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Growth accounting and endogenous technical change

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HIGHLIGHTS

- This study explores growth accounting under endogenous technological progress.
- The Solow approach is inconsistent with knowledge-driven technological progress.
- The Mankiw-Romer-Weil approach is inconsistent with lab-equipment technological progress.
- We also examine the importance of capital accumulation on growth in China.

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ABSTRACT

This study explores growth accounting under endogenous technological progress. It is well known that the Solow approach overstates (understates) the contribution of capital accumulation (technological progress) to economic growth and that the Mankiw-Romer-Weil approach addresses this issue. However, we find that the Mankiw-Romer-Weil approach is inconsistent (consistent) with the lab-equipment (knowledge-driven) specification for technological progress. We also examine the importance of capital accumulation on growth in China under the two approaches.

1. Introduction

The traditional approach to growth accounting, introduced by Solow (1957), decomposes economic growth into the growth rates of factor inputs and technological progress measured by total factor productivity (TFP); see Barro (1999) for a review. Interpreting these accounting relationships as causal relationships however requires an assumption that the growth rates of factor inputs, e.g., physical capital, are independent from technological progress. An important result from the seminal Solow growth model is that long-run growth in output and capital is driven by technological progress. Therefore, interpreting the accounting relationships from the Solow approach as causal relationships may overstate (understate) the contribution of capital accumulation (technological progress) to growth; see e.g., Aghion and Howitt (2007) for this critique. An alternative approach to growth accounting, originated from Mankiw et al. (1992),[1] addresses this issue by essentially scaling up the importance of technological progress and measuring the contribution of capital by the growth rate of the capital–output ratio, rather than the growth rate of capital.

This study examines the validity of these two approaches to growth accounting under endogenous technical change.[2] We consider two common specifications for technological progress: the *knowledge-driven* and *lab-equipment* specifications. As Hsieh and Klenow (2010) write, "in contrast to the well-understood endogeneity of physical capital in the neoclassical growth model,

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[1] See also Klenow and Rodríguez-Clare (1997), Hall and Jones (1999) and Hayashi and Prescott (2002).

[2] See also Barro (1999), Aghion and Howitt (2007) and Hsieh and Klenow (2010).

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the determinants of [...] TFP are much less well understood". We find that the Mankiw–Romer–Weil approach is consistent with the knowledge-driven specification that features labor as input in innovation. Under this knowledge-driven specification, technological progress does not require physical capital, so the Mankiw–Romer–Weil approach that scales down (up) the contribution of capital accumulation (technological progress) is valid. However, under the lab-equipment specification that features final goods as input in innovation, the Mankiw–Romer–Weil approach understates the contribution of capital accumulation to growth because capital accumulation contributes to technological progress. Intuitively, because innovation indirectly uses research capital, growth is increasing in capital investment. Finally, we also examine the importance of capital accumulation on growth in China under the two approaches and discuss their different implications in the conclusion.

2. Review of growth accounting

This section briefly reviews the two approaches to growth accounting. Let's start with the following aggregate production function:

$$Y = K^{\alpha}(AL)^{1-\alpha}, \tag{1}$$

where Y denotes output, A denotes technology, K denotes physical capital, and L denotes effective labor, which includes human capital and raw labor. The parameter $\alpha \in (0, 1)$ determines capital intensity in production. In the following subsections, we present the Solow and Mankiw–Romer–Weil approaches and show their different implications on the contribution of capital to growth.

2.1. The Solow approach

We take the log of (1) and differentiate it with respect to time to obtain

$$\frac{\dot{Y}}{Y} = (1-\alpha)\frac{\dot{A}}{A} + \alpha\frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L}, \tag{2}$$

where $\dot{x}/x$ denotes the growth rate of variable $x \in \{Y, A, K, L\}$. In other words, (2) decomposes the growth rate of output into the growth rates of technology, physical capital and effective labor. Given that our focus is on the relative importance of technological progress and capital accumulation, we consider a constant effective labor L for simplicity.[3] Under the Solow approach, the share of growth that capital is responsible for is measured by $\alpha(\dot{K}/K)/(\dot{Y}/Y)$. On the balanced growth path, the capital–output ratio is constant, which implies that capital is responsible for the share α of long-run growth in output.

As an illustration, we consider China's data to explore the importance of capital accumulation on growth in China. From Brandt et al. (2008), the average value of capital share in China is about 0.5.[4] From Zhu (2012), the average growth rates of output and physical capital have been roughly the same since 1978.[5] Therefore, we consider the following stylized facts for China: $\alpha = 1/2$, and a constant K/Y since the late 1970's. Under the Solow approach to growth accounting, one would conclude that capital accumulation $\dot{K}/K$ has been responsible for about half of the growth in China. To see this, the contribution of capital to growth in China under the Solow approach is

$$\text{Solow approach: } \frac{\alpha\dot{K}/K}{\dot{Y}/Y} \approx \alpha \approx \frac{1}{2}.$$

However, this Solow approach may overstate (understate) the contribution of capital accumulation (technological progress). The reason is that capital accumulation is partly driven by technological progress. As the seminal Solow growth model shows, long-run growth in output and capital is driven by technological progress. In the next subsection, we consider an alternative approach to growth accounting that addresses this issue.

2.2. The Mankiw–Romer–Weil approach

Mankiw et al. (1992) consider an alternative approach to growth accounting. In essence, it involves dividing both sides of (1) by Y^{α} to obtain

$$Y^{1-\alpha} = A^{1-\alpha}(K/Y)^{\alpha}L^{1-\alpha}. \tag{3}$$

Then, taking the log of (3) and differentiating it with respect to time yield

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\alpha}{1-\alpha}\frac{(\dot{K/Y})}{(K/Y)}, \tag{4}$$

where we have assumed $\dot{L}/L = 0$. An interpretation of (4) is that capital accumulation is driven by technological progress. Therefore, we should scale up the importance of A by a factor of $1/(1-\alpha)$. If capital has made an additional contribution to output growth, then K should have grown at a faster rate than Y in the short run. On the balanced growth path, the capital–output ratio is constant, so that capital does not contribute to long-run growth.

Using the Mankiw–Romer–Weil approach, Zhu (2012) concludes that economic growth in China is mainly driven by growth in technology A because K/Y has been roughly constant since 1978; formally, the contribution of capital to growth in China is

$$\text{Mankiw–Romer–Weil approach: } \frac{\alpha}{1-\alpha}\frac{(\dot{K/Y})}{(K/Y)}\frac{1}{\dot{Y}/Y} \approx 0.$$

Therefore, according to the Mankiw–Romer–Weil approach, capital has made almost zero contribution to growth in China, whereas according to the Solow approach, capital has contributed to as much as half the growth in China. Given the very different implications, we next examine these two approaches under endogenous technological progress.

3. Growth accounting under endogenous technical change

The previous section reviews that the two approaches to growth accounting have different implications on the contribution of capital to growth. The reason is that the Solow approach does not consider the underlying determinant that drives capital accumulation, whereas the Mankiw–Romer–Weil approach assumes that capital accumulation is driven by technological progress but not vice versa. In reality, technological progress is an endogenous process. In this section, we consider two common specifications for technological progress and explore the validity of the Solow and Mankiw–Romer–Weil approaches under each specification.

3 Extending the analysis by allowing for growth in effective labor L would not change our results.

4 Given innovation under imperfect competition, capital intensity α differs from capital share, which however is a reasonable proxy under a small aggregate markup.

5 The average annual growth rate of the capital–output ratio K/Y in China from 1978 to 2007 was 0.04%.