivity of physical capital, human capital, natural capital and raw labor. All marginal products are found to be positively correlated with output per worker, which is contradictory to previous works, and helps explain why factors do not seem to flow from rich countries to poor countries.

A useful extension would be to incorporate some of the previous techniques aimed at reducing the explanatory power of the Solow residual into this new variable share framework. Many of these techniques involve more sophisticated measures of human capital, including the consideration of health, the incorporation of test scores and the allowance for imperfect substitution between schooling levels. It is not obvious that these extensions will reduce the explanatory power of the

Solow residual by the same magnitudes or in the same patterns as when they were applied in previous studies predicated on an assumption of constant shares.

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Appendix 1. Countries available in the dataset

Country	Year 1995	2000	2005
Argentina	X	X	X
Australia	X	X	X
Austria	X	X	X
Bahrain		X	X
Belgium	X	X	X
Bolivia	X	X	
Botswana	X	X	
Brazil	X	X	X
Bulgaria		X	X
Canada	X	X	X
Chile	X	X	X
Colombia	X	X	X
Costa Rica	X	X	X
Cote d'Ivore	X	X	
Czech Republic		X	X
Denmark	X	X	X
Egypt		X	X
Finland	X	X	X
France	X	X	X
Germany	X	X	X
Greece		X	X
Honduras		X	X
Hong Kong	X	X	X
Hungary		X	X
Iran	X	X	X
Israel	X	X	X
Italy		X	X
Jamaica		X	X
Japan	X	X	X
Korea, Rep.	X	X	X
Kyrgystan		X	X
Latvia		X	X
Lithuania		X	X
Luxembourg		X	X
Macao (China SAR)		X	X
Malta		X	X
Mexico	X	X	X
Moldova		X	X
Mongolia	X	X	X

Mozambique	X	X	
Netherlands	X	X	X
New Zealand	X	X	X
Niger	X	X	X
Norway		X	X
Panama	X	X	X
Philippines	X	X	X
Poland		X	X
Portugal		X	X
Romania		X	X
Russian Fedaration		X	X
Slovakia		X	X
Spain		X	X
Sri Lanka		X	X
Sweden	X	X	X
Switzerland	X	X	X
Tajikistan		X	X
Trinidad and Tobago		X	X
Ukraine		X	X
United Kingdom	X	X	X
United States	X	X	X
Uruguay		X	X
Venezuela	X	X	X
Total	34	62	58

Appendix 2. Factor Share Analysis

Appendix 2.1 Factor Share Regression Results: Pooled Sample

Table A1. Pooled Factor Shares

	Dependent Variable			
	Physical Capital's Share	Natural Capital's Share	Human Capital's Share	Raw Labor's Share
Variable	1	2	3	4
Intercept	0.146***	0.295***	0.311***	0.248***
	(15.222)	(22.070)	(24.479)	(27.896)
		{17.649}	{18.433}	{19.279}
Real GDP per Worker	1.590E-06***	-2.305E-06***	1.145E-06***	-4.292E-07**
	(8.553)	(-8.913)	(4.653)	(-2.496)
		{-6.896}	{3.834}	{-2.107}
Adjusted R^2	0.321	0.339	0.119	0.033
F-test for no heteroskedasticity	0.931	5.811	15.944	10.945
	[3.056]	[3.056]	[3.056]	[3.056]
Sample	154 obs.	154 obs.	154 obs.	154 obs.

Notes: t-statistics are in parantheses, ( ).

{ } indicates t-statistics computed using White corrected standard errors.

Square brackets are 5% critical values of the F distribution.

* indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Appendix 2.2 Factor Share Plots and Regression Results: Separated by Year

The International Organization for Standardization's (ISO) three-letter country codes are used as data markers in all plots.

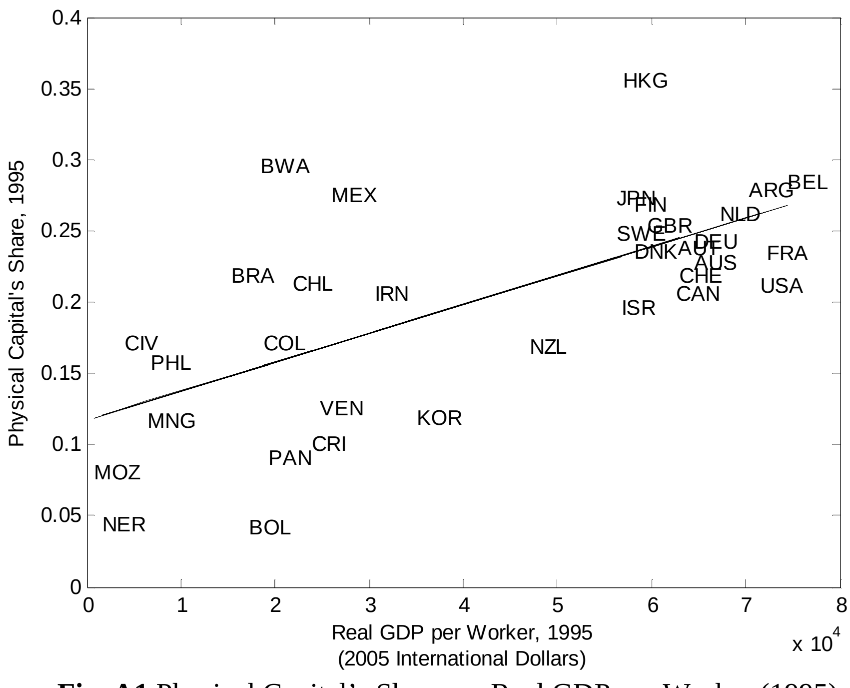

Fig. A1 Physical Capital's Share vs. Real GDP per Worker (1995)

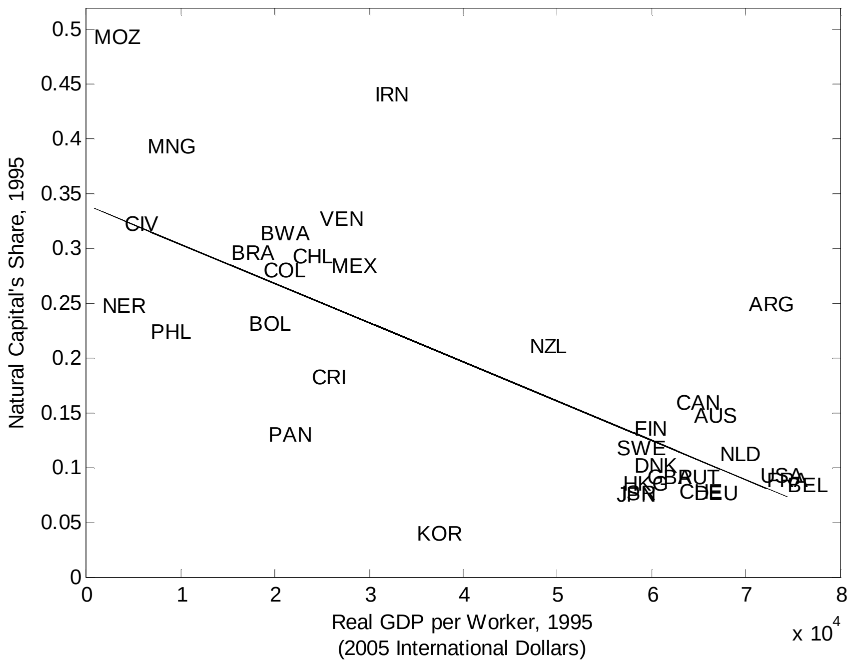

Fig. A2 Natural Capital's Share vs. Real GDP per Worker (1995)

