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Unveiling the Hidden Impact of Urban Land Rents on TFP

Why TFP growth in densely populated
economies with rapidly growing capital
stocks has been severely underestimated

Bas B. Bakker

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WORKING PAPER

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**Unveiling the Hidden Impact of Urban Land Rents on Total Factor Productivity:
Why TFP growth in densely populated economies with rapidly growing capital stocks has been
severely underestimated****Prepared by Bas B. Bakker***

August 2023

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ABSTRACT: This paper addresses the puzzling decline of Total Factor Productivity (TFP) levels in rapidly growing economies, such as Singapore, despite advancements in technology and high GDP per capita growth. The paper proposes that TFP growth is not negative; instead, standard growth decompositions have underestimated TFP growth by overestimating the contribution of capital, failing to account for the substantial part of capital income directed to urban land rents. This leads to an overestimation of changes in capital stock's contribution to growth and thereby an underestimation of TFP growth. A revised decomposition suggests that TFP growth in economies with high land rents and rapid capital stock growth, such as Singapore, has been considerably underestimated: TFP levels have not declined but increased rapidly.

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WORKING PAPERS

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1 Introduction and Executive Summary

In a number of very rapidly growing economies, TFP *levels* have declined in the past half century. For example, in Singapore, GDP per capita in 2019 was 8½ times the level in 1970s, but TFP was almost 10 percent lower (Figure 1.1). In Malaysia, Türkiye, and Panama, TFP levels were also lower, even though GDP per capita growth has been rapid.

Lower TFP is a puzzle, as it would imply that it takes more inputs to produce a given level of GDP than it did in the past. But we know technological progress has been spectacular. It would seem bizarre to argue that technology in Singapore in 1970 was more advanced than it was in 2019.

There is also a puzzle that TFP growth in seemingly similar economies has been strikingly different. Singapore has seen no TFP growth in the last fifty years, while TFP growth in Hong Kong SAR has been considerable (Figure 1.2).¹

This paper proposes a solution for this puzzle. TFP growth has not been negative; rather, standard growth decompositions have underestimated TFP growth by overestimating the contribution of capital.

- They assume that the contribution of capital to growth is equal to the growth rate of the capital stock times the capital income share—which is calculated as 1- labor income share.
- But a considerable part of capital income goes to land rents rather than to the owners of the physical capital stock.²
- A proper decomposition should include not only capital and labor, but also land, with the contributions of each factor determined by the growth rate of the production factor times the share of the rewards of the production factor in GDP.
- This means that growth decompositions should use a lower coefficient for the capital stock—they should use the capital income share *excluding land rents* rather than the total capital income share.
- That means that standard growth decompositions overestimate the contribution of changes in the capital stock to growth—and thereby underestimate TFP growth.
- The overestimation can be significant in economies where land rents are high and the capital stock has grown very rapidly—which includes Singapore.³

¹See, for example, [Young \(1992\)](#).

²Note that in the paper we do not focus on the share of land rents for agriculture or natural resources, but on *urban* land rents—capital income going to land owners in urban areas.

³The increase in the capital stock in Singapore has been truly dramatic: the capital stock in 2019 was 39 times as high as in 1970. To put this into perspective, in the United States the capital stock was 4.7 times as high.

We do not have data for the share of land rents in GDP in Singapore and Hong Kong SAR, nor do we have data on their aggregate land value. We therefore try to derive a plausible estimate. We show that the share of land rents in GDP is not constant—it is higher in more densely populated areas. We derive a lower bound for the share of land rents in GDP of Singapore and Hong Kong SAR by looking at land rents in countries where population density is lower than in Hong Kong SAR and Singapore.

- We argue that land values are higher in more densely populated areas. GDP is higher too, but the differences are less pronounced than the difference in land values. As a result, the ratio of land values to GDP is higher in more densely populated areas.
- Assuming the return on land is the same everywhere, this implies that the ratio of land rents to GDP is higher in more densely populated areas.
- We show that for US states there is a strong link between population per developed area and the ratio of the value of developed land to GDP: the higher the population density, the higher the value of land relative to GDP. Assuming that the return on land is equal across US states, this implies that share of land rents in GDP depends on population density as well.
- We then show that a similar link exists for US states between *weighted* population density⁴ and land rents.
- We show that for OECD countries for which the OECD has data on the aggregate value of land, there is a strong link between weighted population density and the share of land rents in GDP.
- We use this link to derive a lower bound for the share of land rents to GDP in Singapore and Hong Kong SAR—two economies for which we do not have data on either land rents or land values. In Korea, where weighted population density is the highest among all OECD economies for which the OECD has data on aggregate land values, land rents are slightly less than 25 percent of GDP. As Hong Kong SAR and Singapore have a much higher weighted population density, they should have a higher land rent ratio. We therefore assume, very conservatively, that land rents in Hong Kong SAR and Singapore are 25 percent of GDP.

That would imply that TFP growth in Singapore has been substantially underestimated. In Singapore, the capital stock has grown by 7.5 percent annually between 1970 and 2019. The average capital income share during this period was 56 percent of GDP. If land rents were 25 percent of GDP, TFP was underestimated by $0.25 \times 7.5 = 1.75$ percent annually. This

⁴Population-weighted density is the mean of the densities of subareas of a larger area weighted by the populations of those subareas (Ottensmann (2018))

would imply that TFP did not *decline* by 0.2 percent annually between 1970 and 2019, but increased by 1.55 percent.⁵

We also show that Singapore and Hong Kong SAR are much more similar than standard TFP estimates suggest. The capital stock in Singapore has grown more rapidly than in Hong Kong SAR, which implies that TFP growth has been more underestimated.⁶

Krugman (1994) in his famous paper noted that ‘Economic growth that is based on expansion of inputs, rather than on growth in output per unit of input, is inevitably subject to diminishing returns.’ Yet standard growth decompositions assume that diminishing returns to scale do not exist. They assume that very rapid growth of inputs should lead to an equally large growth of output. To the extent output grows by less, they attribute this to declining TFP.

The paper shows that Singapore has not suffered from negative TFP growth. Rather, with one fixed production factor (land), there have been declining returns to scale from increasing capital and labor.

- The capital stock in Singapore in 2019 was 39 times as high as in 1970 while human capital was 15 times as high. With unchanged TFP, constant returns to scale in capital and labor, and a capital income share of 60 percent, this should have led to an output level that is 27 times as high. As output was only 24 times as high, growth decomposers conclude that TFP growth was negative.
- But with unchanged TFP, declining returns to scale in capital and labor, and a coefficient on capital that is 35 percent rather than 60, the same increase in inputs would only lead to an output level that is 11 times as high. That means that more than half the increase in output was the result of TFP!

Finally, both declining returns to scale and negative TFP growth lead to output growing by less than inputs. But the difference between the two is more than semantics.

- Declining TFP implies that more inputs are needed to produce the same level of output, which suggests that efficiency is declining or technology is regressing.⁷
- Declining returns to scale means that an increase in inputs leads to a less than proportionate increase in output. It does not mean that efficiency is declining or technology is regressing.⁸

⁵We derive a more precise calculation in the paper, using annual data for the growth of the capital stock and the capital income share. The more precise estimate is 1.70 percent.

⁶The underestimation of TFP growth has also taken place in advanced economies, but the magnitude of the underestimation has been much smaller. Take the United States. The average annual growth rate of the capital stock between 1970 and 2019 has been 3.2 percent, while the average capital income share between 1970 and 2019 was 39 percent. Assuming that land rents were 15 percent of GDP, the underestimation of TFP was $0.15 \times 3.2 = 0.5$ percent per year.

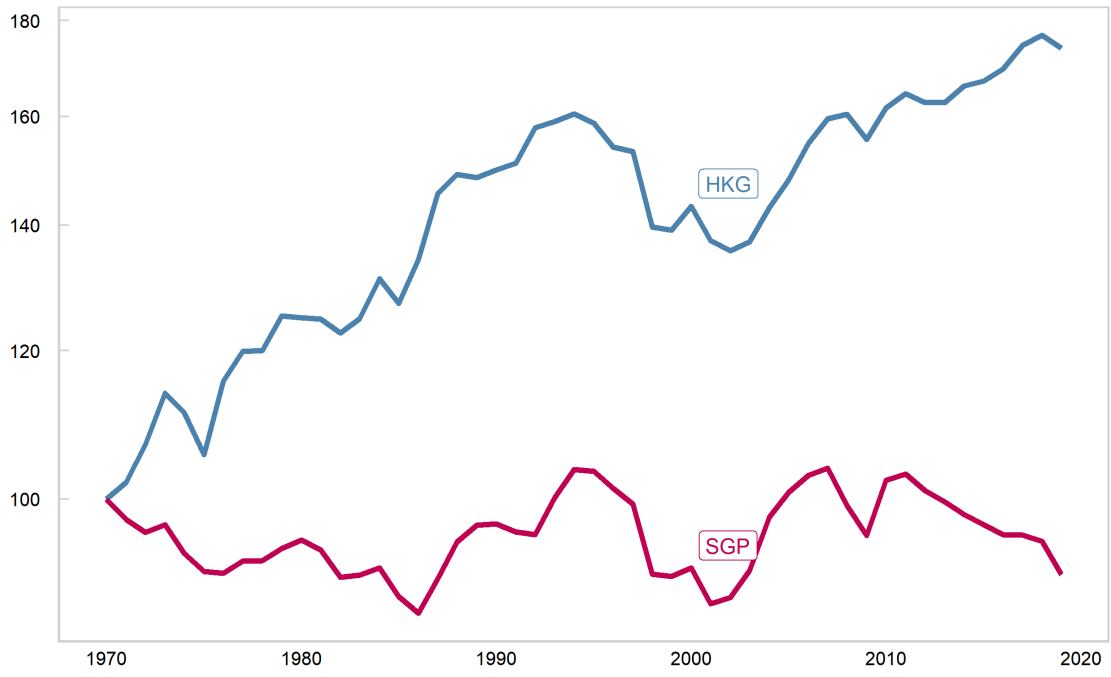
⁷TFP is usually interpreted as a measure of technology, summarizing how intensively and efficiently

Figure 1.1. Growth of GDP per capita and TFP according to Penn World Tables 10.0, 1970-2019

(1970=100)



Figure 1.2. Hong Kong SAR and Singapore: TFP according to PWT 10.0



inputs are used in production. ([Crafts and Woltjer \(2021\)](#), page 672).

⁸It is true that the absence of land available for development will eventually reduce output growth and per capita income. This may be mitigated to some extent by a shift into less land-intensive sectors and such a shift will be incentivized by relative cost developments.

