Summary Report for Empirical Growth Comparison of World Countries: Penn World Data 10.1

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1 Exercise 1: Growth Accounting Developing Countries

Empirical Findings and Interpretation

To quantify the sources of economic growth, we implemented a standard growth accounting decomposition using a Cobb-Douglas production function of the form:

$$Y_t = A_t K_t^{\alpha} (h_t L_t)^{1-\alpha}, \tag{1}$$

where Y_t denotes real GDP, K_t is the capital stock, L_t is employment, h_t represents human capital per worker, and A_t is total factor productivity (TFP). We assume a capital share $\alpha = \frac{1}{3}$ and compute annual growth rates using log differences. The contribution of each input to output growth is then estimated as $\alpha \Delta \ln K_t$ for capital, $(1-\alpha)\Delta \ln L_t$ for labor, and $(1-\alpha)\Delta \ln h_t$ for human capital. The residual is attributed to TFP growth.

Our empirical results are visualised in the next page, showing annual growth contributions for France, Germany, the USA, and India from 1990 to 2019. For instance, India's human capital figure shows that the dominant contributor to output growth is TFP, especially during high-growth years like the early 2000s and post-2008 recovery. Capital contributions also rise steadily, while labour and human capital have relatively stable and modest effects.

In contrast, the USA exhibits smoother growth patterns with significant TFP fluctuations during the Global Financial Crisis, see the USA with the HC graph. The decomposition without human capital underestimates the explanatory power of labour inputs, especially during the 1990s and early 2000s. France and Germany reveal similar patterns where capital contributes modestly, labour plays a smaller role, and TFP fluctuates with economic shocks. Human capital contributions are consistently low but stable across all advanced economies.

Averaging the results, Table 1 summarises the decomposition. India shows the highest average output growth (6.84% annually), with capital and TFP playing nearly equal roles. For the USA and France, TFP and capital explain roughly one-third of the growth, while human capital remains a minor but non-negligible component.

These findings are consistent with the growth accounting literature and emphasise the importance of productivity and capital deepening, especially in emerging markets. Human capital plays a supportive but secondary role in driving long-run economic growth.

Empirical Findings and Interpretation

To quantify the sources of economic growth, we implemented a standard growth accounting decomposition using a Cobb-Douglas production function of the form:

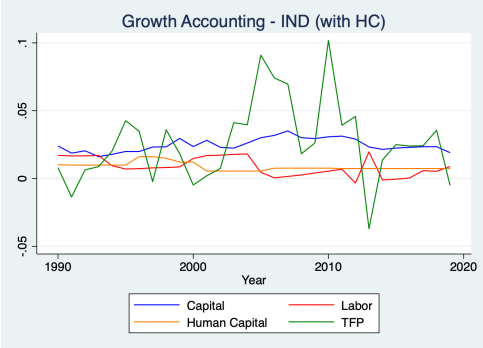
$$Y_t = A_t K_t^{\alpha} (h_t L_t)^{1-\alpha}, \tag{2}$$

where Y_t denotes real GDP, K_t is the capital stock, L_t is employment, h_t represents human capital per worker, and A_t is total factor productivity (TFP). We assume a capital share $\alpha = \frac{1}{3}$ and compute annual growth rates using log differences. The contribution of each input to output growth is then estimated as $\alpha \Delta \ln K_t$ for capital, $(1-\alpha)\Delta \ln L_t$ for labor, and $(1-\alpha)\Delta \ln h_t$ for human capital. The residual is attributed to TFP growth.

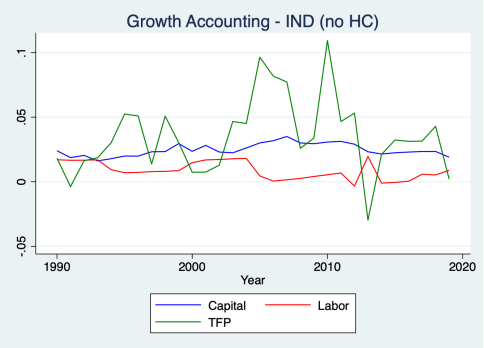
Our empirical results are presented in Figures 1. Each panel contains two line plots per country: one including human capital (HC) and one using only capital and labor. These show the yearly contribution of each input (capital, labor, human capital, TFP) to output growth between 1990 and 2019.