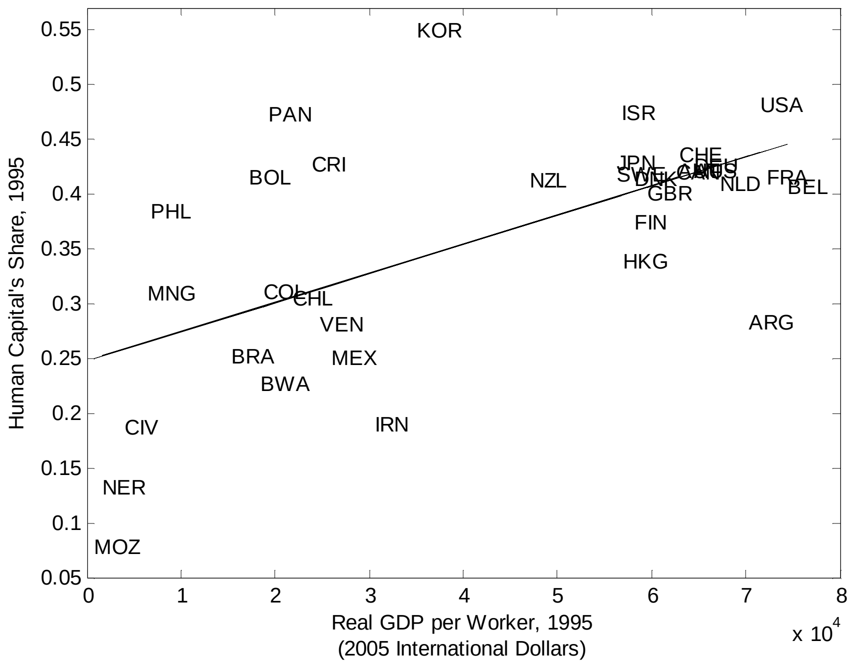

Fig. A3 Human Capital's Share vs. Real GDP per Worker (1995)

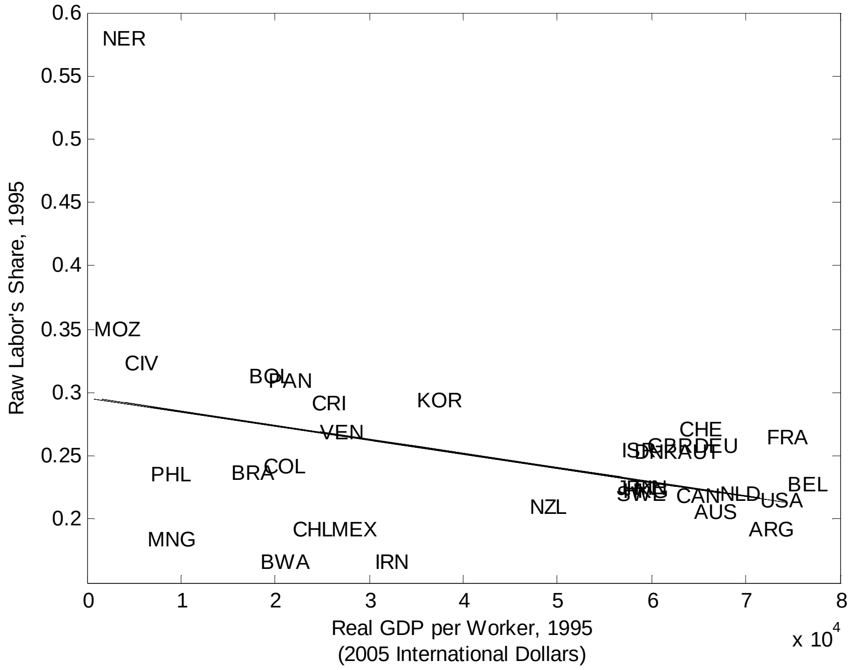

Fig. A4 Raw Labor's Share vs. Real GDP per Worker (1995)

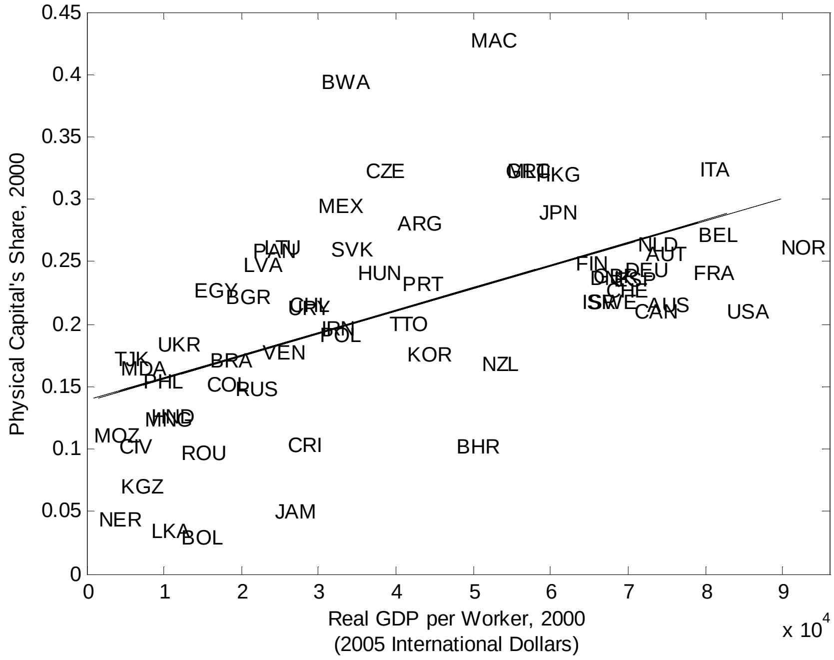

Fig. A5 Physical Capital's Share vs. Real GDP per Worker (2000)