2 Existing Literature

The role of land

Land played a pivotal role in classical economic theory. Agriculture, as the dominant sector during that era, underscored the significance of land. [Hansen and Prescott \(2002\)](#) argued that the pre-industrial era used a *Malthus* technology—a land-intensive technology where land is a fixed factor and there are decreasing returns to labor. The theory of rent, particularly emphasized by economists like Ricardo, explored the income earned by landowners due to its scarcity and productivity.

In contrast, modern economic growth theory limits the role of land. [Hansen and Prescott \(2002\)](#) argue that the modern era operates on a called "Solow" technology, which exhibits constant returns to scale with capital and labor as inputs. If land still has a role, it is primarily as a source of natural resources or natural capital that can be depleted ([Brandt et al. \(2017\)](#)).

The significant decrease in the value of agricultural land has contributed to a shift in economists' production functions. [Piketty and Zucman \(2014\)](#) observe that the value of agricultural land in France and the United States, which once amounted to four to five years of national income around 1700, is now "negligible."

But while the value of *agricultural* land has declined sharply, the value of *urban* land has increased sharply. [Knoll et al. \(2017\)](#) presents annual house prices for 14 advanced economies since 1870. They show that real house prices stayed constant from the nineteenth to the mid-twentieth century, but rose strongly and with substantial cross-country variation in the second half of the twentieth century. Rising land prices explain about 80 per cent of the global house price boom.

The land price increase has been particularly pronounced in densely populated areas. [Barr et al. \(2018\)](#) estimates that the value of all land in Manhattan (28 square miles) was US\$ 1.74 trillion. The link between urban density and land prices has been extensively discussed in the literature. See, for example, [Duranton and Puga \(2020\)](#) and [Glaeser and Gyourko \(2018\)](#).

There have been papers that have focused on the economic impact of the land price increases. [Rognlie \(2015\)](#) argues that the increase in the (net) capital income share in recent decades is entirely the result of an increase in capital income of the housing sector. [Ganong and Shoag \(2017\)](#) argues that rising housing prices in high-income areas in the US has deterred low-skill migration and slowed income convergence.

To our knowledge, there is no paper that discusses the sharp increase in land prices for growth accounting.

Low TFP growth in some Asian Tigers

[Krugman \(1994\)](#), in his famous paper 'The Myth of Asia's Miracle', popularized the idea that economic growth in Singapore and other rapidly growing Asian economies was solely

the result of an increase in inputs and that total factor productivity had not increased at all:

‘But it is only when one actually does the quantitative accounting that the astonishing result emerges: all of Singapore’s growth can be explained by increases in measured inputs. There is no sign at all of increased efficiency. In this sense, the growth of Lee Kuan Yew’s Singapore is an economic twin of the growth of Stalin’s Soviet Union—growth achieved purely through mobilization of resources.’

Young (1992) compared Hong Kong and Singapore. He noted that ‘while the Hong Kong government has emphasized a policy of *laissez faire*, the Singaporean government has, since the early 1960s, pursued the accumulation of physical capital via forced national saving and the solicitation of a veritable deluge of foreign investment.’ He found that ‘While total factor productivity growth has contributed substantially to economic growth in Hong Kong, its contribution to growth in Singapore is next to nil.’ He suggested this could be explained by Singapore’s industrial policies: ‘Singapore is a victim of its own targeting policies, which are increasingly driving the economy ahead of its learning maturity into the production of goods in which it has lower and lower productivity.’

In an overview article about TFP growth in Asia, Felipe (1999) argues that attributing low TFP growth to industrial policy is not warranted:

‘Performing a growth accounting exercise with the aim of decomposing overall growth or fitting a production function is not the same as explaining the ultimate causes of growth. Therefore, most explanations about the growth of the countries under study, advanced *ex-post*, are unwarranted, and thus, fallacious. In other words, there is an unfilled gap between calculating zero productivity growth and attributing it to the failure of industrial policy.’

TFP and Income Differentials

It is well established in the literature that cross-country differentials in income *levels* are largely due to differences in TFP. See for example, the overview in Jones (2016).⁹

Similarly, in the longer run, differences in per capita GDP growth tend to be associated with differences in TFP growth (Figure 1.1). Differences in labor productivity growth also tend to be associated with differences in TFP growth (Figure 2.1).

However, there are some important exceptions. Panama, Türkiye, Malaysia and Singapore are all economies with rapid labor productivity growth but negative TFP growth.

⁹It is also well established that differences in TFP are due to differences in human capital and governance and other institutions (see for example, Jones (2016) and Bakker et al. (2020)).

There are also some puzzles. Why has Singapore, where labor productivity has *tripled* since 1970, had virtually the same TFP growth as Jamaica—where labor productivity is *lower* than in 1970 (Figure 2.2)?

Figure 2.1. Labor productivity and TFP Growth according to PWT 10.0, 1970-2019

(1970=100)

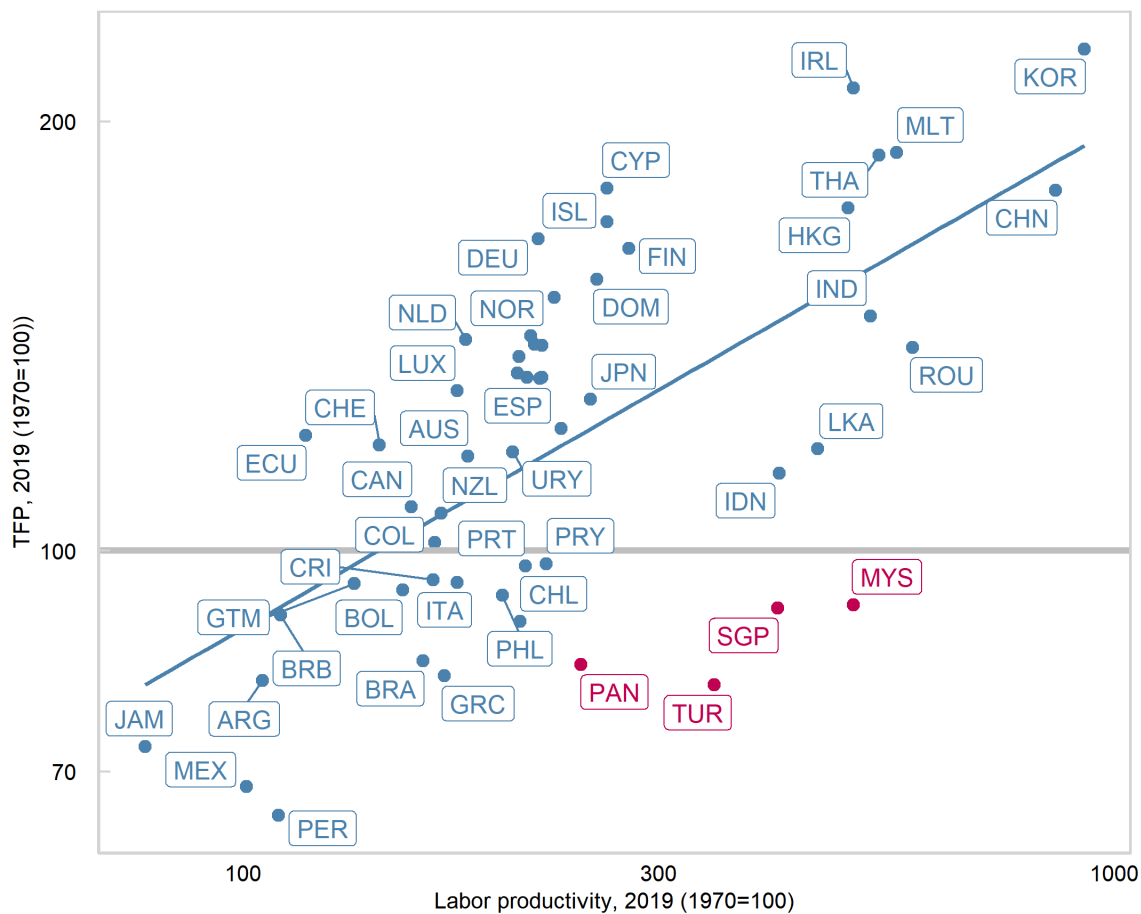
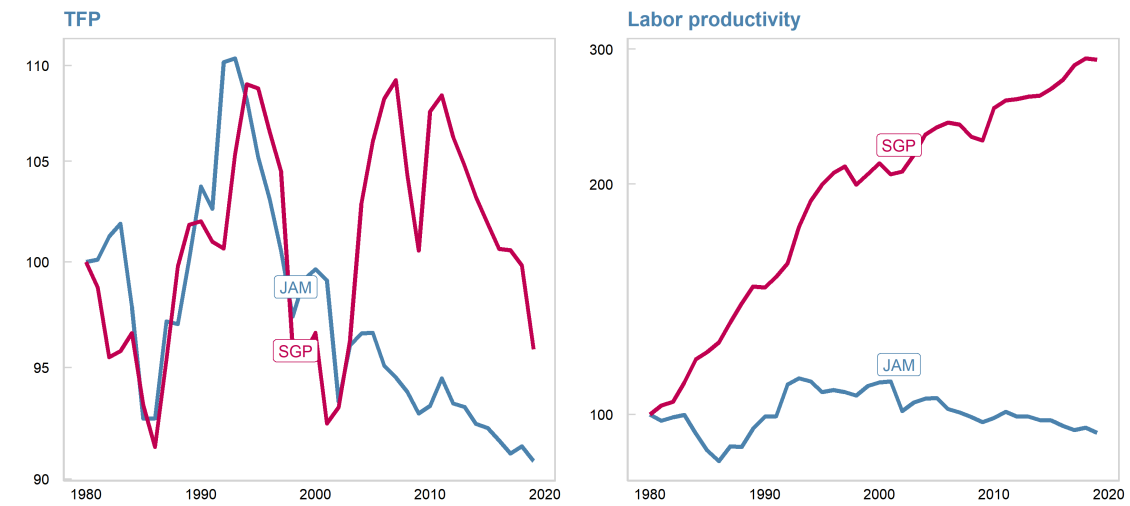


Figure 2.2. Singapore and Jamaica: TFP and Labor Productivity Growth according to PWT 10.0, 1980-2019
(1980=100)



Source: Penn World Tables 10.01.

3 Standard Growth Decompositions overstate the Contribution of Capital

3.1 Standard growth decomposition

Standard growth decompositions assume that there are constant returns to scale; and that there is perfect competition which in turn implies that factors get paid their marginal products. The production function is:

$$Y = AF(K, L) \quad (3.1.1)$$

If we totally differentiate the above production function we get;

$$dY = F(K, L)dA + AF_K dK + AF_L dL \quad (3.1.2)$$

With perfect competition this equation becomes:

$$dY = F(K, L)dA + r dK + w dL \quad (3.1.3)$$

If we divide by Y we get:

$$\frac{dY}{Y} = \frac{dA}{A} + \frac{rK}{Y} \frac{dK}{K} + \frac{wL}{Y} \frac{dL}{L} \quad (3.1.4)$$

If we define α as the share of total income that goes to capital we can rewrite this as:

$$\frac{dY}{Y} = \frac{dA}{A} + \alpha \frac{dK}{K} + (1 - \alpha) \frac{dL}{L} \quad (3.1.5)$$

This equation is typically used to estimate TFP growth:

$$\frac{d\hat{A}}{\hat{A}} = \frac{dY}{Y} - \alpha \frac{dK}{K} - (1 - \alpha) \frac{dL}{L} \quad (3.1.6)$$

where $\frac{d\hat{A}}{\hat{A}}$ is estimated TFP growth.

