Computation of Potential GDP Growth: What Growth Rate is Sustainable?

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Abstract

In this manuscript, we discuss applicable models to estimate Potential GDP of a country. We also present potential estimation approaches. Estimation of Potential GDP is very important for policy makers. Generally, Potential GDP refers to the sustainable level of output for an economy. In the long-run, actual and potential GDP should grow at the same rate since grow in excess of potential requires using resources beyond their optimal levels. Thus, potential GDP sets the upper limit for an economy's growth rate and raising the level of potential GDP is the key to increasing the income and standard of living of the population.

1. Introduction

Potential GDP refers to the sustainable level of output for an economy. In the long-run, actual and potential GDP should grow at the same rate since growth in excess of the potential growth rate requires using resources beyond their optimal levels. Thus, potential GDP sets the upper limit for an economy's growth rate and raising the level of potential GDP is the key to increasing the income and standard of living of the population. What is of concern for economists and policymakers is that potential GDP or long-term growth, in both the advanced and developing economies, has slowed in recent years (Exhibit 1).

In Japan, the slowdown began in the 1990s, while US and European growth has been lackluster since the early 2000s. Growth in the developing economies slowed following the 2009 financial crisis, especially in China and Latin America. India's economy, in contrast, has been relatively resilient with average GDP growth declining modestly from 7.5% in 2001-2010 to 6.9% in 2011-2016 and is well above its average growth rate from 1971 to 1990. Recent GDP data for India has shown increased volatility raising questions about its long-term sustainable rate of growth.

The study examines the factors driving long-term growth in an economy.

Exhibit 1
Divergent Real GDP Growth among Countries

	Average Annual Real GDP Growth (%)				
	1971-1980	1981-1990	1991-2000	2001-2010	2011-2016
Advanced Countries	3.2%	3.1%	2.8%	1.6%	1.8%
United States	3.1	2.9	3.4	1.6	2.0
Germany	2.7	2.3	2.3	0.9	1.7
United Kingdom	1.6	2.7	2.8	1.5	2.0
Japan	4.3	4.0	1.3	0.8	1.0
Developing Countries	4.3	4.2	5.4	6.3	5.0
Developing Asia	6.2	6.9	7.4	8.5	6.9
China	10.4	9.1	10.4	10.5	7.7
India	3.9	5.9	5.6	7.5	6.9
Pakistan	4.5	6.0	3.9	4.8	4.0
Middle East	2.9	3.0	4.0	4.9	3.6
Latin America	6.5	1.6	3.3	3.4	1.8
Africa	3.5	2.5	2.4	5.7	4.1

2.0 Determinants of Economic Growth

Since the publication of Solow's seminal work in 1957, growth accounting has been used to analyze the performance of economies. It starts with the Cobb Douglas production function and decomposes the percentage change in output into components attributed to capital, labor and technology. The Cobb Douglas production function assumes constant returns to scale and diminishing marginal productivity for each input.

$$\Delta Y/Y = \Delta A/A + a\Delta K/K + (1-a)\ \Delta L/L \quad (1)$$

The **growth accounting equation (1)** states that the growth rate of output equals the rate of technological change (A) plus times the growth rate of capital plus (1- α) times the growth rate of labor. Since a 1% increase in capital leads to an α% increase in output, α is the elasticity of output with respect to capital. Similarly, (1-α) is the elasticity of output with respect to labor. Thus, in the Cobb-Douglas production function, the exponents α and (1-α) play dual roles as both output elasticities and the shares of income paid to each factor.

Data on output, capital, labor, and the elasticities of capital and labor is available for most developed countries. The rate of technological change is not directly measured and must therefore be estimated. The elasticities of capital and labor in the growth accounting equation are the relative shares of capital (α) and labor (1- α) in national income and are estimated from the national GDP accounts. For India, the relative shares of labor and capital are approximately 0.58 and 0.42, respectively. This means that an increase in the growth rate of labor will have a significantly larger impact on potential GDP growth than will an equivalent increase in the growth rate of capital, holding all else equal. For example, since capital's share in GDP in the Indian economy is 0.42, a 1% increase in the amount of capital available for each worker increases output by only 0.42%. An equivalent increase in the labor input would boost growth by 0.58%. For China, the relative shares of labor and capital are approximately 0.62 and 0.38, respectively

The growth accounting equation has several uses in studying an economy. First, Solow used the equation to estimate the contribution of technological progress to economic growth. Solow estimated the growth in TFP as a residual in the above equation by plugging in $\Delta Y/Y, \Delta K/K, \Delta L/L$, and a, and solving for $\Delta A/A$. This residual measures the amount of output that cannot be explained by growth in capital or labor and can thus be regarded as progress in TFP.