Table 1: Average Growth Contributions by Country, 1990–2019

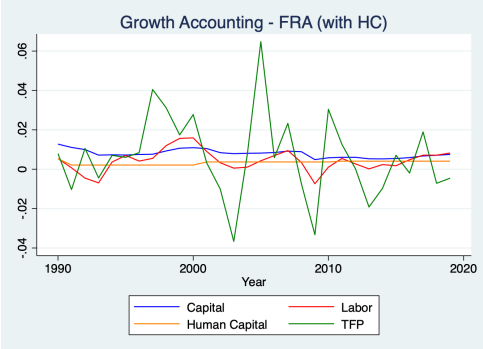
	(1)	(2)	(3)	(4)	(5)
	mean	mean	mean	mean	mean
Capital	0.036	0.007	0.008	0.025	0.010
Labor	0.005	0.003	0.004	0.009	0.006
Human Capital	0.007	0.002	0.003	0.009	0.002
TFP	0.017	0.013	0.006	0.026	0.007
Output Growth	0.065	0.024	0.022	0.068	0.025



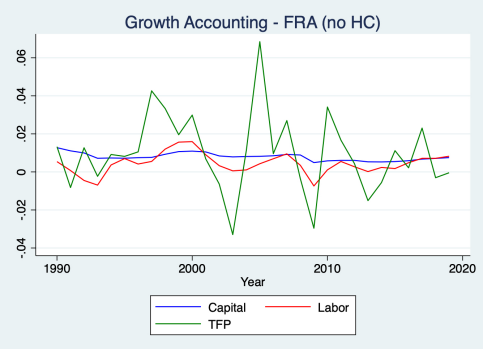
(a) India (with HC)



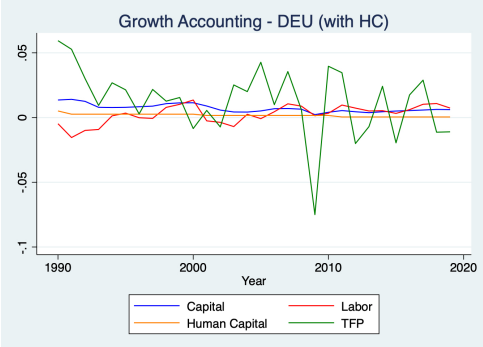
(b) India (no HC)



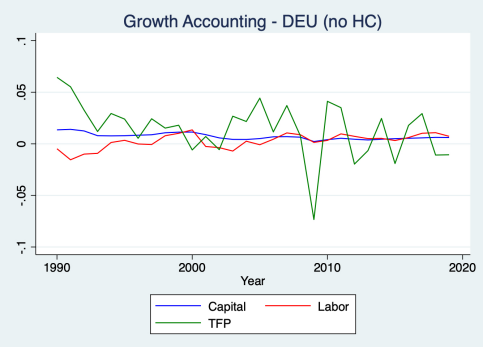
(c) France (with HC)



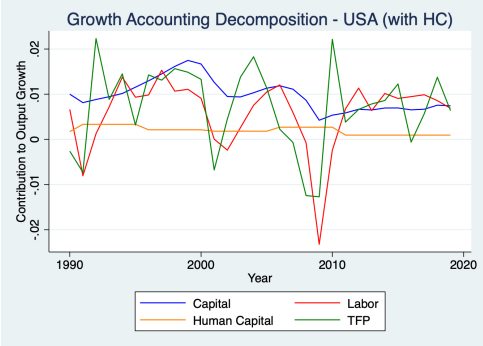
(d) France (no HC)



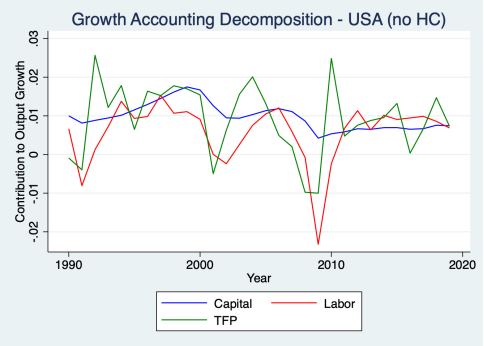
(e) Germany (with HC)