3.2 Growth decomposition when land is included as a production factor

Assume that the real production function is:

$$Y = AF(K, L, T) \quad (3.2.1)$$

where T is land.¹⁰ The only difference between this production function and the previous function is the inclusion of land. As before we assume that there are constant returns to scale; and that there is perfect competition which in turn implies that factors get their marginal products.

¹⁰From the Latin word terra.

Define γ as the share of GDP going to land rents. We can deduce that

$$\frac{dA}{A} = \frac{dY}{Y} - (\alpha - \gamma)\frac{dK}{K} - \gamma\frac{dT}{T} - (1 - \alpha)\frac{dL}{L} \quad (3.2.2)$$

Assuming that the amount of land is fixed we can write this as

$$\frac{dA}{A} = \frac{dY}{Y} - (\alpha - \gamma)\frac{dK}{K} - (1 - \alpha)\frac{dL}{L} \quad (3.2.3)$$

If we compare equation (3.2.3) with (3.1.6) we see that standard growth decompositions assume that the coefficient for the capital stock is equal to the capital income share, whereas the decomposition with a production function that includes land uses a coefficient that is equal to the capital income share *minus the share of land rents in GDP*.

The result is that the more the capital stock grows, the more estimated TFP growth ($\frac{d\hat{A}}{\hat{A}}$) will deviate from actual TFP growth ($\frac{dA}{A}$):

$$\frac{d\hat{A}}{\hat{A}} = \frac{dA}{A} - \gamma\frac{dK}{K} \quad (3.2.4)$$

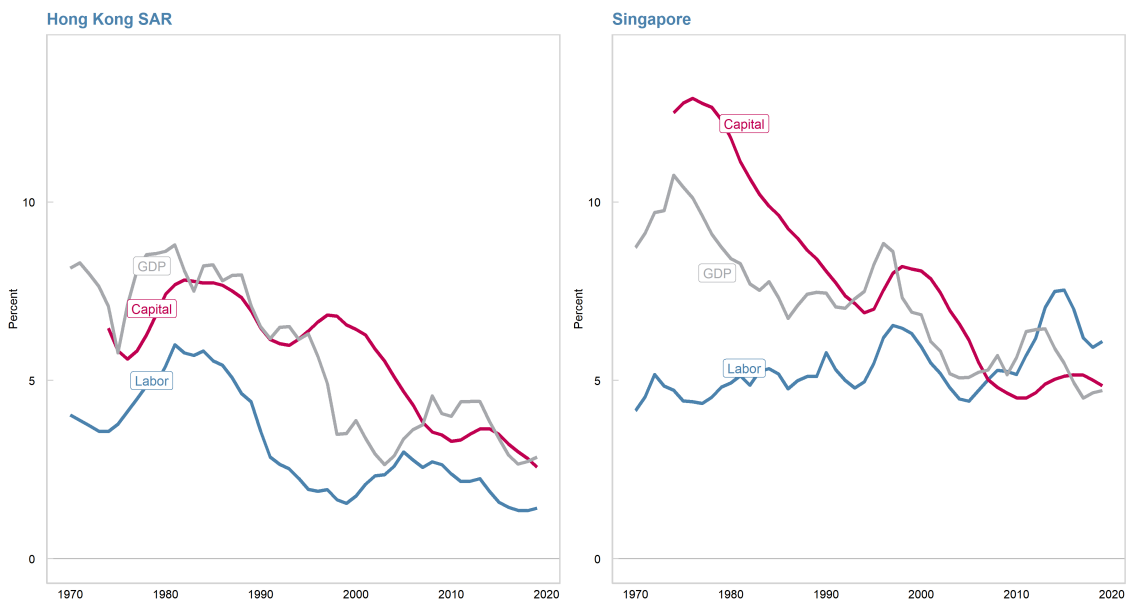
In Singapore, the capital stock has been growing very rapidly (Figure 3.1). This suggests that TFP growth may have been substantially underestimated.

3.3 Capital deepening is associated with a decline in TFP growth

To further support the idea that the negative TFP growth estimates in Penn World Tables are the result of an overestimation of the contribution of capital, we will show that capital deepening (an increase in the capital-output ratio) is associated with a decline in TFP growth as estimated by Penn World Tables. Figure 3.2 shows that there is a strong negative link between changes in the capital-output ratio and changes in TFP.

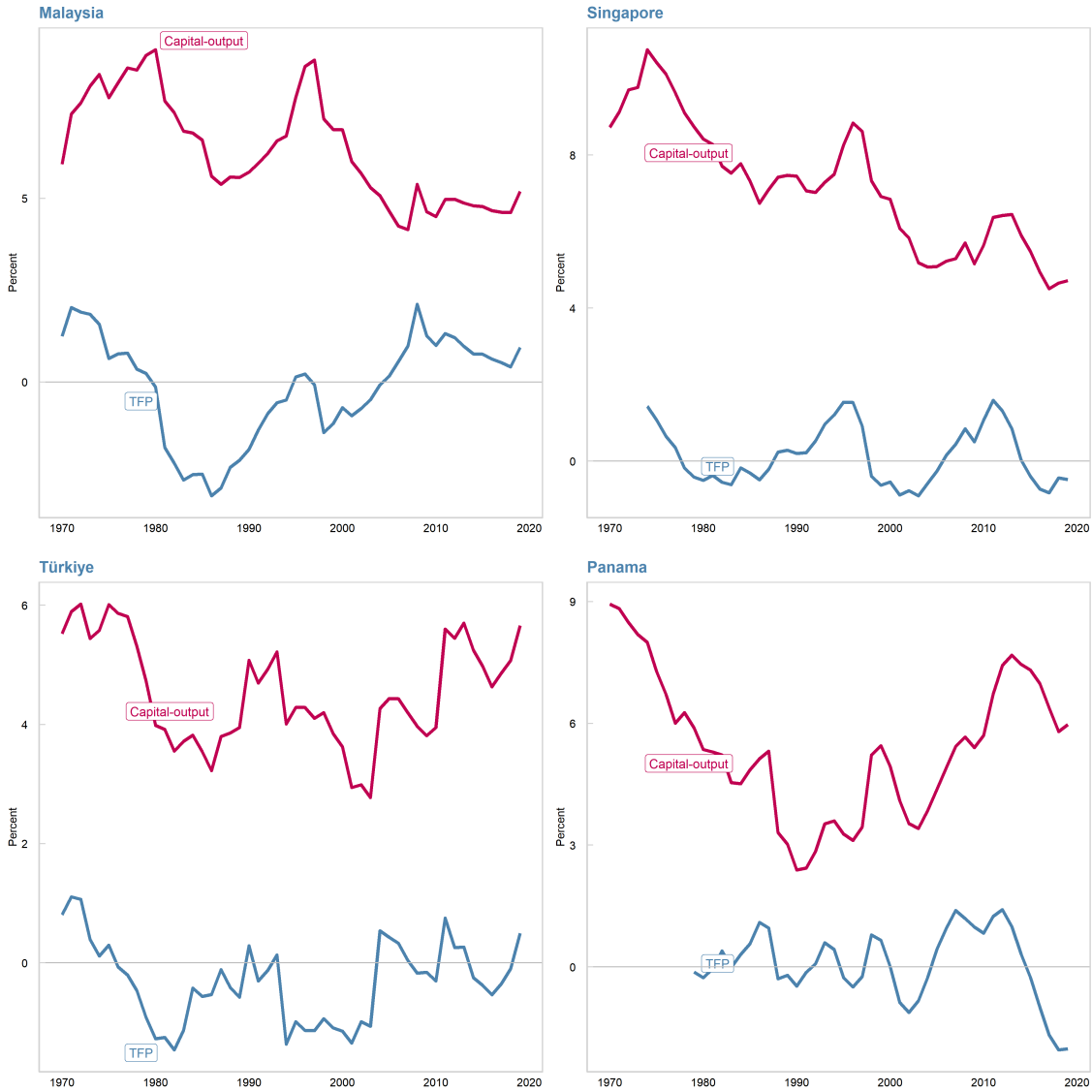
In theory, the link between the change in the capital-output ratio and the change in TFP could also go the other way. Low TFP growth could lead to low GDP growth and an increase in the capital output ratio. *In practice*, however, this does not seem to be the case. The link between changes in the capital output ratio and GDP growth is *positive* suggesting that capital deepening is associated with *faster* growth (Figure 3.3).

Figure 3.1. Growth of GDP and Factor Inputs in Hong Kong SAR and Singapore
 (Percent, ten-year moving average)



