Have countries accumulated enough capital? A non-parametric approach*

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Abstract

In this paper, we analyze the effect of capital accumulation on economic growth and verify whether countries have accumulated enough capital. We make use of panel data for 92 countries from 1965–2019, combined with intuitive robust non-parametric modeling based on linear programming. Our result indicates first that capital accumulation is important for economic growth. Second, we show that developing countries suffer from under-investment in capital, while developed countries have unexploited capacity. Therefore, to promote sustainable growth, developing countries need to implement policies to increase their capital stock. However, the situation of developed countries indicates that more capital accumulation is not the correct path for these countries, but better capital use is. Finally, we highlight the particular patterns of China and India and challenge our results by running three sensitivity tests. They confirm our early findings.

Keywords: capital; under-investment; unexploted capacity; non-parametric.

JEL codes: O30; D24; O47.

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1 Introduction

Finding the main drivers of economic growth, as well as its dynamics, has received particular attention in the literature (e.g. Mankiw et al.,1992; Breton, 2011; Batrancea et al., 2022). Researchers have extensively used the neoclassical growth model to understand economic growth. This approach is based on an aggregate production function that considers capital and labor as the main inputs. Consequently, empirical studies have been carried out on the link between these inputs and economic growth, with an extensive focus on labor input (e.g. Walheer, 2016; AlKathiri, 2022).

However, the role of capital is not insignificant. The key contribution of capital accumulation in the economic growth process was recognized a long time ago by economists (Mankiw et al.,1992; McKinsey, 1996). Understanding its role and impact has received particular attention in the empirical macroeconomic literature (e.g. Piketty et al., 2019; Caunedo and Keller, 2021; Koopman and Wacker, 2023).

While different angles have been studied, to the best of our knowledge, there is no empirical research that aims to verify whether countries have accumulated enough capital or more is needed. Unlike studies based on regression (i.e. parametric) methods, we suggest using robust intuitive linear programming (i.e. nonparametric) to assess the role of capital accumulation in economic growth.

2 Literature review

Although several studies are focusing on capital accumulation, there are no empirical studies analyzing whether countries have under-invested or underexploited capacities. Following the pioneering paper of Solow (1957), who states that the accumulation of capital leads to economic growth, many studies have looked at the effect of capital accumulation on growth (see Topcu et al., 2020 for an overview). To sum up, it is commonly agreed that capital accumulation positively affects economic growth (Moller and Wacker, 2017).

Our paper has the following distinguished features: we analyze capital accumulation from a new angle by testing whether countries are in a situation of underinvestment or unexploited capacity, and we use a non-parametric method.

3 Data and descriptive statistics

Variables are constructed using the common practice in the literature: output Y is measured by real GDP at chained PPPs, physical capital K in stock term, and labor L in persons engaged. Output and capital are deflated. Data are taken from the Penn World Table 10.1. By removing missing values, we obtain a balanced sample of 92 countries betweeen 1965 and 2019, i.e. 5,060 observations.

We provide descriptive statistics for the initial (1965) and final (2019) periods in Table 1. In the same table, we display the correlation coefficients between our variables.

Table 1: Descriptive statistics

statistics	output (billions)	capital (billions)	labor (millions)
1965			
min	0.34	0.81	0.16
average	159.13	613.16	19.72
median	31.44	108.05	4.24
max	4,515.72	17,730.63	394.28
std	505.45	2,004.31	54.15
corr with capital	0.98		
corr with labor	0.64	0.52	
2019			
min	3.51	22.51	0.38
average	1,209.11	5,182.91	84.71
median	289.00	1,250.44	19.65
max	20,595.84	99,608.66	2,155.97
std	3,185.39	13,501.92	258.01
corr with capital	0.97		
corr with labor	0.86	0.91	

Output and the two inputs show positive growth between 1965 and 2019. The average output and labor have risen from 1965 to 2019. Regarding capital, its average has risen from nearly 613 billion in 1965 to more than 5,182 billion in 2019. The correlation coefficients show a strong positive correlation between the output and the two inputs. The relationship with capital is stronger and this remains true over time.