Second, the growth accounting equation is used to empirically measure the sources of growth in an economy. In such studies, the growth accounting equation is used to quantify the contribution of each factor to long-term growth in an economy and answer questions such as: How important are labor and demographic factors to growth? What is the contribution of capital and how important is capital deepening as a source of growth? What is the impact of TFP? The growth accounting equation can be expanded by considering different forms of capital and labor inputs such as human capital and knowledge capital, and by considering the quality of the inputs as well.

Finally, the growth accounting equation is used to measure potential output. Potential GDP is estimated using Equation 4 with trend estimates of labor and capital and a estimated as one minus the labor share of GDP. The difficult task is estimating the growth rate of TFP, which, by definition, is a residual in the growth accounting equation. [1]The standard methodology treats TFP as exogenous and estimates its growth rate using various time series models.

2.1 Labor Productivity Approach

An alternative method of measuring potential GDP is the ***labor productivity growth* accounting equation**. It is very similar to the Solow approach but is simpler and models potential GDP as a function of the labor input and the productivity of the labor input. It avoids the need to estimate the capital input and the difficulty associated with computing total factor productivity. The disadvantage is that it incorporates both capital deepening and TFP progress in the productivity term in a way that can be difficult to analyze and to predict over long periods of time. Under this approach, the equation for estimating potential GDP is

Growth rate in potential GDP = long-term growth rate of labor force
+long-term growth rate in labor productivity (5)

Thus, potential GDP growth is a combination of the long-term growth rate of the labor force and the long-term growth rate of labor productivity. If the labor force is growing at 1% per year, and productivity per worker is rising at 2% per year, then potential GDP is rising at 3% per year.

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[1]TFP is computed as the growth in output less growth in the factor inputs. These would include labor and capital in the traditional Solow two-factor production model. If the production function is expanded by including more inputs, the weighted growth rates of these inputs would also be subtracted from the growth in output.

2.2 Steady State rate of growth

Based on the neoclassical growth model, in the steady state, the growth rate of capital per worker is equal to the growth rate of output per worker. Thus

$\Delta k/k = \Delta y/y = \Delta A/A + a\ \Delta k/k$

from which we get

$\Delta y/y = \Delta k/k = (\Delta A/A)/(1-a)$

Letting θ denote the growth rate of TFP (i.e., ΔA/A), we see that the equilibrium sustainable growth rate of output per capita (= growth rate of capital per worker) is a constant which depends only on the growth rate of TFP (θ) and the elasticity of output with respect to capital (a). Adding back the growth rate of labor (n) gives the sustainable growth rate of output.

$$Growth\ rate\ of\ Output\ per\ capita = \frac{\theta}{1-\alpha}$$

$$Growth\ rate\ of\ Output = \frac{\theta}{1-\alpha} + n \qquad \textbf{(6)}$$

This is the key result of the neoclassical model. It is worth noting that [θ/(1-a)] is the steady state growth rate of labor productivity.

2.3 Capital Deepening versus Technological Progress

The property of diminishing marginal returns plays a significant role in assessing the contribution of capital and technology to economic growth. Exhibit 2 shows the relationship between per capita output and the capital-to-labor ratio. It shows that adding more and more capital to a fixed number of workers increases per capita output but at a decreasing rate. As indicated in Exhibit 2, growth in per capita output comes from two sources: capital deepening and/or from an improvement in technology, often referred to as technological progress.

Capital deepening**,** an increase in the capital-to-labor ratio**,** is reflected in the exhibit by a move along the production function from point A to B. The increase in the capital-to-labor ratio reflects rising investment in the economy. The ratio will increase if the growth rate of capital (net investment) exceeds the growth rate of labor. However, once the capital-to-labor ratio becomes very high, as at point B, further additions to capital have relatively little impact on per capita output (e.g. moving to point D). This occurs because the marginal product of capital declines as more capital is added to the labor input. Once the economy reaches this point, capital deepening will not be a significant source of sustained growth in the economy.