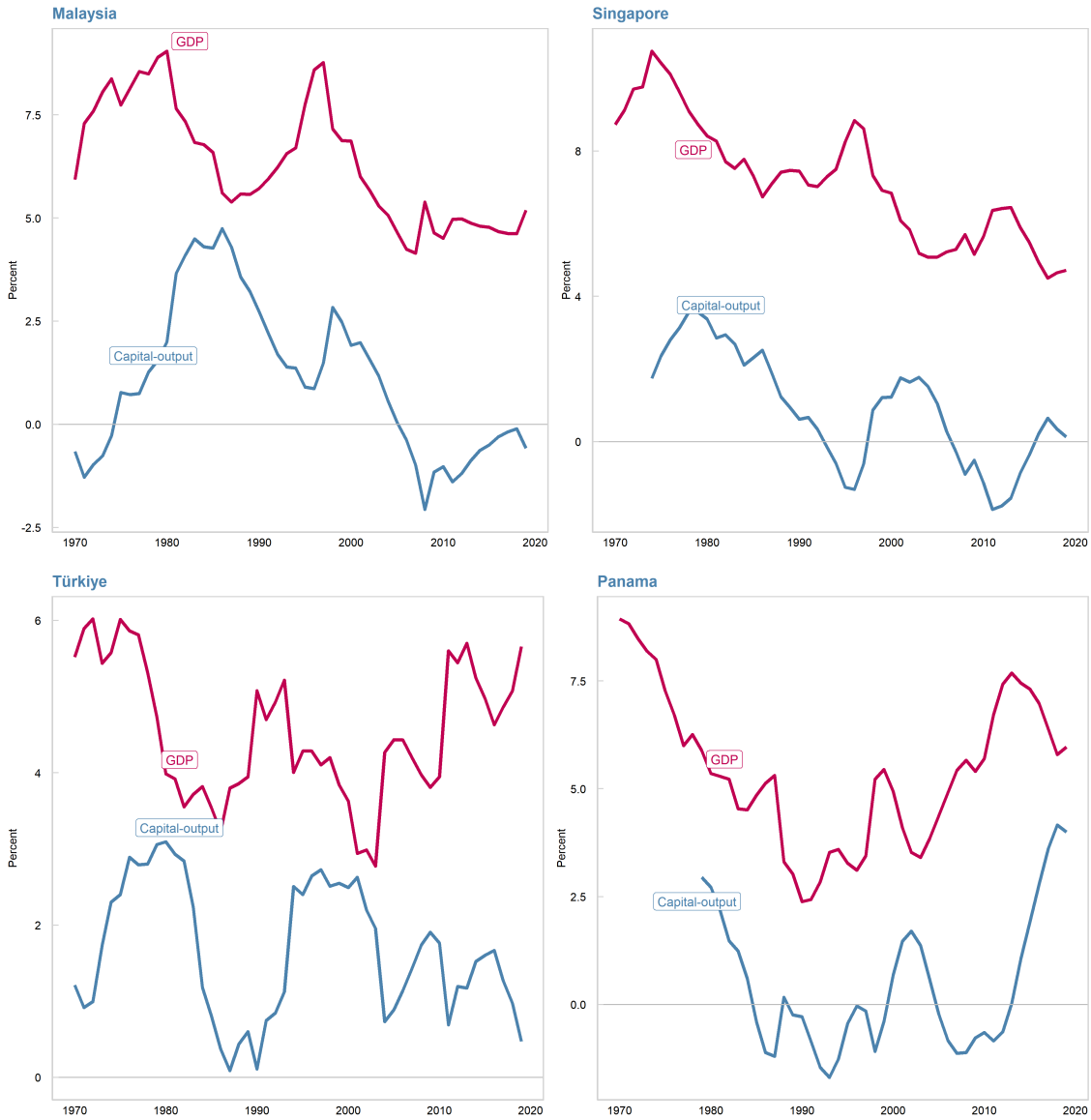
Labor is hours worked * human capital.
 Source: Penn World Tables 10, IMF Staff Calculations.

Figure 3.2. Change in Capital-Output and TFP according to Penn World Tables 10.0
(Percent, ten-year moving average)



Source: Penn World Tables 10, IMF Staff Calculations.

Figure 3.3. Change in Capital-Output and GDP
(Percent, ten-year moving average)



Source: Penn World Tables 10, IMF Staff Calculations.

4 Determining land rents from the value of Land

4.1 Theory

The share of land rents in GDP, γ , is equal to:

$$\gamma = \frac{r_T P_T T}{P_Y Y} \quad (4.1.1)$$

where r_T is the return on land, P_T is the price of land, T is the amount of land, Y is real GDP and P_Y is the GDP deflator.

We assume that the net return on the capital stock, r_K , is the same as the net return on land:¹¹

$$r_T = r_K - \delta = r \quad (4.1.2)$$

It follows that:

$$r P_T T + (r + \delta) P_K K = \alpha P_Y Y \quad (4.1.3)$$

where α is the capital-income share (i.e., the share of GDP that does not go to labor) and δ is the depreciation rate of the capital stock. It follows that

$$r = \frac{\alpha P_Y Y - \delta P_K K}{P_T T + P_K K} \quad (4.1.4)$$

The share of land rents in GDP is:

$$\gamma = \frac{r P_T T}{P_Y Y} \quad (4.1.5)$$

We thus need five variables to calculate land rents:

- The value of land ($P_T T$)
- The value of the capital stock ($P_K K$)
- Nominal GDP ($P_Y Y$)
- The capital income share (α)
- The depreciation rate on the capital stock (δ)

¹¹Note that the net return on the capital stock is equal to the gross return minus depreciation. The net return on land is equal to the gross return—there is no depreciation.

4.2 Calculating land rents for OECD countries

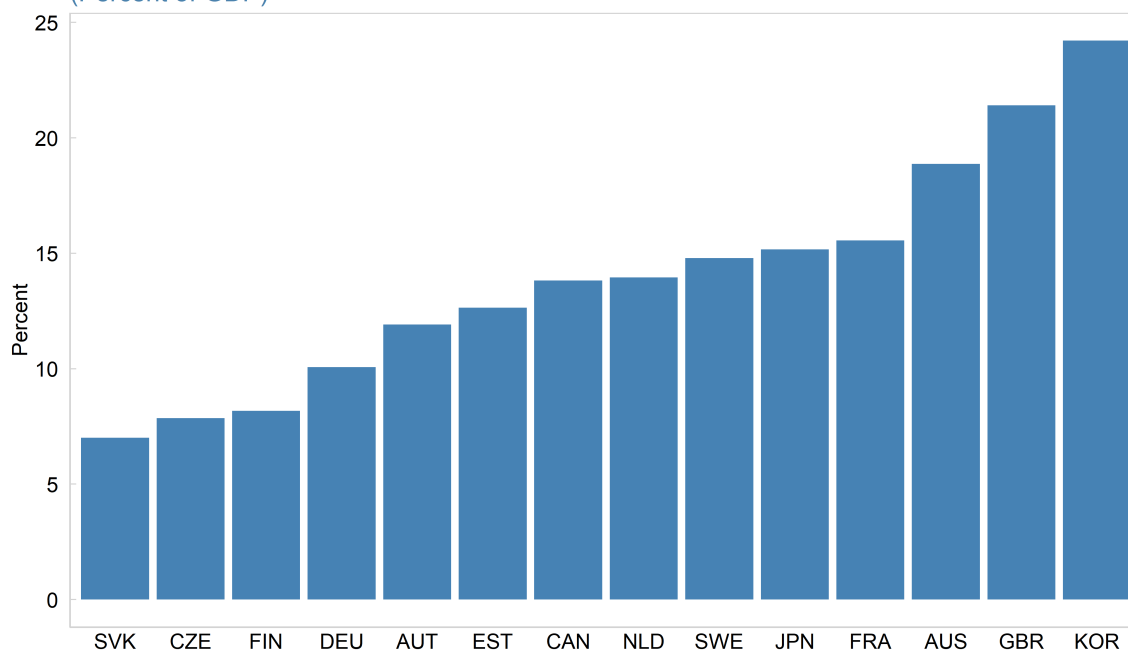
To calculate land rents for a number of OECD countries we combine OECD data and data from Penn World Tables:

- We use OECD data on the value of the capital stock, the value of land, and GDP.
- We use Penn World Tables 10.0 data on the capital income share and the depreciation rate

We first calculate r using equation (4.1.4). We then calculate the land rent to GDP ratio from equation (4.1.5).

The results are in Figure 4.1. Land rents are highest in Korea, at about 24 percent of GDP. In Great Britain, they are 21 percent of GDP. They are lowest in Germany, at about 10 percent of GDP.¹²

Figure 4.1. Land Rents in OECD Countries, 2018
(Percent of GDP)



¹²These estimates for Australia are similar to Putland (2018), who estimates land rents in Australia in 2018 at slightly over 20 percent of GDP.

5 Determining Land rents from Population Density

Unfortunately, we do not have data on the aggregate value of land in Singapore or Hong Kong SAR that we could use to determine the ratio of land rents to GDP in those economies. We will therefore estimate the land rents to GDP ratio by looking at other densely populated economies for which we have land rents estimates.

It is well known that land values in densely populated areas are much higher than in less densely populated areas. According to [Albouy et al. \(2018\)](#), five urban agglomerations (New York, Los Angeles, San Francisco, Washington, DC, and Chicago) account for 48% of all urban land value in the United States. According to [Barr et al. \(2018\)](#) the entire amount of developable land on Manhattan in 2014 was worth approximately \$1.74 trillion.

More densely populated area also produce more GDP, but the difference is less pronounced than the difference in land values. In 2018, the share of the five urban agglomerations in US GDP was 22.3 percent—less than half the share in US land values.

This suggests that the ratio of land values to GDP is higher in more densely populated areas. And assuming that the return on land is constant, this implies that the share of land rents in GDP is also higher in more densely populated areas.

5.1 Population per developed area and land rents: Evidence from US states

[Larson \(2015\)](#) has calculated land values and areas for developed land, agricultural land and federal land for each of the 48 contiguous United States. Developed land is worth an average of \$106,000 per acre, versus non-developed land, which is estimated to be worth about \$6,500 per acre. Agricultural land is estimated to be worth \$2,000 per acre vs non-agricultural land which is worth an average of \$21,000 per acre.

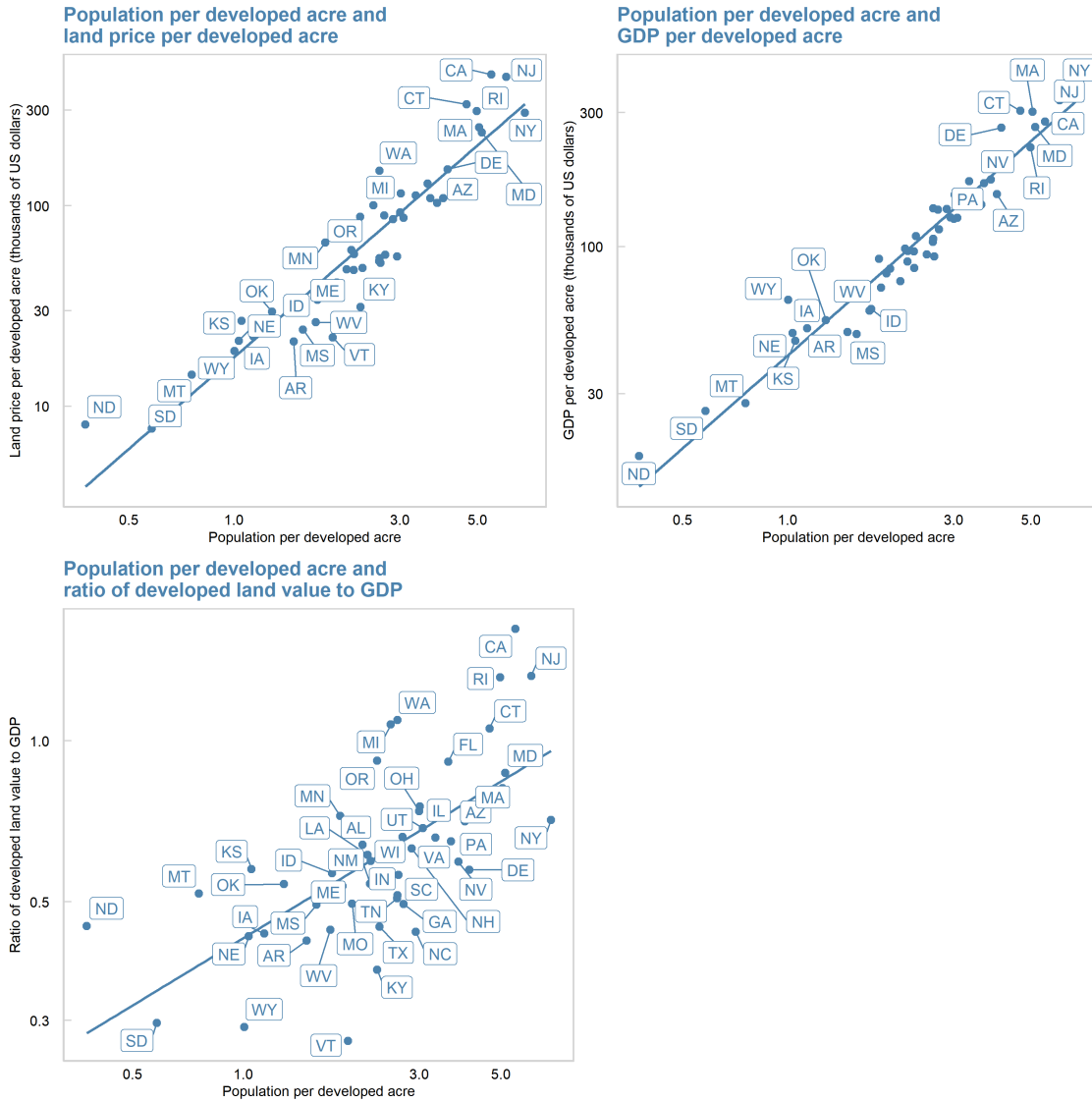
There is a strong relationship between the population per developed acre and the developed land price (Figure 5.1, top left panel). Among US states, for every 10 percent increase in population density, land prices increase by 51 percent. In California, where 5.5 persons live per developed acre, the land price per developed acre is 450 thousand dollars. In South Dakota, where 0.6 persons live per developed acre, the land price per developed acre is only 8 thousand dollars.