4 Methodology

Our starting point is standard macro-economic modeling where countries use a time-varying technology and two inputs, labor L and capital K, to generate output Y. Also, we acknowledge the presence of inefficient behavior. We obtain for every country i at time t the following production process:

$$Y_{it} = f_t(L_{it}, K_{it}) \times e_t(L_{it}, K_{it}). \tag{1}$$

In words, $f_t(L_{it}, K_{it})$ is the time-varying production function at time t, and therefore represents potential output. The distance between actual and potential outputs is captured by $e_t(L_{it}, K_{it})$. When potential output exceeds the actual one, i.e. $e_t(L_{it}, K_{it}) < 1$, it reveals an inefficiency behavior and thus a potential output gain. $e_t(L_{it}, K_{it})$=1, therefore, is the benchmark situation.

To capture the impact of capital accumulation on the economic growth process, we suggest using the following simple ratio:

$$\frac{e_t(L_{it}, 1)}{e_t(L_{it}, K_{it})}. \tag{2}$$

On the denominator, we have the (in)efficiency component as defined in (1). On the numerator, we have a counterfactual (in)efficiency component where the capital impact is ignored (it is set to unity). The ratio therefore compares (in)efficiencies with and without the capital impact.

When the ratio is smaller than unity, it reveals under-investment. In that case, $e_t(L_{it}, 1) < e_t(L_{it}, K_{it})$ which means that ignoring the capital variations across countries reveals more potential output improvement. In other words, more capital is requested to improve the output further.

On the opposite, when the ratio is larger than one, it reveals that capita is not fully used: $e_t(L_{it}, 1) > e_t(L_{it}, K_{it})$ implies that performances are better when ignoring the capital impacts. That is, there is unexploited capacity.

5 Estimation

We reconstruct the production functions employing linear programming (Henderson and Russell, 2005; Walheer, 2021). To avoid trivial reconstructions, we assume that

the production functions are monotone, quasi-concave, satisfy constant returns-to-scale, and that technological degradation is not possible.

To be fair, a disadvantage of using linear programming is that measurement errors and potential outliers are ignored. To mitigate this shortcut, we adopt the well-known order-m estimator (Daraio and Simar, 2007). The basic principle is to compute expected potential outputs obtained with random sub-samples of m peers (here $m = 25$).

The estimated potential output at time t for country i with respect to sub-sample b is estimated as follows:

$$\begin{aligned} \hat{f}_t^b(L_{it}, K_{it}) = \max_{\forall u,s:\lambda_{us}\geq 0; Y\geq 0} & Y \\ Y &\leq \sum_{u=1}^{t}\sum_{s=1}^{m_b} \lambda_{us} Y_{us}, \\ L_{it} &\geq \sum_{u=1}^{t}\sum_{s=1}^{m_b} \lambda_{us} L_{us}, \\ K_{it} &\geq \sum_{u=1}^{t}\sum_{s=1}^{m_b} \lambda_{us} K_{us}. \end{aligned} \tag{3}$$

Once the linear programmings are solved B times (here $B = 1,000$), we obtain the expected estimated potential output as:

$$\hat{f}_t(L_{it}, K_{it}) = \mathbb{E}[\hat{f}_t^b(L_{it}, K_{it})]. \tag{4}$$

The estimated efficiency score $\hat{e}_t(L_{it}, K_{it})$ is obtained by plugging the estimated potential output $\hat{f}_t(L_{it}, K_{it})$ in (1). The counterfactual efficiency score $\hat{e}_t(L_{it}, 1)$ is obtained similarly but when capital values are equal to unity.

6 Results

Using the estimation method explained in Section 5, we compute the ratio in (3). We present our results in Figures 1–5 and Table 2. In Figure 1–5, we give the yearly ratios. In Table 2, we present descriptive statistics for countries that have unexploited capacity.

Overall, there is an increase in the ratio over time (0.64 in 1965 against 0.72 in

2019) while under-investment is the main rule (Figure 1). Several countries (31 over 92) have crossed the value of unity for the ratio highlighting a situation of unexploited capacity. Note that 21 are still in an unexploited situation in 2019 (Table 2); 46.74% have a positive (average) change for the ratio for the period 1965–2019.