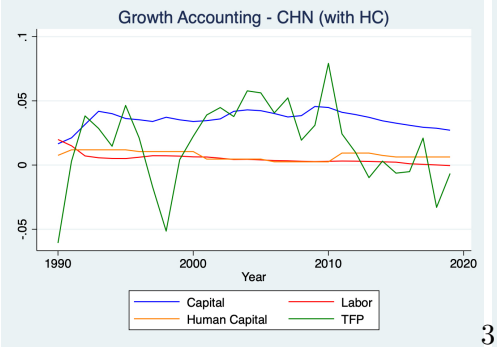
(f) Germany (no HC)



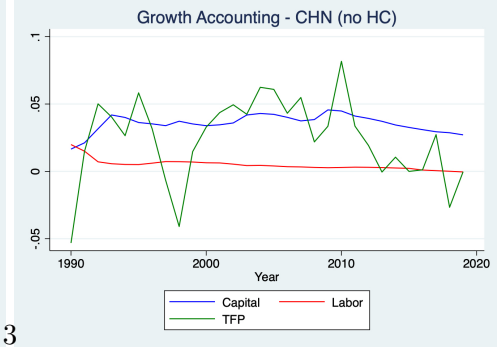
(g) USA (with HC)



(h) USA (no HC)



(i) USA (with HC)



(j) USA (no HC)

Figure 1: Growth accounting decomposition by country (with and without human capital),

2 Can China Sustain Its GDP per Capita Growth?

Although China has been a Growth miracle in modern economic history, its future trajectory of GDP per capita is increasingly dependent on a complex blend of structural reforms, demographic transitions, and geopolitical considerations.

One can answer this question through a functional analysis, where we are wondering about the long-term output of an aggregate production function. And the major variables that China can play with are capital accumulation, labour dynamics, and technological progress.

2.1 Capital Accumulation and Diminishing Returns

As in many growth frameworks, the economies driven by capital accumulation eventually face diminishing returns to capital if not supported by technological progress. One can use the Solow Model to support this. Additionally, China's capital accumulation is encountering diminishing returns not just due to physical saturation but also due to capital misallocation and state-driven investment efficiency. Bai, Hsieh and Qian[1] found that real returns to capital declined from 25 per cent in 1978 to 5 per cent by the early 2000s. Moreover, Gyourko, Ma, and Wang (2022)[2] empirically studied returns to real estate investment, a key form of capital in China. They observed vast overbuilding and asset mispricing, showing the real estate investment yielding low or negative returns in many cases.

2.2 Labour Force Dynamics and Human Capital

Labour force as an input can be considered the determinant of steady-state consumption and income per capita. The Ramsey-Cass-Koopmans model channels population growth as the major determinant. Theoretically, a declining labour force must reduce the effective labour input and lower the per capita output if productivity gains are not offset. Empirically, there is some evidence that may support this condition. Cai and Lu argue that China's demographic power—once a growth engine—has largely exhausted its contribution[3]. Aiyar et al. estimate that ageing could reduce China's GDP per capita growth by 0.5–0.7 percentage points annually between 2020 and 2030, unless offset by significant improvements in human capital[4].

2.3 Technological Progress and Total Factor Productivity (TFP)

In the grand scheme of China's growth trajectory, technological progress and total factor productivity (TFP) become increasingly pivotal. Especially in endogenous growth models (e.g. Romer, 1990; Aghion & Howitt, 1992), sustained per capita growth stems from innovation, R&D, and knowledge spillovers. Considering this, one may want to check the technological progress empirically. This is formalized in seminal models by Romer (1990), which emphasizes

[1] Bai, Chong-En, Hsieh, Chang-Tai, and Qian, Yingyi. The Return to Capital in China. *Brookings Papers on Economic Activity*, 2006(2):61–88.