More densely populated area also produce more GDP, but the difference is less pronounced than the difference in land values. Among US states, a 10 percent higher population per developed acre is associated with an 11 percent higher GDP per acre (Figure 5.1, top right panel).

As a result, the ratio of the value of developed land increases as population density increases (Figure 5.1, bottom panel). Among US states, a 10 percent higher population per developed acre is associated with a 41 percent higher developed land value to GDP ratio. In California, developed land is worth 160 percent of GDP. In South Dakota 30 percent.

Assuming that the return on developed land is the same across states, it follows that the share of land rents on developed land in GDP is higher in more densely populated states.

Figure 5.1. US States; Population per Developed Area and Land Values



5.2 Population-weighted density and Land Rents: Evidence from US States

The conventional crude population density is not a good measure of the density at which the population lives (Craig (1984)). If we were to divide the Australian population by the total area of Australia, we would conclude that population density is very low and that land rents therefore should be low. However, the population in Australia is very concentrated. Only 0.29 percent of Australia consists of urban area, and 61 percent of the population lives in just five cities. Similarly, in the US, most of the population lives on the east and west coast.

A better measure of the density at which the population lives is population-weighted density. Population-weighted density is the mean of the densities of subareas of a larger area weighted by the populations of those subareas (Ottensmann (2018)).¹³

In the US, there is a strong link between weighted population density and the developed land price (Figure 5.2, left panel). In California, where the weighted population density is 8,213 per square mile, the land price per developed acre is 450 thousand dollars. In South Dakota, where the weighted population density is 1,045 per square mile, the land price per developed acre is only 8 thousand dollars.

As a result, the ratio of the value of developed land increases as weighted population density increases (Figure 5.2, bottom panel). Assuming that the return on developed land is the same across states, it follows that the share of land rents on developed land in GDP are higher in more densely populated states.

¹³ Suppose a country has two areas, 1 and 2. Area 1 has an area of 1 and a population of 99; area 2 has an area of 99 and a population of 1. The density of area 1 is thus 99; and the density of area 2 is $\frac{1}{99}$. The population density of the entire country is $\frac{99+1}{1+99} = 1$. The weighted population density is $\frac{99}{100} \cdot 99 + \frac{1}{100} \cdot \frac{1}{99} = 98.01$.

Figure 5.2. US States: Weighted Population Density and Land Values



5.3 Land rents and population weighted density in OECD Countries

We will now establish the link between population weighted density and land rents for the OECD countries for which the OECD has data on the value of land (see section 4.2).¹⁴

Figure 5.3, top panel, shows that in countries with higher weighted population density, the ratio of land values to GDP is higher. In Finland, where the weighted population density is 948 per square kilometer, the value of land is equal to 87 percent of GDP. In Korea, where the weighted population density is 9,134 per square kilometer, the value of land is equal to 433 percent of GDP.

Figure 5.4, bottom panel shows that in countries with higher weighted population density, the ratio of land rents to GDP is higher. In Finland, where the weighted population density is 948 per square kilometer, land rents are equal to 8.2 percent of GDP. In Korea, where the weighted population density is 9,134 per square kilometer, land rents are equal to 24.2 percent of GDP.

5.4 Deriving a lower bound for Hong Kong SAR and Singapore

We do not have data on land rents or the value of land for Hong Kong SAR and Singapore. We will derive a lower bound for land rents, based on the share of land rents in less densely populated economies.

The weighted population density in Korea (where land rents are 24.2 percent of GDP) is 9,134 per square kilometer. In Singapore, the weighted population density is 23,239 and in Hong Kong SAR 46,807

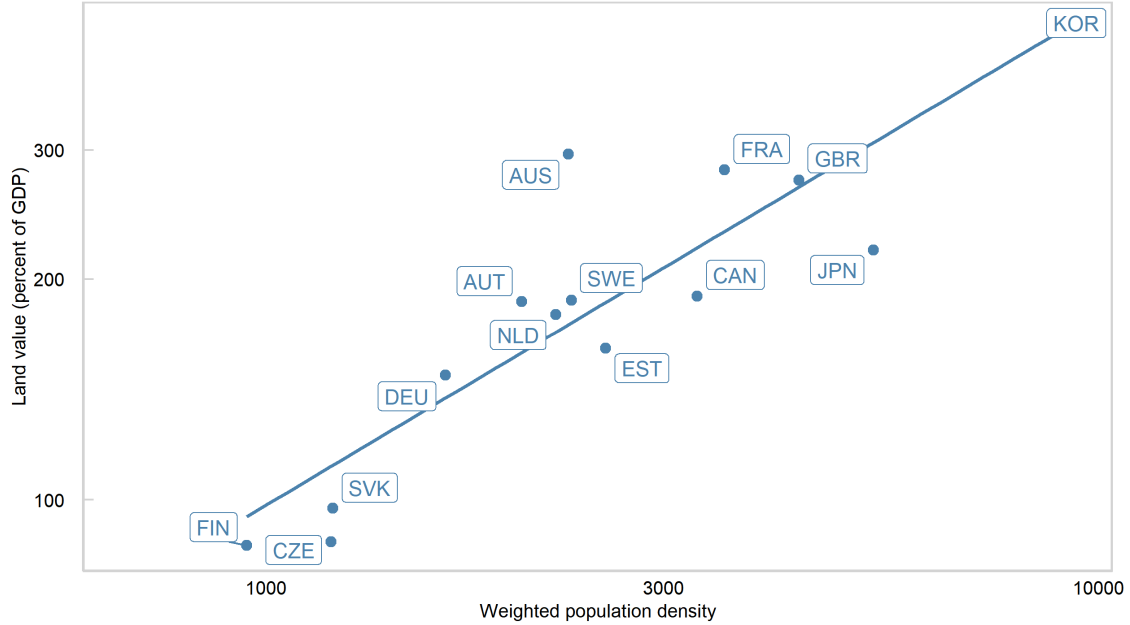
It would seem reasonable therefore that land rents in Singapore and Hong Kong SAR are at least 25 percent of GDP.

¹⁴The OECD has only data on the value of *all* land—not broken down by category.

Figure 5.3. OECD Countries: Population Density and Land Rents

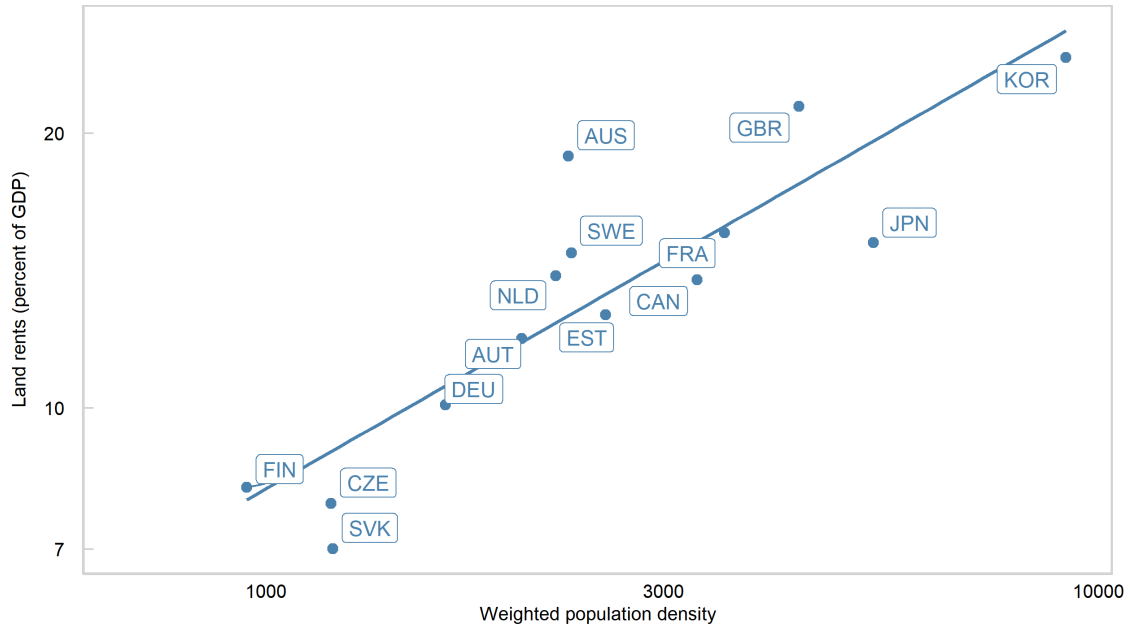
Weighted population density and Land value

(Percent of GDP)



Weighted population density and land rents

(Percent of GDP)