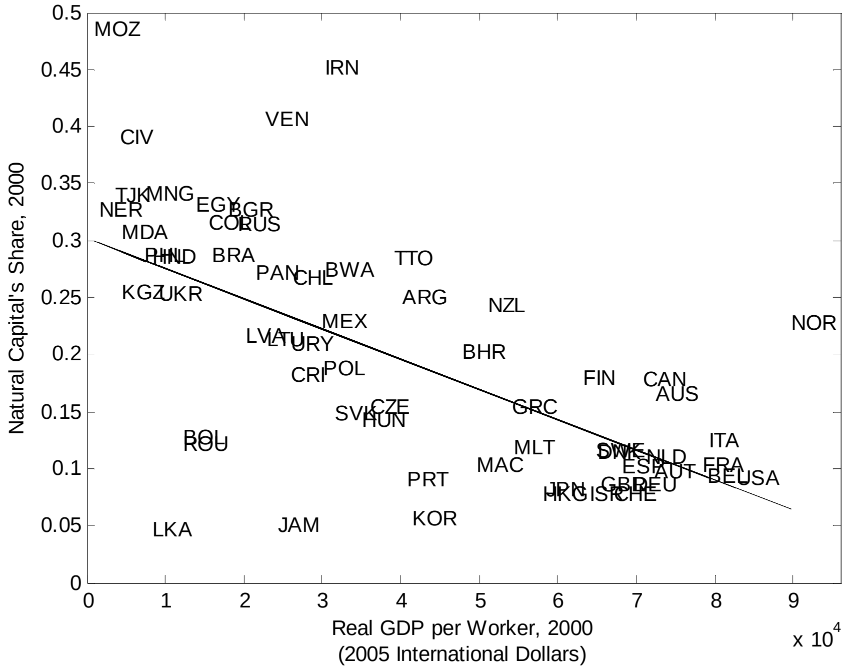

Fig. A6 Natural Capital's Share vs. Real GDP per Worker (2000)

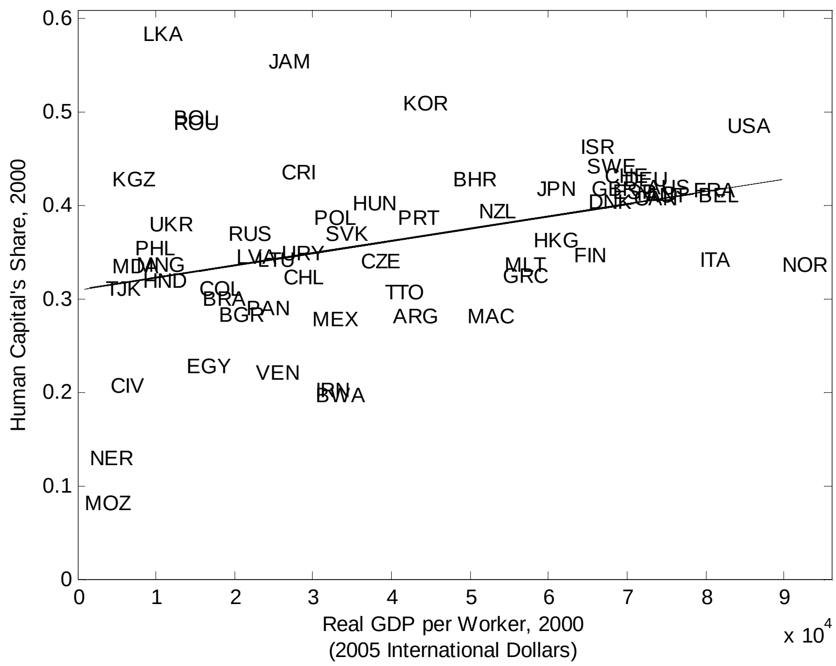

Fig. A7 Human Capital's Share vs. Real GDP per Worker (2000)

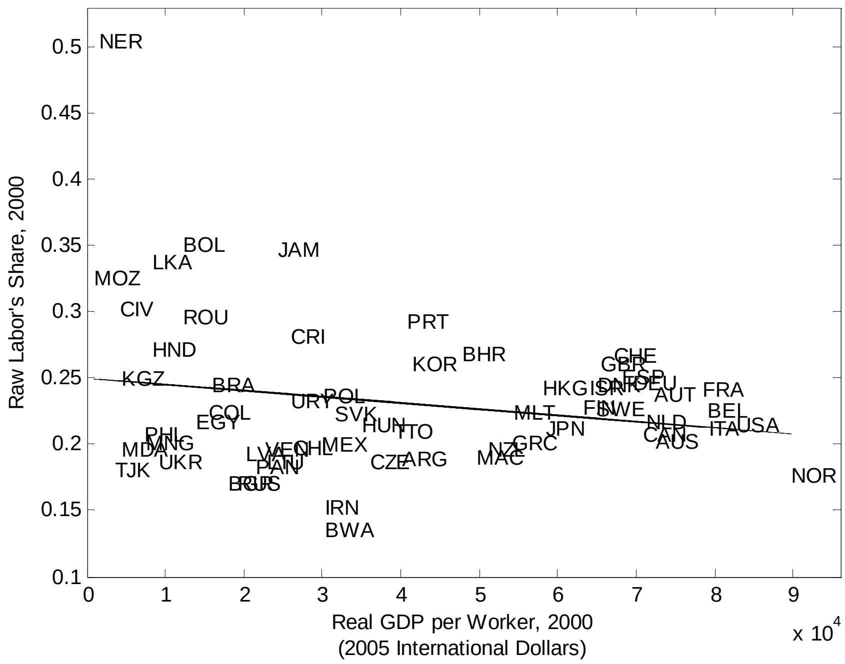

Fig. A8 Raw Labor's Share vs. Real GDP per Worker (2000)

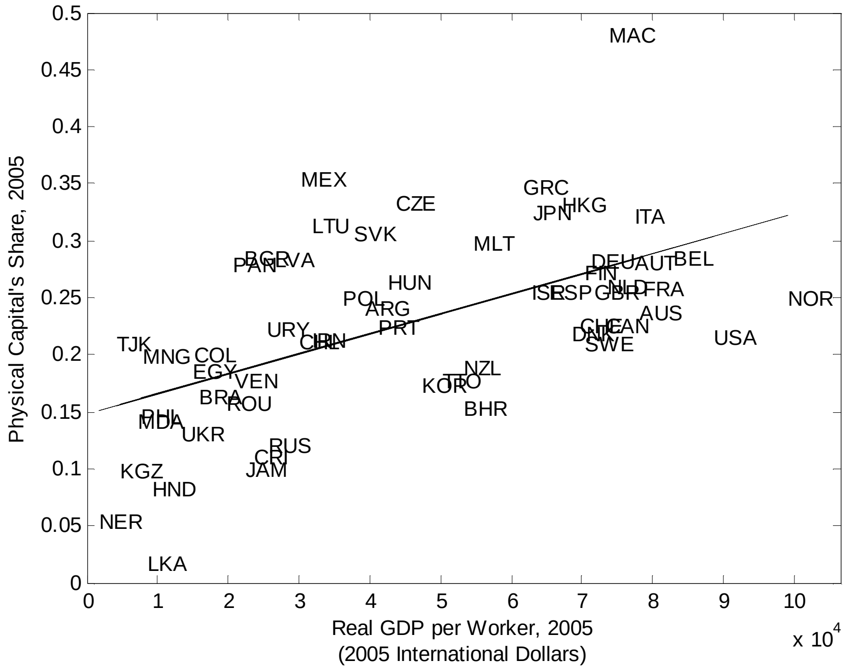

Fig. A9 Physical Capital's Share vs. Real GDP per Worker (2005)