In Figure 2, we compare the three countries with the highest ratios over the period: the United States, China, and India. The United States is the only country with a ratio of unity from 1965 (with Luxembourg, Table 2). China and India both present important under-investments in 1965 while they have the largest unexploited capacity in 2019. We see that India surpassed the United States in 1981 and China in 1987.

Next, we highlight additional countries in Figure 3–5. In Figure 3, we give the ten countries with the highest positive changes. All these countries are developing ones and have under-investment for the whole period. In Figure 4, we show the ten worst performers, i.e. those with the smallest changes. Some of these countries were close to the benchmark case in 1965 and their situation is worse and worse over time.

Finally, in Figure 5, we display the ratio evolution for a group of developed countries and followers. We see a similar pattern (cycle) with an initial situation of under-investment. Then, a short period of unexploited capacity (1975–1985) is followed by a stable situation (1985–2000). The period 2000–2019 is characterized by unexploited capacity.

In Table 2, we give the year a country presents unexploited capacity for the first and the last times, the values of the ratios for the initial and final years, and the number of years with unexploited capacity. Most of the countries with unexploited capacity which lasts over time are developed countries. The average annual change for the ratio is 0.91% in Table 2 with an average value of 0.83 and 1.17 in 1965 and 2019. This means that these countries have moved from an under-investment situation to an unexploited capacity one.

To challenge our results, we run several sensitivity tests: we try several values for m; we remove outliers; and we include human capital as an augmented factor of labor (Barro and Lee, 2013). These sensitivity tests confirm our main findings: under-investment is still the rule while several developed countries present unexploited capacity.