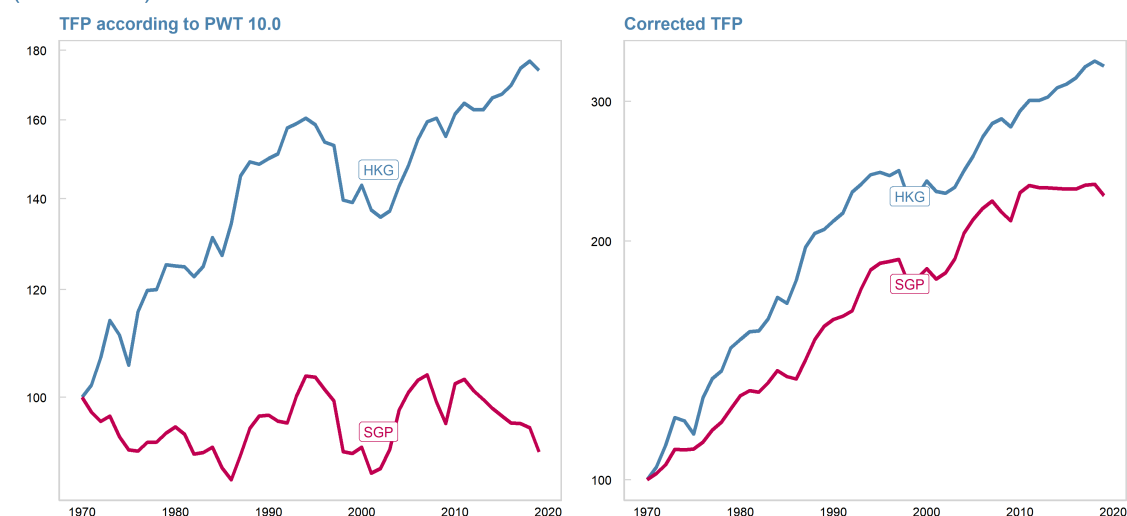


6 Revisiting low TFP growth

6.1 Re-estimating TFP for Hong Kong SAR and Singapore

We next recalculate TFP growth in Hong Kong SAR and Singapore, assuming that the share of land rents in GDP is 25 percent. The results are in Figure 6.1. They show that:

**Figure 6.1. Singapore and Hong Kong SAR:
TFP in PWT 10 and Corrected TFP
(1970=100)**



Source: Penn World Tables 10, IMF Staff Calculations.

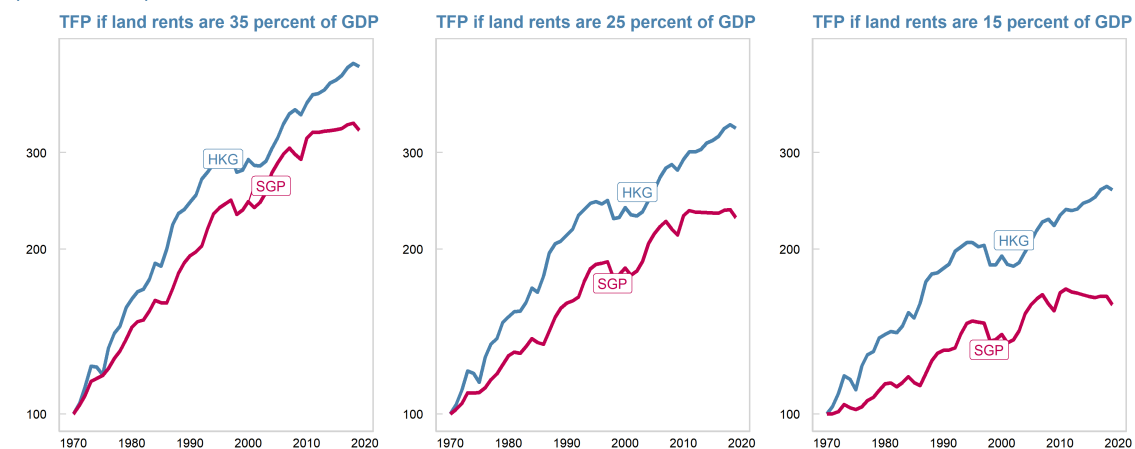
- TFP growth in Singapore has not been negative. TFP more than doubled between 1970 and 2019.
- TFP growth in Hong Kong SAR was also underestimated, but by less than Singapore.¹⁵
- In the original estimates, there is a very large difference between TFP growth in Hong Kong SAR and Singapore. But in the corrected estimates, the difference is much more modest.

¹⁵It should be recognized that weighted population density in Hong Kong SAR (46,807) is significantly higher than in Singapore (23,239), and that land rents in Hong Kong SAR are therefore likely to be higher as well. According to the linear relationship in Figure 5.3, the share of land rents to GDP should be 61 percent in Hong Kong SAR and 42 percent in Singapore. For Hong Kong SAR, where the capital income share is about 48 percent of GDP, this number is obviously too high. For Singapore where the capital income is 57 percent of GDP, it would imply that about 70 percent of capital income goes to land rents.

6.2 Sensitivity Analysis

We also ran a sensitivity analysis using two different values for the land rents to GDP ratio: 15 percent and 35 percent. The results are in Figure 5.3. Even with a land rent of 15 percent of GDP, TFP growth in Singapore has been quite substantial.

**Figure 6.2. Singapore and Hong Kong SAR:
Sensitivity of TFP to Share of Land Rents**
(1970=100)



Source: Penn World Tables 10, IMF Staff Calculations.

6.3 Other economies

We also recalculated TFP for Malaysia, Panama and Türkiye—rapidly growing other economies where TFP has been declining according to Penn World Tables. We derived the share of land rents in GDP from the weighted population density, using the relationship of Figure 5.3. The resulting land rents to GDP ratios are in Figure 6.3. The corrected TFP levels are in Figure 6.4. When corrected for the share of capital income going to land rents, all countries had significant positive TFP growth.

Figure 6.3. Estimates of Land rents to GDP for Malaysia, Panama and Türkiye

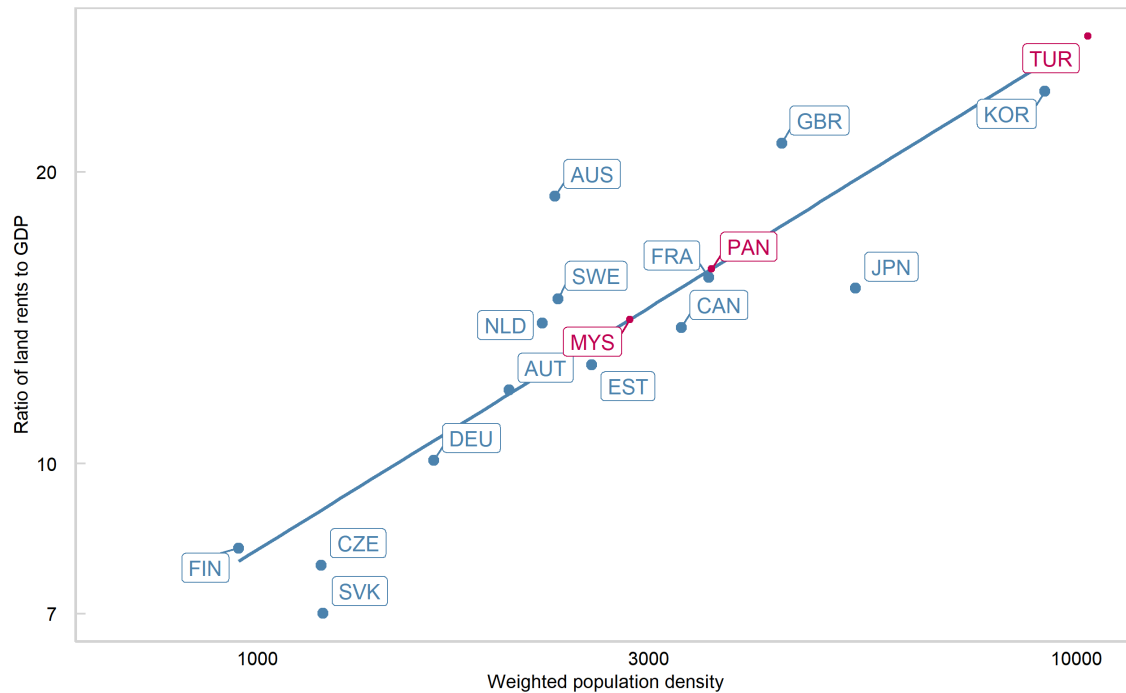
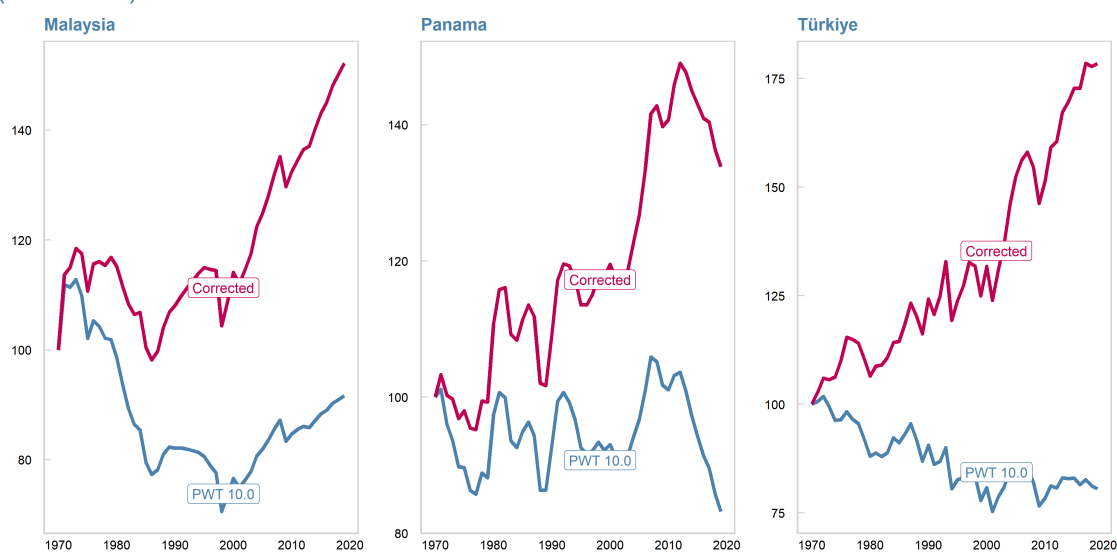


Figure 6.4. TFP Levels: Penn World Tables and Recalculated
(1970=100)