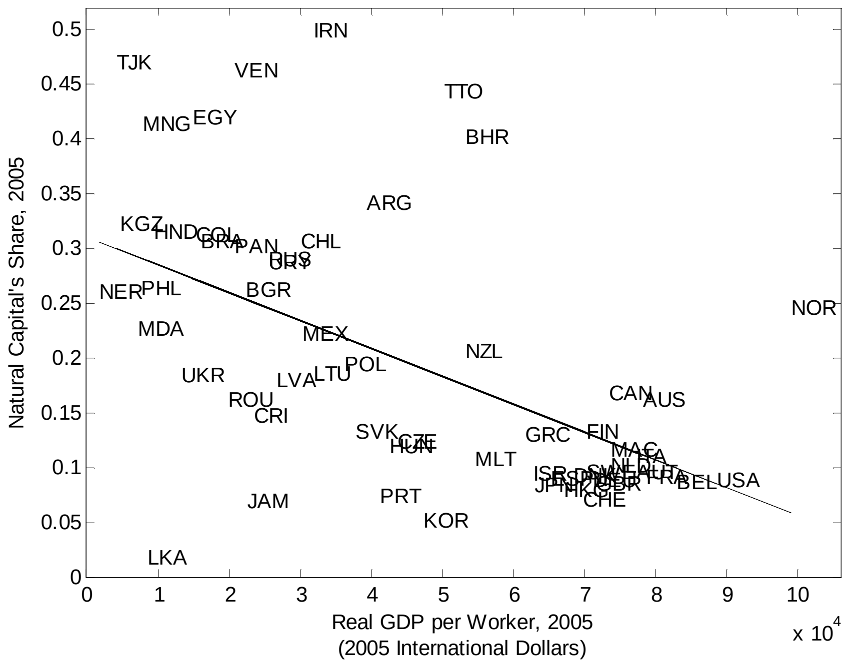

Fig. A10 Natural Capital's Share vs. Real GDP per Worker (2005)

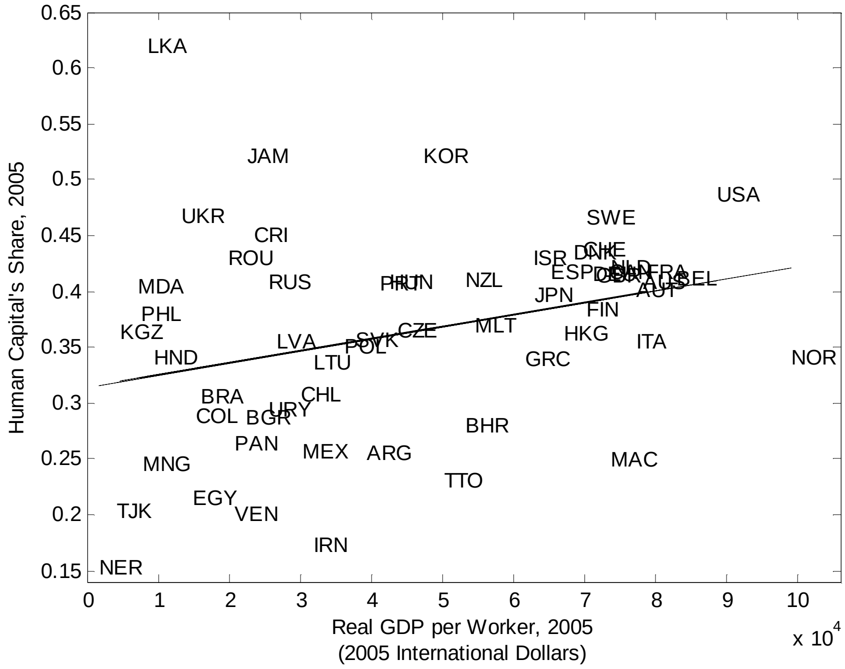

Fig. A11 Human Capital's Share vs. Real GDP per Worker (2005)

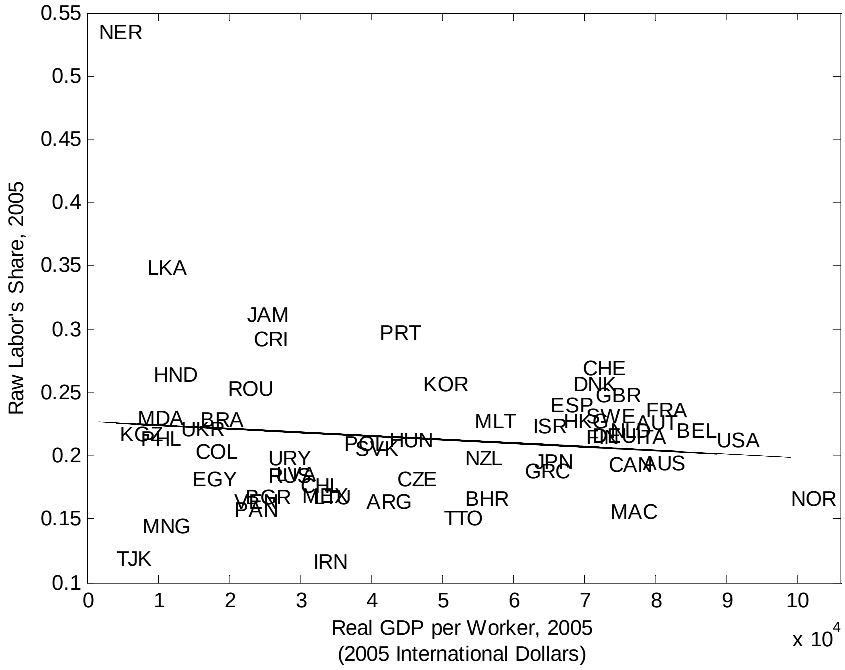

Fig. A12 Raw Labor's Share vs. Real GDP per Worker (2005)

Table A2. Factor Shares by Year

	Dependent Variable											
	1995				2000				2005			
	Physical Capital's Share	Natural Capital's Share	Human Capital's Share	Raw Labor's Share	Physical Capital's Share	Natural Capital's Share	Human Capital's Share	Raw Labor's Share	Physical Capital's Share	Natural Capital's Share	Human Capital's Share	Raw Labor's Share
Variable	1	2	3	4	5	6	7	8	9	10	11	12
Intercept	0.117***	0.339***	0.247***	0.296***	0.147***	0.287***	0.320***	0.246***	0.160***	0.290***	0.327***	0.223***
	(6.060)	(12.596)	(8.481)	(12.814)	(9.664)	(15.425)	(16.701)	(20.222)	(9.830)	(11.615)	(15.768)	(15.571)
				{8.035}			{13.063}	{15.085}			{12.770}	{10.942}
Real GDP per Worker	2.025E-06***	-3.580E-06***	2.668E-06***	-1.113E-06**	1.540E-06***	-2.184E-06***	1.001E-06**	-3.569E-07*	1.448E-06***	-2.020E-06***	7.637E-07**	-1.913E-07
	(4.977)	(-6.327)	(4.356)	(-2.292)	(5.038)	(-5.865)	(2.607)	(-1.462)	(4.953)	(-4.502)	(2.053)	(-0.742)
				{-1.714}			{2.368}	{-1.380}			{1.899}	{-0.644}
Adjusted R^2	0.419	0.542	0.353	0.114	0.286	0.354	0.087	0.018	0.292	0.253	0.053	-0.008
F-test for no heteroskedasticity	2.986	1.116	2.784	4.792	0.215	3.117	6.138	4.198	0.239	1.212	4.211	3.560
	[3.295]	[3.295]	[3.295]	[3.295]	[3.150]	[3.150]	[3.150]	[3.150]	[3.162]	[3.162]	[3.162]	[3.162]
Sample	34 obs.	34 obs.	34 obs.	34 obs.	62 obs.	62 obs.	62 obs.	62 obs.	58 obs.	58 obs.	58 obs.	58 obs.