[2] Gyourko, J., Ma, S., & Wang, Y. (2022). Misallocation in the Chinese Real Estate Market. *NBER Working Paper No. 30106*.

[3] Cai, F., & Lu, Y. (2013). Population Change and Resulting Slowdown in Potential Output Growth in China. *China & World Economy*, 21(2), 1–14.

[4] Aiyar, S., Ebeke, C., & Shao, X. (2016). The Impact of Workforce Aging on European Productivity. *IMF Working Paper WP/16/238*.

the role of ideas and increasing returns to knowledge, and Aghion and Howitt (1992), who frame growth as a process of "creative destruction," driven by firm-level innovation that replaces outdated technologies[5]. Empirically, Brandt, Van Biesebroeck, and Zhang (2012) show that China's TFP growth has been largely driven by export-oriented manufacturing sectors that benefited from international integration and foreign technology transfer[6]. However, sustaining this TFP growth becomes increasingly difficult as China approaches the global technology frontier.

2.4 Conclusion

While China has achieved unprecedented gains in GDP per capita through capital deepening, demographic dividends, and integration into global markets, the sustainability of this growth is now increasingly constrained. With diminishing returns to capital, an ageing workforce, and institutional barriers to innovation, China's future trajectory hinges on successfully transitioning to a productivity- and innovation-led growth model and structural reforms.

References

[1] Aghion, Philippe, and Howitt, Peter. *A Model of Growth Through Creative Destruction.* Econometrica, 60(2), 323–351, 1992.

[2] Aiyar, Shekhar, Ebeke, Christian, and Shao, Xuehui. *The Impact of Workforce Aging on European Productivity.* IMF Working Paper WP/16/238, International Monetary Fund, 2016.

[3] Bai, Chong-En, Hsieh, Chang-Tai, and Qian, Yingyi. *The Return to Capital in China.* Brookings Papers on Economic Activity, 2006(2):61–88.

[4] Brandt, Loren, Van Biesebroeck, Johannes, and Zhang, Yifan. *Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing.* Journal of Development Economics, 97(2), 339–351, 2012.

[5] Cai, Fang, and Lu, Yang. *Population Change and Resulting Slowdown in Potential Output Growth in China.* China & World Economy, 21(2), 1–14, 2013.

[6] Gyourko, Joseph, Ma, Shuwei, and Wang, Yongheng. *Misallocation in the Chinese Real Estate Market.* National Bureau of Economic Research Working Paper No. 30106, 2022.

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[8] Romer, Paul M. *Endogenous Technological Change.* Journal of Political Economy, 98(5), S71–S102, 1990.

[5] Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(5), S71–S102. Aghion, P., Howitt, P. (1992). A Model of Growth Through Creative Destruction. *Econometrica*, 60(2), 323–351.

[6] Brandt, L., Van Biesebroeck, J., Zhang, Y. (2012). Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing. *Journal of Development Economics*, 97(2), 339–351.

[9] Zilibotti, Fabrizio. *Growing Like China: A Roadmap for the Middle-Income Trap*. In C. Adam, S. O'Connell, and D. Bevan (Eds.), *The Oxford Handbook of the Chinese Economy*. Oxford University Press, 2020.

Appendix: Stata Code for Growth Accounting Analysis

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*------------------------------------------------------------
* Samet Efe Keskin, April 29
* Growth Accounting Exercise - Homework 4
* Penn World Table 10.0
*------------------------------------------------------------

cd "/Users/efekeskin/Desktop"
use "pwt1001.dta", clear

keep if inlist(countrycode, "FRA", "DEU", "USA", "IND", "CHN")
keep if year >= 1989 & year <= 2019
*Note that one need to previous year to calculate the growth, since we're analyzing the 1990

keep countrycode country year rgdpo rkna emp hc
sort countrycode year
egen country_id = group(countrycode)
xtset country_id year

*Generating log variables
gen lnY = ln(rgdpo)
gen lnK = ln(rkna)
gen lnL = ln(emp)
gen lnhc = ln(hc)