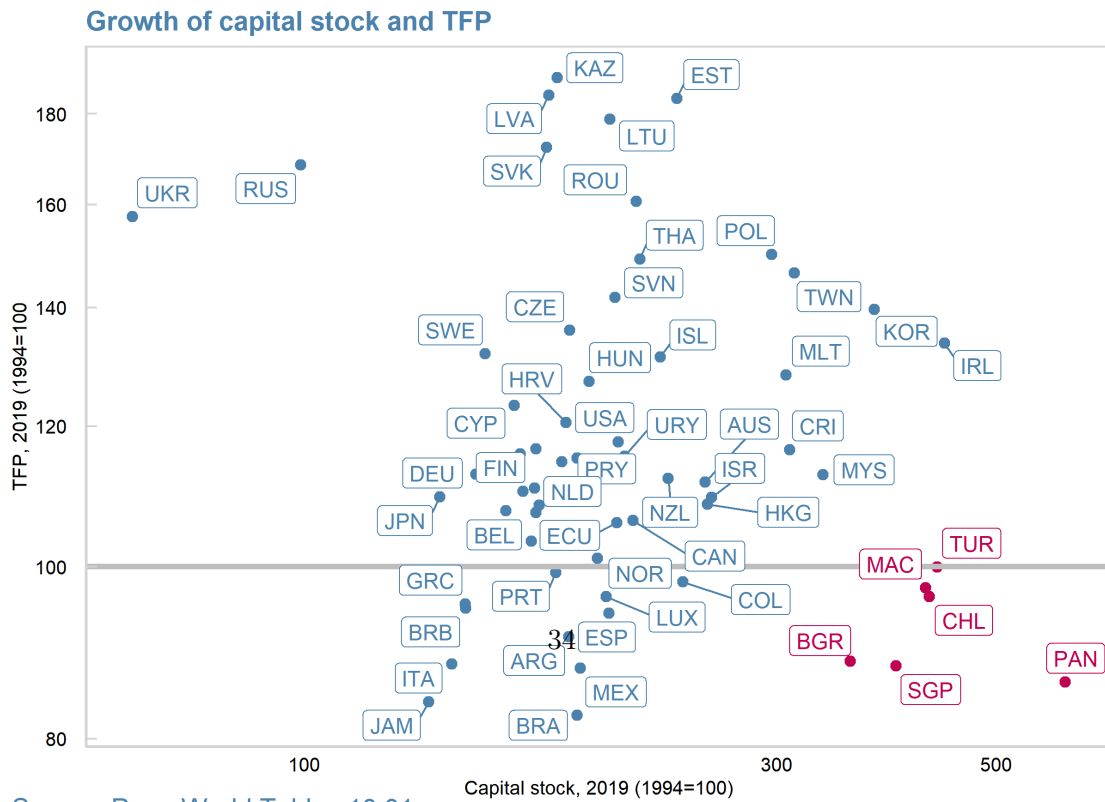
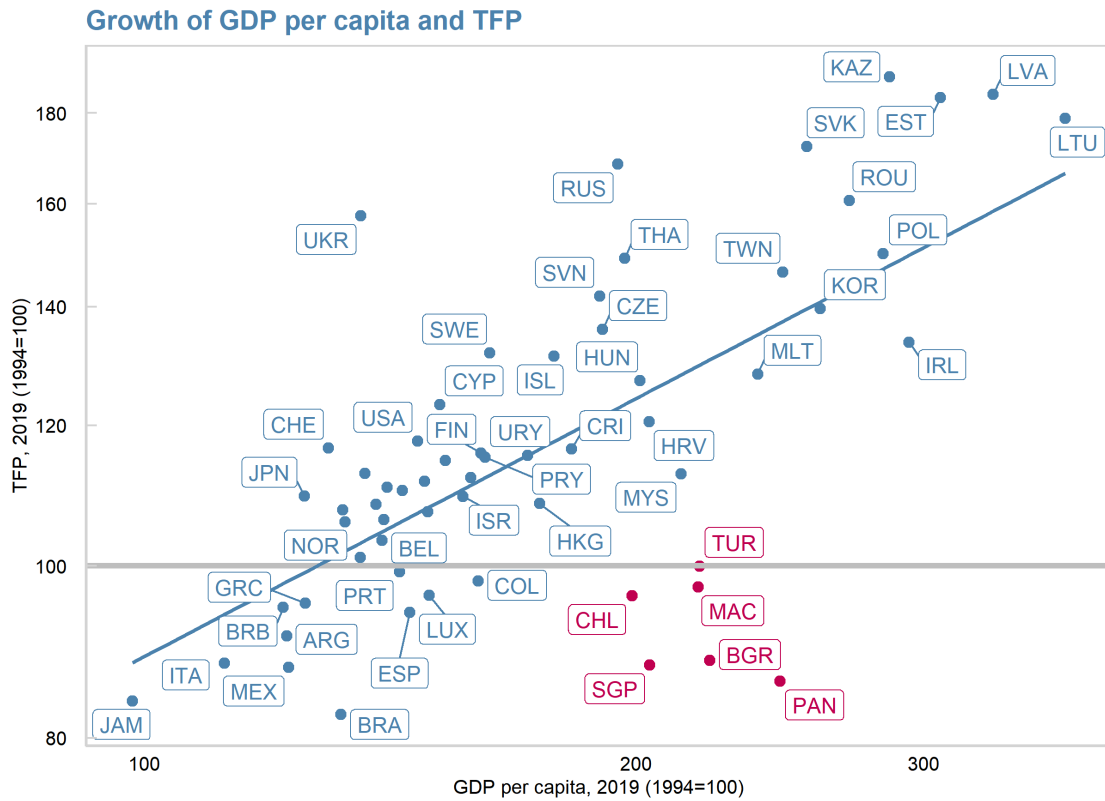
Source: Penn World Tables 10, IMF Staff Calculations.

7 Further evidence that TFP growth is underestimated in economies with rapidly growing capital stocks: 1994-2019

As further evidence that TFP growth is underestimated in economies with rapidly growing capital stocks, we look at the 1994-2019 period. For this period, a much larger sample of economies is available than for the 1970-2019 period. We constrain our sample to economies with a GDP per capita in 1994 of at least 7,500 US dollars.

- The top panel of Figure 7.1 shows that there are seven economies which combined very rapid GDP per capita growth with negative TFP growth: Chile, Singapore, Türkiye, Macao, Bulgaria and Panama.
- The bottom panel of Figure 7.1 shows that these are also economies where the capital stock grew very rapidly.
- The rapid growth of the capital stock is likely to have led to a substantial underestimation of TFP growth. In Panama, for example, the capital stock grew by 7.3 percent annually between 1994 and 2019. Assuming a share of land rents in GDP of 18 percent, the contribution of the capital stock was overestimated by 1.3 percentage point year. This means that the TFP did not *decline* by 0.6 percent annually, but *increased* by 0.7 percent.

Figure 7.1. GDP per capita and TFP Growth according to PWT 10.0, 1994-2019



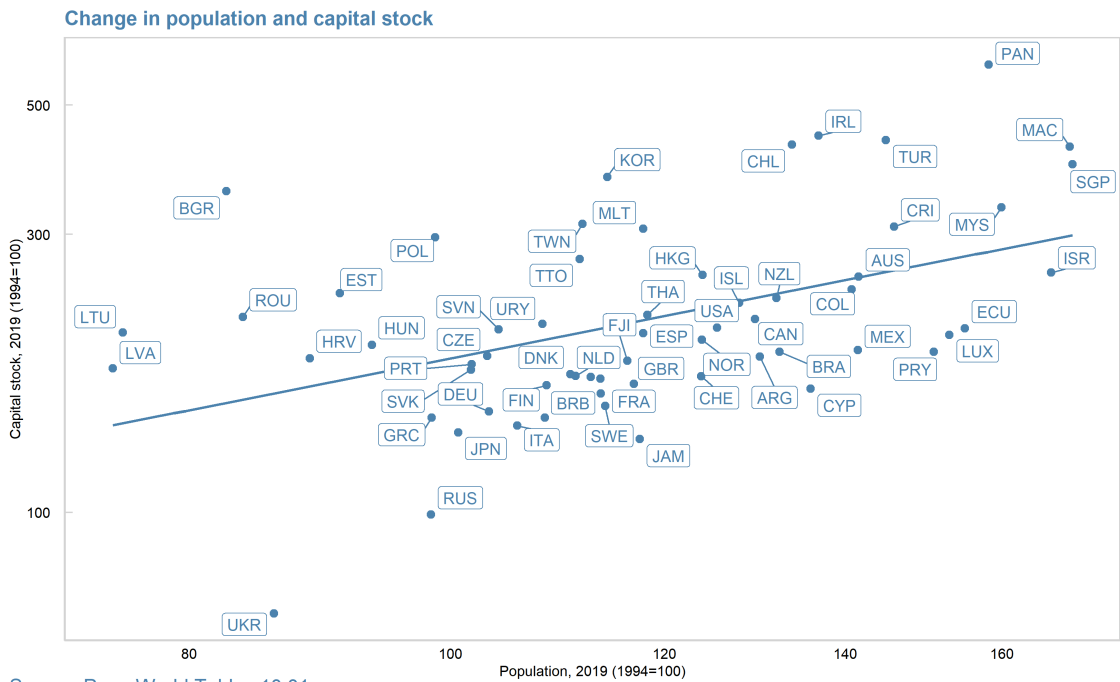
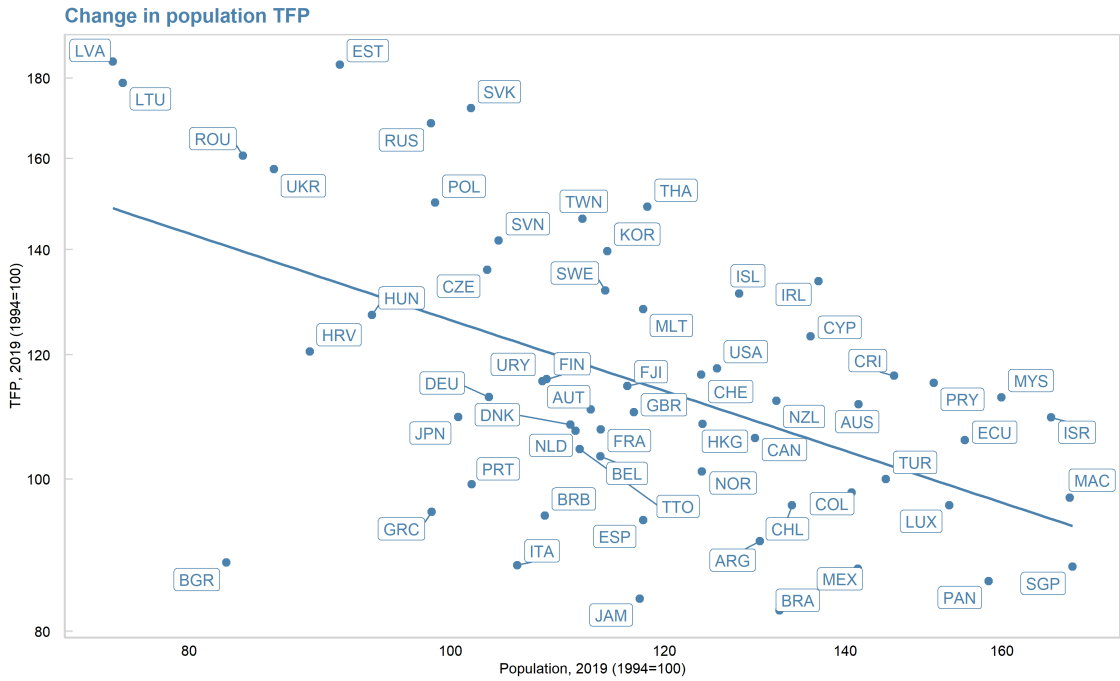
Source: Penn World Tables 10.01.