Notes: t-statistics are in parantheses, ( ).

{ } indicates t-statistics computed using White corrected standard errors.

Square brackets are 5% critical values of the F distribution.

* indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Appendix 3: Alternative methodology for computing physical and natural capital shares.

Recall that *total* capital's share is computed as

$$TCS = 1 - \left(\frac{Employee\ Compensation}{GDP - TPILS - Gross\ Mixed\ Income} \right).$$

As an alternative to the Sturgill (2012) methodology, natural capital's share can be computed as

$$\gamma = \frac{CPR + MQV}{GDP - TPILS - Gross\ Mixed\ Income} \quad \text{(A1)}$$

where *CPR* stands for "Crop and Pastureland Rents" and *MQV* stands for "Mining and Quarrying Value Added." The *CPR* data is obtained from Joshua Wilde who constructed the total land rents in accordance with raw data provided by Giovanni Ruta at The World Bank. Ruta takes the value of each crop or pastureland commodity (meat, milk and wool) produced in a given country for a given year and combines the values with estimates of production costs to impute a land rental rate for each product. He then aggregates over all agricultural products to find total rents to cropland for each country.

The *MQV* data comes from table 2.1 of the United Nation's online national accounts database (UN data). Since *MQV* and all other data from the UN used to estimate the denominator of ( ) are reported in local currency units, we convert *CPR* into local currency units using exchange rates (local currency units/US $) obtained from the World Bank's World Development Indicators (WDI) database.

Given estimates of *TCS* and γ, physical capital's share (α) can be backed out as a residual. Our estimates of α and γ using this alternative method are provided in figures A13 and A14. The qualitative results are equivalent to those yielded by the estimates in the main text. Physical and natural capital shares are positively and negatively related to output per worker, respectively, at statistically significant levels. See Table A3 for the formal regression results.

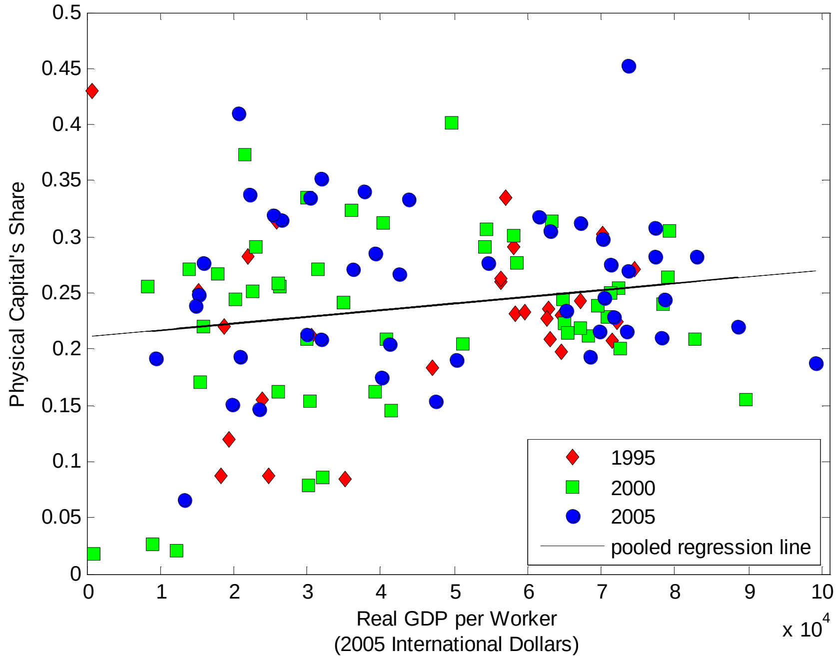

Fig. A13 Physical Capital's Share vs. Real GDP per Worker: Alternative Method

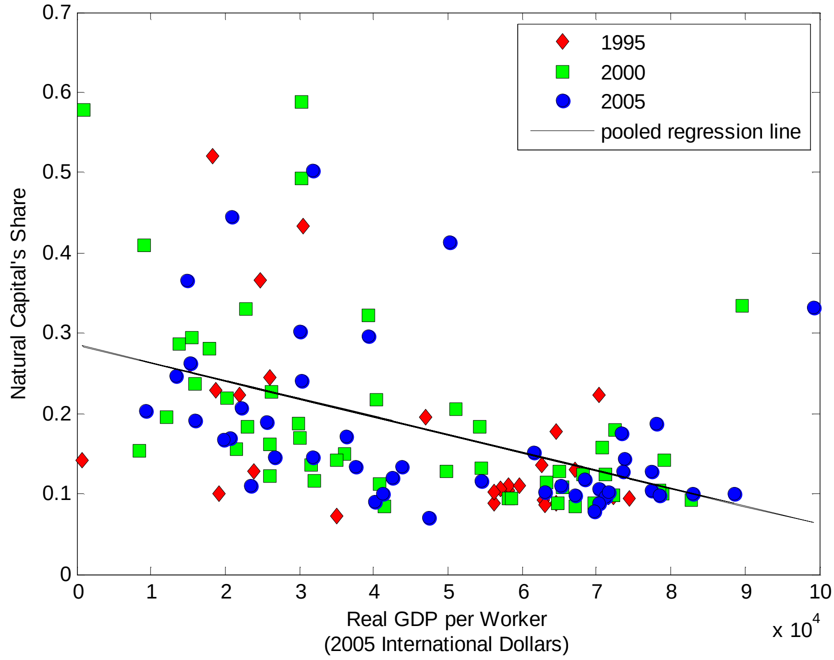

Fig. A14 Natural Capital's Share vs. Real GDP per Worker: Alternative Method

Table A3. Physical and Natural Capital Shares: Alternative Method

	Dependent Variable	
	Physical Capital's Share	Natural Capital's Share
Variable	1	2
Intercept	0.212***	0.265***
	(15.396)	(14.774)
	{12.396}	{11.512}
Real GDP per Worker	5.745E-07**	-1.755E-06***
	(2.336)	(-5.469)
	{2.273}	{-4.452}
Adjusted R^2	0.035	0.189
F-test for no heteroskedasticity	13.587	3.964
	[3.070]	[3.070]
Sample	125 obs.	125 obs.