Figure 1: all countries

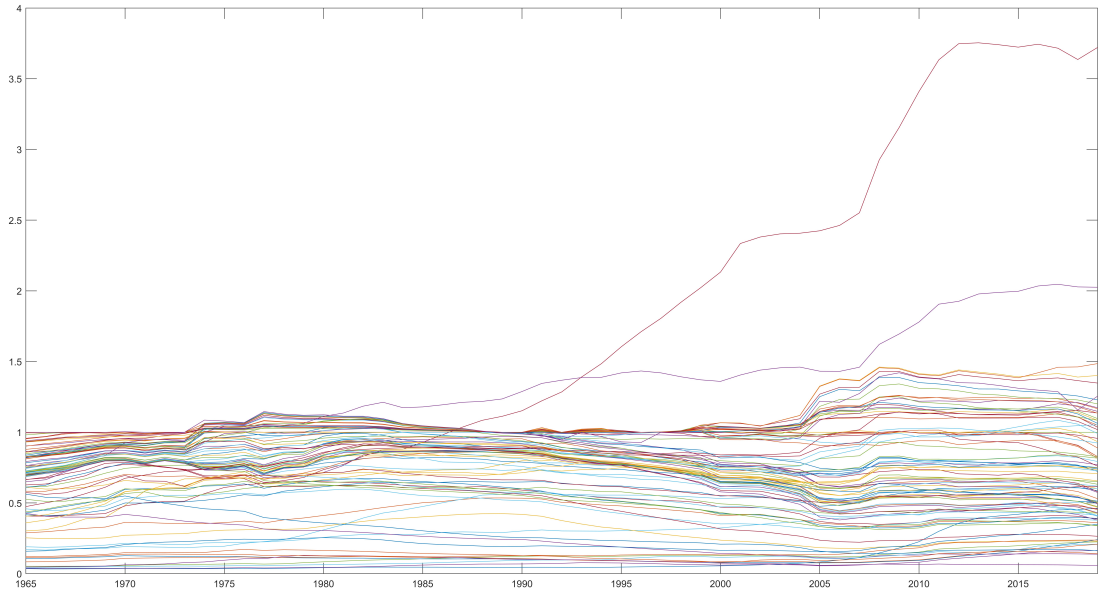


Figure 2: United States – China – India

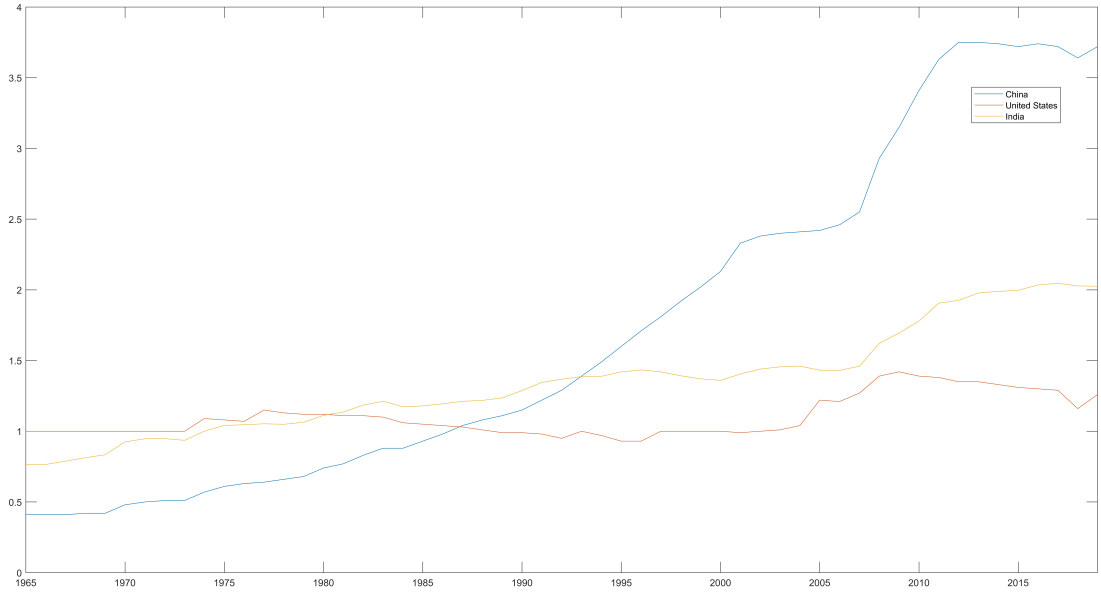


Figure 3: countries with largest positive ratio changes