8 Population growth and TFP

If there are declining returns to scale, we would expect measured TFP growth (as shown in Penn World Tables) to be slower in economies with rapid population growth. To see this, assume we have two economies that are identical in terms of technology and TFP growth. One economy has rapid population growth, the other slow population growth. In the economy with rapid population growth, the capital stock will grow faster. As a result, the overestimation of the growth of the capital stock will be higher, and "measured" TFP growth will be lower in the economy with rapid population growth.

The data bear out these expectations. The top panel of Figure 8.1 shows that measured TFP growth is lower in economies with faster population growth. In these economies, the growth of the capital stock is also faster (bottom panel of Figure 8.1).

Figure 8.1. Population Growth and TFP Growth according to PWT 10.0, 1994-2019



Source: Penn World Tables 10.01.

9 Is land constant?

So far we have assumed that developed land or urban land is fixed. This is not completely true. Cities expand, and previously undeveloped land gets used.

Between 1990 and 2015, urban land¹⁶ in Singapore increased by 0.4 percent a year. With a share of land rents in GDP of 0.25, the contribution to growth was 0.1 percent a year. By assuming land was constant, the growth decomposition overestimated TFP growth by 0.1 percent a year. This does not meaningfully affect our TFP estimates.¹⁷

¹⁶The Global Rural-Urban Mapping Project, Version 1 (GRUMPv1) urban extent grid distinguishes urban and rural areas based on a combination of population counts (persons), settlement points, and the presence of Nighttime Lights . Areas are defined as urban where contiguous lighted cells from the Nighttime Lights or approximated urban extents based on buffered settlement points for which the total population is greater than 5,000 persons. This dataset is produced by the Columbia University Center for International Earth Science Information Network (CIESIN) in collaboration with the International Food Policy Research Institute (IFPRI), The World Bank, and Centro Internacional de Agricultura Tropical (CIAT). See <https://data.worldbank.org/indicator/AG.LND.TOTL.UR.K2>.

¹⁷In some other countries, urban land has grown more rapidly. In the United States, urban land grew by 0.8 percent annually between 1990 and 2015. But (assuming a land rent of 15 percent of GDP), the resulting overestimation of TFP growth would be only 0.12 percentage point annually.

10 Conclusion

This paper has proposed an answer to the puzzle why TFP levels have declined in the past half century in a number of very rapidly economies. TFP levels have not declined. Rather, the contribution of the growth of the capital stock to growth has been overestimated and, as a result, TFP growth has been underestimated.

The overestimation of the contribution of the growth of the capital stock occurs in all economies, but it is most significant in economies where land rents are high and the capital stock has grown very rapidly—which includes economies like Singapore.

Indeed, the results in this paper suggest that TFP levels in Singapore and other rapidly growing countries have not declined—they have grown rapidly. What these economies have suffered from is not declining TFP, but the presence of a fixed production factor (land). If there are three production factors (capital, labor and land) and one of them is fixed (land), a doubling of the other two will lead to less than a doubling of output. In other words, the returns to scale from *an increase in capital and labor* are not constant (as is assumed by standard growth decompositions); they are declining.

To more precisely estimate TFP, time series of the share of land rents in GDP are needed. We leave it for future research to come up with these series.

A production function with declining returns to scale in capital and labor may have some attractive properties. Once the wage rate and the cost of capital is known, the profit maximizing levels of capital and labor can be determined. In standard production functions with constant returns to scale, the wage rate and cost of capital only determine the capital-labor *ratio*. We leave it for future research to further delve into the implications of declining returns to scale in capital and labor.

Bibliography

- Albouy, David, Gabriel Ehrlich, and Minchul Shin (2018), “Metropolitan Land Values.” *The Review of Economics and Statistics*, 100, 454–466, URL <https://direct.mit.edu/rest/article/100/3/454-466/58476>.
- Bakker, Bas B, Manuk Ghazanchyan, Alex Ho, and Vibha Nanda (2020), *The Lack of Convergence of Latin-America Compared with CESEE Is Low Investment to Blame?* International Monetary Fund, Washington, D.C., URL <http://elibrary.imf.org/view/IMF001/29126-9781513547886/29126-9781513547886/29126-9781513547886.xml>.
OCLC: 1184007262.
- Barr, Jason, Fred H. Smith, and Sayali J. Kulkarni (2018), “What’s Manhattan worth? A land values index from 1950 to 2014.” *Regional Science and Urban Economics*, 70, 1–19, URL <https://linkinghub.elsevier.com/retrieve/pii/S0166046217300820>.
- Brandt, Nicola, Paul Schreyer, and Vera Zipperer (2017), “Productivity Measurement with Natural Capital.” *Review of Income and Wealth*, 63, S7–S21, URL <https://onlinelibrary.wiley.com/doi/10.1111/roiw.12247>.
- Crafts, Nicholas and Pieter Woltjer (2021), “Growth Accounting in Economic History: Findings, Lessons and New Directions.” *Journal of Economic Surveys*, 35, 670–696, URL <https://onlinelibrary.wiley.com/doi/10.1111/joes.12348>.
- Craig, John (1984), “Averaging population density.” *Demography*, 21, 405–412, URL <https://read.dukeupress.edu/demography/article/21/3/405/171512/Averaging-population-density>.
- Durantón, Gilles and Diego Puga (2020), “The Economics of Urban Density.” *Journal of Economic Perspectives*, 34, 3–26, URL <https://pubs.aeaweb.org/doi/10.1257/jep.34.3.3>.
- Edwards, Robin, Maksym Bondarenko, Andrew Tatem, and Alessandro Sorichetta (2021), “Unconstrained national Population Weighted Density in 2000, 2005, 2010, 2015 and 2020 (1km resolution).” URL <https://www.worldpop.org/doi/10.5258/SOTON/WP00702>.
- Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer (2015), “The Next Generation of the Penn World Table.” *American Economic Review*, 105, 3150–3182, URL <https://pubs.aeaweb.org/doi/10.1257/aer.20130954>.
- Felipe, Jesus (1999), “Total factor productivity growth in East Asia: A critical survey.” *Journal of Development Studies*, 35, 1–41, URL <http://www.tandfonline.com/doi/abs/10.1080/00220389908422579>.

- Ganong, Peter and Daniel Shoag (2017), “Why has regional income convergence in the U.S. declined?” *Journal of Urban Economics*, 102, 76–90, URL <https://linkinghub.elsevier.com/retrieve/pii/S0094119017300591>.
- Glaeser, Edward and Joseph Gyourko (2018), “The Economic Implications of Housing Supply.” *Journal of Economic Perspectives*, 32, 3–30, URL <https://pubs.aeaweb.org/doi/10.1257/jep.32.1.3>.
- Hansen, Gary D. and Edward C. Prescott (2002), “Malthus to Solow.” *The American Economic Review*, 92, 1205–1217, URL <http://www.jstor.org/stable/3083308>. Publisher: American Economic Association.
- Jones, C.I. (2016), “The Facts of Economic Growth.” In *Handbook of Macroeconomics*, volume 2, 3–69, Elsevier, URL <https://linkinghub.elsevier.com/retrieve/pii/S1574004816000033>.
- Knoll, Katharina, Moritz Schularick, and Thomas Steger (2017), “No Price Like Home: Global House Prices, 1870–2012.” *American Economic Review*, 107, 331–353, URL <https://pubs.aeaweb.org/doi/10.1257/aer.20150501>.
- Krugman, Paul (1994), “The Myth of Asia’s Miracle.” *Foreign Affairs*, 73, 62–78, URL <http://www.jstor.org/stable/20046929>. Publisher: Council on Foreign Relations.
- Larson, William (2015), “New Estimates of Value of Land of the United States.” *Bureau of Economic Analysis*, 30, URL <https://www.bea.gov/system/files/papers/WP2015-3.pdf>.
- Ottensmann, John R (2018), “On Population-Weighted Density.” URL <http://rgdoi.net/10.13140/RG.2.2.11789.44002>. Publisher: Unpublished.
- Piketty, Thomas and Gabriel Zucman (2014), “Capital is Back: Wealth-Income Ratios in Rich Countries 1700–2010 *.” *The Quarterly Journal of Economics*, 129, 1255–1310, URL <https://academic.oup.com/qje/article/129/3/1255/1818714>.
- Putland, Gavin R. (2018), *Trickle-Up Economics. Assessing the impact of privatized land rent on economic growth*. Prosper Australia Research Institute, URL <https://www.prosper.org.au/wp-content/uploads/2018/04/TrickleUp22.pdf>.
- Rognlie, Matthew (2015), “Deciphering the Fall and Rise in the Net Capital Share: Accumulation or Scarcity?” *Brookings Papers on Economic Activity*, 1–54, URL <http://www.jstor.org/stable/43684097>. Publisher: Brookings Institution Press.
- Young, Alwyn (1992), “A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore.” *NBER Macroeconomics Annual*, 7, 13–54, URL <https://www.journals.uchicago.edu/doi/10.1086/654183>.

A Data Sources

Table A1 shows the sources of the data used in this paper. For Pophub World data also see [Edwards et al. \(2021\)](#). For Penn World Tables, also see [Feenstra et al. \(2015\)](#).

Table A.1: Data Sources

Variable	Source	Link	Code
Land values	OECD	9B. Balance sheets for non-financial assets (oecd.org)	N11
Value capital stock	OECD	9B. Balance sheets for non-financial assets (oecd.org)	N211
Nominal GDP	OECD	1. Gross domestic product (GDP) (oecd.org)	B1_GA
Weighted population density OECD countries	Worldpop Hub	WorldPop :: Population Weighted Density	PWD_A
Capital income share	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	1-labsh
Depreciation rate	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	delta
TFP	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	rtfpna
Labor	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	emp
Capital stock	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	rkna
Real GDP	Penn World Tables 10.01	https://doi.org/10.34894/QT5BCC	rgdpna
GDP by US state	Bureau of Economic Analysis	BEA Interactive Data Application	
Weighted population density		https://skyscraperpage.com/forum/showthread.php?t=211827	
Urban land area	World bank	https://data.worldbank.org/indicator/AG.LND.TOTL.UR.K2	



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