Notes: t-statistics are in parantheses, ( ).

{ } indicates t-statistics computed using White corrected standard errors.

Square brackets are 5% critical values of the F distribution.

* indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Appendix 4. Unit-corrected factors of production

Country	Year	$\tilde{k}$	h	$\tilde{n}$
Argentina	1995	3.3374	1.4621	0.7241
Argentina	2000	1.7702	1.4862	0.3820
Argentina	2005	1.5740	1.5619	0.5402
Australia	1995	2.9849	2.1019	0.4647
Australia	2000	3.1517	2.1229	0.5879
Australia	2005	3.4074	2.1487	0.5643
Austria	1995	2.9221	1.4584	0.2699
Austria	2000	3.2329	1.5332	0.2966
Austria	2005	3.4875	1.5889	0.2868
Bahrain	2000	2.3050	1.4695	1.1083
Bahrain	2005	1.9939	1.5754	1.2710
Belgium	1995	3.2049	1.7101	0.2264
Belgium	2000	3.1992	1.7718	0.2661
Belgium	2005	3.4589	1.8328	0.2529
Bolivia	1995	0.6542	1.3040	0.8755
Bolivia	2000	0.4735	1.4055	0.5164
Botswana	1995	0.9976	1.3661	0.2563
Botswana	2000	1.6351	1.4787	0.2760
Brazil	1995	0.7633	0.8451	0.2501
Brazil	2000	0.7429	1.0330	0.3036
Brazil	2005	0.6983	1.1717	0.3178
Bulgaria	2000	1.1451	1.6084	0.4089
Bulgaria	2005	1.0887	1.6678	0.2436
Canada	1995	2.6202	1.8994	0.4874
Canada	2000	2.6779	1.9543	0.5489
Canada	2005	2.8350	2.2083	0.5148
Chile	1995	0.9032	1.4993	0.3008
Chile	2000	1.2386	1.5504	0.3741
Chile	2005	1.4117	1.6758	0.4972
Colombia	1995	0.7281	1.0291	0.2891
Colombia	2000	0.6775	1.1176	0.3408
Colombia	2005	0.6166	1.1465	0.2336
Costa Rica	1995	0.7717	1.2620	0.3411
Costa Rica	2000	0.7913	1.3469	0.3391
Costa Rica	2005	0.8051	1.3626	0.2599
Cote d'Ivore	1995	0.1692	0.4712	0.0773
Cote d'Ivore	2000	0.1382	0.5709	0.1295
Czech Republic	2000	2.2325	2.1252	0.2582
Czech Republic	2005	2.5179	2.3610	0.2248
Denmark	1995	2.3828	1.6698	0.2476
Denmark	2000	2.5650	1.6758	0.3004
Denmark	2005	2.8445	1.7081	0.2934
Egypt	2000	0.6352	0.9218	0.2251
Egypt	2005	0.6197	1.0429	0.3398

Finland	1995	3.0011	1.5504	0.3645
Finland	2000	2.6125	1.6222	0.4549
Finland	2005	2.7481	1.6879	0.3240
France	1995	3.0654	1.4565	0.2769
France	2000	3.0658	1.6459	0.3194
France	2005	3.1406	1.7101	0.2692
Germany	1995	3.0007	1.5677	0.2297
Germany	2000	3.2033	1.7244	0.2723
Germany	2005	3.2466	2.1393	0.2454
Greece	2000	3.1407	1.5162	0.3619
Greece	2005	3.3530	1.7122	0.3031
Honduras	2000	0.3917	0.9652	0.2147
Honduras	2005	0.4288	1.0789	0.3985
Hong Kong	1995	2.7893	1.6065	0.1622
Hong Kong	2000	3.2554	1.5851	0.1893
Hong Kong	2005	3.4929	1.7061	0.2031
Hungary	2000	2.0621	1.9922	0.2961
Hungary	2005	2.2331	2.0580	0.2437
Iran	1995	1.7342	0.9652	0.8976
Iran	2000	1.7411	1.1632	0.9747
Iran	2005	1.9267	1.3643	1.0985
Israel	1995	2.3121	1.9168	0.2183
Israel	2000	2.5412	1.9810	0.2205
Israel	2005	2.5060	2.0102	0.2228
Italy	2000	3.4319	1.4974	0.3185
Italy	2005	3.4278	1.5657	0.2851
Jamaica	2000	0.9065	1.5504	0.2227
Jamaica	2005	0.9288	1.6419	0.1577
Japan	1995	3.3374	1.8541	0.2223
Japan	2000	3.5766	1.9322	0.2447
Japan	2005	3.6778	2.0079	0.2308
Korea, Rep.	1995	1.6789	1.8541	0.1362
Korea, Rep.	2000	2.1640	1.9587	0.1666
Korea, Rep.	2005	2.5456	2.0672	0.1824
Kyrgystan	2000	0.2077	1.5105	0.1832
Kyrgystan	2005	0.1713	1.4565	0.1371
Latvia	2000	1.4748	1.5909	0.3136
Latvia	2005	1.5289	1.7718	0.2339
Lithuania	2000	1.3760	1.6320	0.2718
Lithuania	2005	1.4549	1.8137	0.2081
Luxembourg	2000	5.7475	1.6518	0.4462
Luxembourg	2005	6.7246	1.7020	0.4485
Macao (China SAR)	2000	2.5832	1.0688	0.1501
Macao (China SAR)	2005	2.4172	1.2423	0.1405
Malta	2000	2.7936	1.6084	0.2487
Malta	2005	2.7504	1.7326	0.2384

Mexico	1995	1.2365	1.1591	0.3078
Mexico	2000	1.2573	1.2685	0.2369
Mexico	2005	1.3040	1.4236	0.1978
Moldova	2000	0.5125	1.5735	0.2319
Moldova	2005	0.5016	1.6320	0.1938
Mongolia	1995	0.6699	1.2996	0.5516
Mongolia	2000	0.5554	1.3107	0.3728
Mongolia	2005	0.4398	1.3423	0.2224
Mozambique	1995	0.0315	0.1136	0.0472
Mozambique	2000	0.0396	0.1307	0.0421
Netherlands	1995	2.9245	1.8328	0.3020
Netherlands	2000	2.9264	1.8885	0.2946
Netherlands	2005	3.1335	1.9059	0.2953
New Zealand	1995	2.1583	2.1701	0.6531
New Zealand	2000	2.2291	2.2156	0.7845
New Zealand	2005	2.2089	2.2813	0.5890
Niger	1995	0.0632	0.1534	0.0864
Niger	2000	0.0438	0.1739	0.0810
Niger	2005	0.0481	0.1974	0.0564
Norway	2000	4.0057	2.0124	0.8463
Norway	2005	4.2502	2.2593	1.0149
Panama	1995	0.9123	1.4290	0.3144
Panama	2000	1.1196	1.4881	0.2840
Panama	2005	0.9643	1.5909	0.2531
Philippines	1995	0.3156	1.3355	0.1082
Philippines	2000	0.3135	1.4019	0.1420
Philippines	2005	0.2780	1.4639	0.1216
Poland	2000	1.2943	1.6202	0.3094
Poland	2005	1.5205	1.6698	0.2862
Portugal	2000	2.1107	1.2099	0.1981
Portugal	2005	2.2957	1.2642	0.1818
Romania	2000	0.8972	1.7142	0.2708
Romania	2005	1.0955	1.7470	0.2722
Russian Fedaration	2000	1.4710	1.9654	0.7622
Russian Fedaration	2005	1.3070	2.0124	0.7699
Slovakia	2000	1.6715	1.9278	0.2321
Slovakia	2005	1.7466	1.9676	0.1832
Spain	2000	2.9850	1.6026	0.3107
Spain	2005	3.1282	1.6778	0.2672
Sri Lanka	2000	0.3973	1.8349	0.1317
Sri Lanka	2005	0.3980	1.9037	0.0967
Sweden	1995	2.3511	1.8994	0.2694
Sweden	2000	2.3845	1.9631	0.3069
Sweden	2005	2.4216	2.0603	0.2640
Switzerland	1995	3.5802	1.6459	0.3082
Switzerland	2000	3.5396	1.6439	0.2907