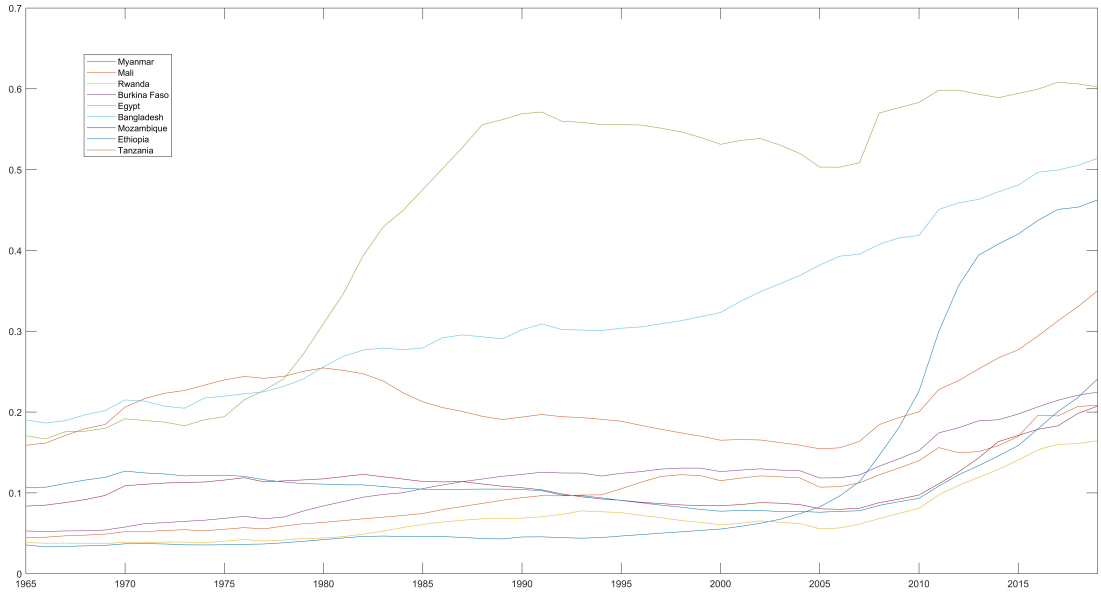


Figure 4: countries with largest negative ratio changes

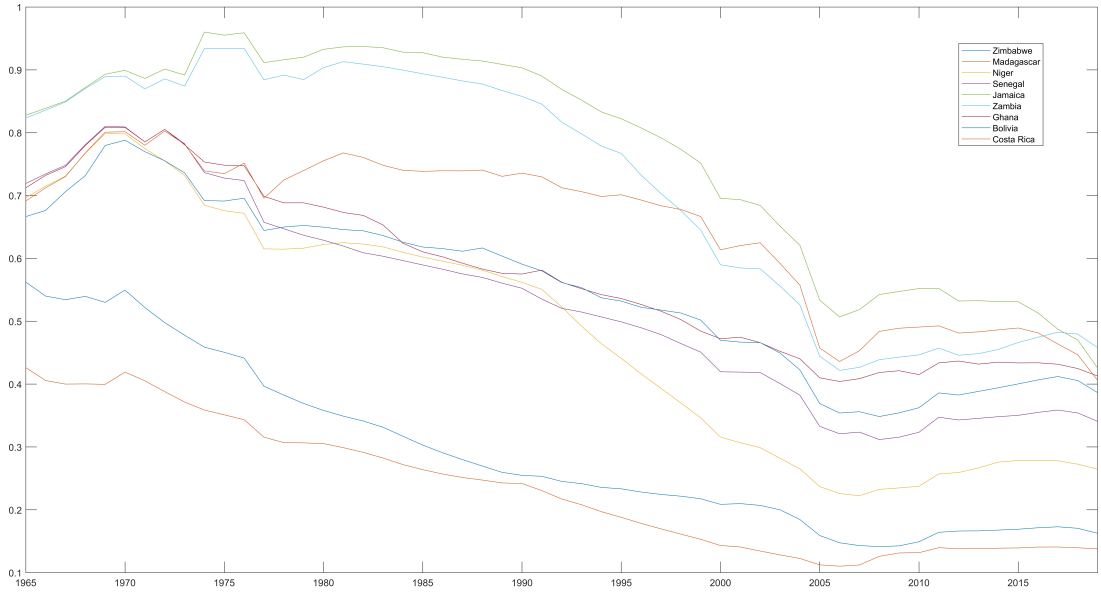
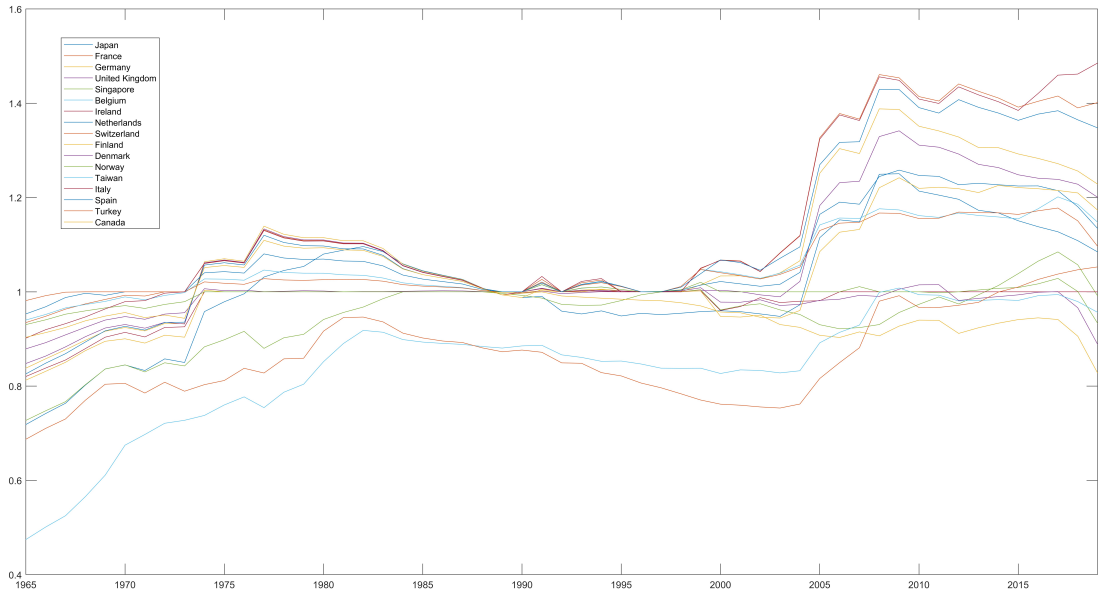