*Calculating growth rates (log differences)
gen dlnY = lnY - L.lnY
gen dlnK = lnK - L.lnK
gen dlnL = lnL - L.lnL
gen dlnhc = lnhc - L.lnhc

*Calculating contributions -  = 1/3
gen alpha = 1/3
gen capital_contrib = alpha * dlnK
gen labor_contrib = (1-alpha) * dlnL

*Compute TFP growth (residual)
```

```
gen tfp_growth = dlnY - (capital_contrib + labor_contrib)

*Decomposition including human capital
* Effective labor growth = dln(hc * L) = dlnhc + dlnL
gen effective_labor_growth = dlnhc + dlnL

gen human_capital_contrib = (1-alpha) * dlnhc
gen pure_labor_contrib = (1-alpha) * dlnL

*TFP growth considering human capital separately
gen tfp_growth_hc = dlnY - (capital_contrib + human_capital_contrib + pure_labor_contrib)

*Plotting
*without human capital
twoway (line capital_contrib year if countrycode=="USA", lcolor(blue)) ///
       (line labor_contrib year if countrycode=="USA", lcolor(red)) ///
       (line tfp_growth year if countrycode=="USA", lcolor(green)), ///
       title("Growth Accounting Decomposition - USA (no HC)") ///
       ytitle("Contribution to Output Growth") ///
       legend(order(1 "Capital" 2 "Labor" 3 "TFP"))

*Including human capital
twoway (line capital_contrib year if countrycode=="USA", lcolor(blue)) ///
       (line pure_labor_contrib year if countrycode=="USA", lcolor(red)) ///
       (line human_capital_contrib year if countrycode=="USA", lcolor(orange)) ///
       (line tfp_growth_hc year if countrycode=="USA", lcolor(green)), ///
       title("Growth Accounting Decomposition - USA (with HC)") ///
       ytitle("Contribution to Output Growth") ///
       legend(order(1 "Capital" 2 "Labor" 3 "Human Capital" 4 "TFP"))

*Repeating the same task for each country
levelsof countrycode, local(countries)
foreach c of local countries {
    twoway (line capital_contrib year if countrycode=="`c'", lcolor(blue)) ///
           (line labor_contrib year if countrycode=="`c'", lcolor(red)) ///
           (line tfp_growth year if countrycode=="`c'", lcolor(green)), ///
           title("Growth Accounting - `c' (no HC)") ///
           name(gr_nohc_`c', replace) ///
           legend(order(1 "Capital" 2 "Labor" 3 "TFP"))

    twoway (line capital_contrib year if countrycode=="`c'", lcolor(blue)) ///
           (line pure_labor_contrib year if countrycode=="`c'", lcolor(red)) ///
```

```
            (line human_capital_contrib year if countrycode=="`c'", lcolor(orange)) ///
            (line tfp_growth_hc year if countrycode=="`c'", lcolor(green)), ///
            title("Growth Accounting - `c' (with HC)") ///
            name(gr_hc_`c', replace) ///
            legend(order(1 "Capital" 2 "Labor" 3 "Human Capital" 4 "TFP"))
}

table countrycode, statistic(mean capital_contrib) ///
                   statistic(mean pure_labor_contrib) ///
                   statistic(mean human_capital_contrib) ///
                   statistic(mean tfp_growth_hc) ///
                   statistic(mean dlnY)

* Clean the workspace first for Summary Report
preserve

* Keep only 1990{2019
keep if year >= 1990

* Store estimates one-by-one for each country
levelsof countrycode, local(countries)

foreach c of local countries {
    estpost summarize capital_contrib pure_labor_contrib human_capital_contrib tfp_growth_hc
    eststo `c'
}

* Now export all in one LaTeX table
esttab `countries' using "growth_summary.tex", ///
    cells(mean(fmt(3))) ///
    unstack noobs nomtitles label replace ///
    title("Average Growth Contributions by Country, 1990--2019") ///
    varlabels(capital_contrib "Capital" ///
              pure_labor_contrib "Labor" ///
              human_capital_contrib "Human Capital" ///
              tfp_growth_hc "TFP" ///
              dlnY "Output Growth") ///
    alignment(D{.}{.}{-1})
```