Switzerland	2005	3.5038	1.6658	0.2634
Tajikistan	2000	0.3376	1.6399	0.1624
Tajikistan	2005	0.1957	1.6124	0.1061
Trinidad and Tobago	2000	1.4763	1.5257	0.5078
Trinidad and Tobago	2005	1.4750	1.5987	0.8935
Ukraine	2000	0.9278	1.8243	0.3098
Ukraine	2005	0.7975	1.9190	0.2742
United Kingdom	1995	2.3530	1.4309	0.2040
United Kingdom	2000	2.2889	1.4899	0.1996
United Kingdom	2005	2.4396	1.5561	0.1958
United States	1995	2.7360	2.3309	0.2906
United States	2000	3.0148	2.3510	0.3181
United States	2005	3.3126	2.4016	0.3299
Uruguay	2000	0.8695	1.3697	0.2069
Uruguay	2005	0.8432	1.3514	0.2644
Venezuela	1995	1.3455	0.8397	0.8471
Venezuela	2000	1.2499	0.9107	0.6932
Venezuela	2005	1.1184	1.0076	0.7121

Appendix 5: Robustness Check – Estimations of equations 6 and 6A with alternative data.

Let the physical and natural capital stock estimates from the main text (urban land treated as natural capital) correspond to scenario A0. Let the factor share estimates from the main text (Sturgill (2012) methodology) correspond to scenario B0.

Define the alternative physical and natural capital stock series as:

A1: Both physical and natural capital are taken from the World Bank without changes (i.e. the estimate of urban land is categorized as physical capital.)

Define the two alternative factor share series as:

B1: The factor share series described in Appendix 4. (We lose 19 observations relative to the Sturgill (2012) methodology discussed in the main text).
B2: An extended alternative factor share series where the 19 missing observations are estimated as the fitted values from an OLS regression of the original series (B1) on output per worker.

Below we estimate equations 6 and 6A for the following scenarios:
A1,B0; A0,B1; A0, B2; A1,B1; A1,B2.
Note that in scenarios 1 and 5 below, there are 91 observations instead of 92. Relative to the discussion in the main text, we lose one observation. Specifically, we lose the growth rate of Macao from 1995 to 2000. The value of natural capital for Macao reported by the World Bank is zero for both years, and in scenarios 1 and 5, we do not add the urban land estimate to the reported value of natural capital, so a "0" remains for Macao. Our regressions rely on natural logs, and since the natural log of "0" is undefined, we lose the observation.

1. A1, B0. K and N without urban land correction, delta and alpha calculated according to method 1 (ignoring urban land)

Table A4.1. Estimation of equation 6.

Variables	(1) $\tilde{S}$	(2) $\tilde{S}$	(3) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-12.86***	-12.41***	-12.03***
	[1.141]	[0.923]	[0.944]
$\Delta\beta_t$ (C_2)	-4.291**	-2.774*	-2.518*
	[1.984]	[1.439]	[1.426]
$\Delta\gamma_t$ (C_3)	-13.97***	-12.58***	-12.61***
	[1.145]	[0.881]	[0.866]
Constant	0.0187	-0.163***	-0.161***
	[0.0332]	[0.0581]	[0.0571]
Observations	91	91	91
R-squared	0.956	0.996	0.997
Year fixed effects	NO	NO	YES
Country fixed effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table A4.2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.000005942
$\frac{\phi_H}{\phi_L}$	0.080584200
$\frac{\phi_N}{\phi_L}$	0.000003334

Table A4.3. Estimation of equation 6A.

VARIABLES	(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$ (C$_1$)	-11.75***	-11.65***
	[1.275]	[1.125]
α_t (C$_2$)	-0.317	-0.118
	[0.253]	[0.839]
$\Delta\beta_t$ (C$_3$)	-4.047**	-2.746
	[1.845]	[1.814]
β_t (C$_4$)	0.195	0.237
	[0.333]	[1.567]
$\Delta\gamma_t$ (C$_5$)	-14.75***	-13.17***
	[1.198]	[1.181]
γ_t (C$_6$)	0.442	0.611
	[0.286]	[1.141]
$\Delta\alpha_t * D_{2005}$	-0.317	-0.118
	[0.253]	[0.839]
$\Delta\beta_t * D_{2005}$	0.195	0.237
	[0.333]	[1.567]
$\Delta\gamma_t * D_{2005}$	0.442	0.611
	[0.286]	[1.141]
Constant	-0.108	-0.361
	[0.209]	[0.945]
Observations	91	91
Country effects	NO	YES

Table A4.4

Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.000008702
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000001910

2. Scenario A0, B1. K and N with urban land correction, delta and alpha calculated according to alternative method, including available observations only

Table A5.1. Estimation of equation 6.

Variables	(1) $\tilde{S}$	(2) $\tilde{S}$	(3) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-11.87***	-11.70***	-11.46***
	[0.858]	[1.136]	[1.224]
$\Delta\beta_t$ (C_2)	-2.178	-1.959	-1.571
	[1.385]	[1.850]	[2.000]
$\Delta\gamma_t$ (C_3)	-13.19***	-12.70***	-12.45***
	[0.847]	[1.171]	[1.270]
Constant	0.0496***	-0.115**	-0.111*
	[0.0169]	[0.0534]	[0.0549]
Observations	73	73	73
R-squared	0.964	0.995	0.995
Year fixed effects	NO	NO	YES
Country fixed effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table A5.2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.000010514
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000003918

Table A5.3. Estimation of equation 6A.