Table 2: Countries with unexploited capacity

Country	unexploited capacity		ratio		average annual growth	% years ratio > 1
	initial	final	1965	2019		
Argentina	1979	1983	0.78	0.74	-0.07%	9.09%
Australia	1973	2019	1.00	1.17	0.32%	85.45%
Austria	1974	2019	0.86	1.08	0.45%	83.64%
Belgium	1974	2019	0.94	1.15	0.38%	81.82%
Canada	1974	2019	0.90	1.17	0.52%	54.55%
Switzerland	1968	2019	0.98	1.10	0.22%	92.73%
China	1987	2019	0.41	3.72	4.24%	60.00%
Germany	1974	2019	0.84	1.23	0.77%	80.00%
Denmark	1974	2011	0.88	0.89	0.03%	54.55%
Algeria	1976	1988	0.86	0.77	-0.18%	23.64%
Spain	1974	2019	0.83	1.35	0.96%	83.64%
Finland	1974	1999	0.81	0.83	0.06%	43.64%
France	1972	2019	0.93	1.40	0.80%	83.64%
United Kingdom	1974	2019	0.85	1.20	0.70%	72.73%
Greece	1974	2019	0.86	1.04	0.36%	83.64%
India	1974	2019	0.77	2.03	1.85%	83.64%
Iran	1974	2014	0.75	0.92	0.44%	40.00%
Italy	1973	2019	0.90	1.49	0.98%	80.00%
Japan	1977	2019	0.72	1.08	0.82%	49.09%
Korea	2007	2019	0.63	1.14	1.14%	23.64%
Luxembourg	1965	2015	1.00	0.82	-0.36%	85.45%
Mexico	1974	1987	0.82	0.83	0.06%	25.45%
Netherlands	1970	2019	0.95	1.13	0.35%	90.91%
Norway	1974	2018	0.93	0.93	0.01%	80.00%
Portugal	1974	2019	0.82	1.06	0.51%	74.55%
Singapore	1984	2018	0.73	0.99	0.60%	21.82%
Sweden	1974	2019	0.93	1.02	0.18%	83.64%
Turkey	2015	2019	0.69	1.05	0.83%	9.09%
Taiwan	2009	2009	0.47	0.96	1.35%	1.82%
United States	1965	2019	1.00	1.26	0.50%	83.64%
South Africa	1980	1983	0.75	0.73	-0.01%	7.27%
Average	–	–	0.83	1.17	0.91 %	59.12%

Figure 5: developed countries and followers



7 Discussion

Our study highlights that developing countries have under-investment capacity whereas, developed ones have unexploited capacity. As this paper is, to the best of our knowledge, the first to analyze empirically whether countries have accumulated enough capital it is difficult to compare our results to other studies. However, our results are in line with the literature on the importance of capital accumulation. Still, as evidenced by Onyinye et al. (2017), the way countries accumulate capital will either limit or promote their sustainable growth. One weakness of our analysis lies in the fact that we have heterogeneity within the countries analyzed. Although we have applied techniques to limit this, future studies are needed.

8 Conclusion and policy implications

This paper analyses the effect of capital accumulation on economic growth and assesses whether 92 countries are in a situation of under-investment or unexploited capacity over the period 1965-2019. Applying a non-parametric estimation technique,

we find that developing countries are, generally, in an under-investment situation, while developed countries are in a situation of unexploited capacity.

It is therefore important for developing countries to promote policies that will aim to increase their stock of capital. Of course, a related question for these countries is how to attract more capital. Increasing the domestic saving rate and improving international capital market access are two solutions available. At the same time, developed countries have unexploited capacity revealing that more capital accumulation is not the only correct path.

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