VARIABLES	(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-12.65***	-12.27***
	[1.314]	[1.584]
α_t (C_2)	0.470	0.319
	[0.398]	[0.691]
$\Delta\beta_t$ (C_3)	-3.284	-2.944
	[2.067]	[2.589]
β_t (C_4)	0.602	0.768
	[0.550]	[1.001]
$\Delta\gamma_t$ (C_5)	-13.87***	-13.39***
	[1.289]	[1.921]
γ_t (C_6)	0.502	0.354
	[0.411]	[0.904]
$\Delta\alpha_t * D_{2005}$	0.470	0.319
	[0.398]	[0.691]
$\Delta\beta_t * D_{2005}$	0.602	0.768
	[0.550]	[1.001]
$\Delta\gamma_t * D_{2005}$	0.502	0.354
	[0.411]	[0.904]
Constant	-0.366	-0.436
	[0.359]	[0.673]
Observations	73	73
Country effects	NO	YES

Table A5.4
Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.000004671
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000001532

3. A0, B2. K and N with urban land correction, delta and alpha calculated according to alternative method, including available observations and replacing unavailable for an estimation (augmented)

Table A6.1. Estimation of equation 6.

	(1)	(2)	(3)
Variables	$\tilde{S}$	$\tilde{S}$	$\tilde{S}$
$\Delta\alpha_t$ (C_1)	-12.87***	-11.89***	-11.82***
	[1.037]	[0.940]	[0.971]
$\Delta\beta_t$ (C_2)	-3.936**	-2.101	-1.978
	[1.754]	[1.486]	[1.537]
$\Delta\gamma_t$ (C_3)	-14.18***	-12.99***	-12.91***
	[1.019]	[0.970]	[1.004]
Constant	0.0717***	-0.108**	-0.105*
	[0.0191]	[0.0498]	[0.0511]
Observations	92	92	92
R-squared	0.957	0.997	0.997
Year fixed effects	NO	NO	YES
Country fixed effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table A6.2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.000007356
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000002466

Table A6.3. Estimation of equation 6A.

VARIABLES	(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$ (C$_1$)	-12.99***	-12.45***
	[0.971]	[1.197]
α_t (C$_2$)	0.117	0.294
	[0.185]	[0.556]
$\Delta\beta_t$ (C$_3$)	-3.870***	-3.175
	[1.410]	[1.946]
β_t (C$_4$)	0.0574	0.801
	[0.260]	[0.827]
$\Delta\gamma_t$ (C$_5$)	-14.53***	-13.64***
	[0.999]	[1.442]
γ_t (C$_6$)	0.298	0.388
	[0.236]	[0.735]
$\Delta\alpha_t * D_{2005}$	0.117	0.294
	[0.185]	[0.556]
$\Delta\beta_t * D_{2005}$	0.0574	0.801
	[0.260]	[0.827]
$\Delta\gamma_t * D_{2005}$	0.298	0.388
	[0.236]	[0.735]
Constant	-0.0143	-0.440
	[0.158]	[0.550]
Observations	92	92
Country effects	NO	YES

Table A6.4
Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.000003937
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000001187

4. A1, B1. K and N without urban land correction, delta and alpha calculated according to alternative method, including available observations only

Table A7.1. Estimation of equation 6.

Variables	(1) $\tilde{S}$	(2) $\tilde{S}$	(3) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-12.23***	-11.76***	-11.57***
	[0.849]	[1.130]	[1.221]
$\Delta\beta_t$ (C_2)	-2.370*	-1.777	-1.468
	[1.392]	[1.840]	[1.994]
$\Delta\gamma_t$ (C_3)	-13.23***	-12.45***	-12.24***
	[0.839]	[1.165]	[1.266]
Constant	0.0473***	-0.122**	-0.118**
	[0.0174]	[0.0531]	[0.0547]
Observations	72	72	72
R-squared	0.963	0.995	0.995
Year fixed effects	NO	NO	YES
Country effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table A7.2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.000009419
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000004814

Table A7.3. Estimation of equation 6A.

VARIABLES	(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-13.04***	-12.39***
	[1.326]	[1.581]
α_t (C_2)	0.377	0.390
	[0.405]	[0.689]
$\Delta\beta_t$ (C_3)	-3.694*	-2.850
	[2.086]	[2.584]
β_t (C_4)	0.705	0.858
	[0.555]	[0.999]
$\Delta\gamma_t$ (C_5)	-14.06***	-13.19***
	[1.301]	[1.918]
γ_t (C_6)	0.600	0.417
	[0.414]	[0.902]
$\Delta\alpha_t * D_{2005}$	0.377	0.390
	[0.405]	[0.689]
$\Delta\beta_t * D_{2005}$	0.705	0.858
	[0.555]	[0.999]
$\Delta\gamma_t * D_{2005}$	0.600	0.417
	[0.414]	[0.902]
Constant	-0.383	-0.504
	[0.363]	[0.672]
Observations	72	72
Country effects	NO	YES

Table A7.4
Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.000004142
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000001869

5. A1, B2. K and N without urban land correction, delta and alpha calculated according to alternative method, including available observations and replacing unavailable for an estimation (augmented)

Table A8.1. Estimation of equation 6.

Variables	(1) $\tilde{S}$	(2) $\tilde{S}$	(3) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-13.12***	-12.02***	-11.98***
	[1.040]	[0.945]	[0.978]
$\Delta\beta_t$ (C_2)	-3.970**	-2.001	-1.934
	[1.763]	[1.493]	[1.548]
$\Delta\gamma_t$ (C_3)	-14.13***	-12.82***	-12.78***
	[1.023]	[0.974]	[1.011]
Constant	0.0690***	-0.113**	-0.112**
	[0.0193]	[0.0500]	[0.0515]
Observations	91	91	91
R-squared	0.956	0.997	0.997
Year fixed effects	NO	NO	YES
Country effects	NO	YES	YES

Robust Standard Errors in brackets for specification (1). Standard Errors in brackets for specifications (2) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table A8.2
Values for specification 3

	Values
$\frac{\phi_K}{\phi_L}$	0.000006243
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000002825

Table A8.3. Estimation of equation 6A.

VARIABLES	(1) $\tilde{S}$	(2) $\tilde{S}$
$\Delta\alpha_t$ (C_1)	-13.19***	-12.65***
	[0.978]	[1.202]
α_t (C_2)	0.0680	0.375
	[0.188]	[0.559]
$\Delta\beta_t$ (C_3)	-3.949***	-3.191
	[1.422]	[1.954]
β_t (C_4)	0.162	0.923
	[0.264]	[0.830]
$\Delta\gamma_t$ (C_5)	-14.51***	-13.57***
	[1.007]	[1.448]
γ_t (C_6)	0.397	0.482
	[0.239]	[0.738]
$\Delta\alpha_t * D_{2005}$	0.0680	0.375
	[0.188]	[0.559]
$\Delta\beta_t * D_{2005}$	0.162	0.923
	[0.264]	[0.830]
$\Delta\gamma_t * D_{2005}$	0.397	0.482
	[0.239]	[0.738]
Constant	-0.0516	-0.524
	[0.159]	[0.553]
Observations	91	91
Country effects	NO	YES

Table A8.4
Values for specification 2

	Values (4)
$\frac{\phi_K}{\phi_L}$	0.000003210
$\frac{\phi_H}{\phi_L}$	1
$\frac{\phi_N}{\phi_L}$	0.000001284