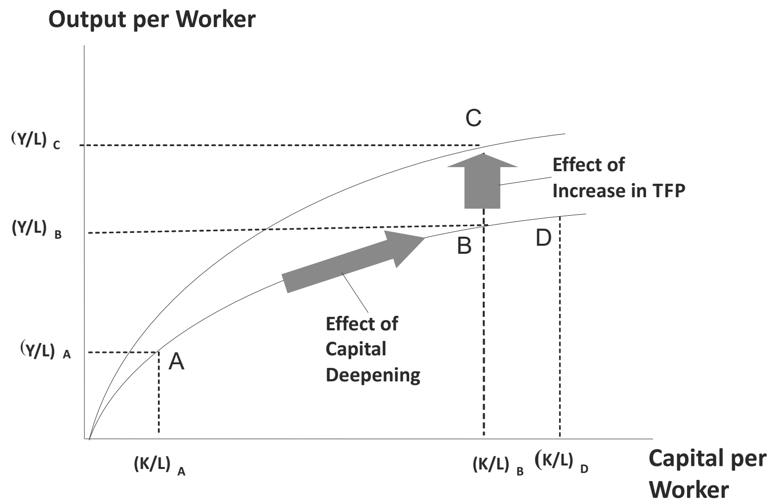
In contrast to moves along a given production function, an improvement in TFP causes a proportional upward shift in the entire production function. As a result, the economy can produce higher output per worker for a given level of capital per worker. This is shown in Exhibit 2 by the move from B to C. Technological progress also increases the marginal product of capital and tends to mitigate the limits imposed on growth by diminishing marginal returns. In summary, sustained growth in per capita output requires progress in TFP.

2.4 Extending the Production Function

As a simplification, the production function in Equation 1 focused on only the labor and capital inputs. A more complete specification of the production function expands the list of inputs to include the following:

- Raw materials: natural resources such as oil, lumber and available land (N)
- Quantity of labor: the number of workers in the country (L)
- Human capital: education and skill level of these workers (H)
- Information, Computer, and Telecommunications (ICT) capital: computer hardware, software and communication equipment (K_{IT})
- Non-ICT capital: transport equipment, metal products and plant machinery other than computer hardware and communications equipment, and non-residential buildings and other structures (K_{NT})
- Public capital: infrastructure owned and provided by the government (K_P)
- Technological knowledge: the production methods used to convert inputs into final products (A) (total factor productivity)

Exhibit 2
Per Capita Production Function
Capital Deepening versus Technological (TFP)



Progress

The expanded production function is expressed mathematically as:

$Y = A\,F(N, L, H, K_{IT}, K_{NT}, K_{P})$

The impact of each of these inputs on economic growth is addressed in the following sections.

2.5 Natural resources

Raw materials, including everything from available land to oil to water, are an essential input to growth. While it seems intuitive that countries with more natural resources will be wealthier, the relation between resource endowment and growth is not so straightforward. Natural resources do account for some of the differences in growth among countries. However, ownership and production of natural resources is not necessary for a country to achieve a high level of income.

2.6 Labor Quantity: Supply

As noted above, economic growth is affected by increases in inputs, mainly labor and capital. Growth in the number of people available for work (quantity of work force) is an important source of economic growth and partially accounts for the superior growth performance of the United States among the advanced economies; in particular, relative to Europe and Japan. Most developing countries such as China, India and Mexico have a large potential labor supply. We can measure the potential size of the labor input as the total number of hours available for work. This, in turn, equals the labor force times the average hours worked per worker. The **labor force** is defined as the percentage of the working age population (ages 16 to 64) that is either employed or available for work but not working (i.e. unemployed). Thus, growth in the labor input depends on four factors:

- **Population growth**

Long-term projections of the labor supply are largely determined by the growth of the working age population. Population growth is determined by fertility rates and mortality rates. The age mix of the population is also important. The percentage of the population over the age of 65 and the percentage below the age of 16 are key considerations. Some of the developed countries, especially in Europe, Japan, and South Korea, are facing a growing demographic burden as non-working elders (over 65) grow as a share of the population. In contrast, growth in many developing countries will receive a demographic boost as the fraction of population below the age of 16 begins to decline. Interestingly, China is like the advanced economies with a growing proportion of the population over age 65.

- **Labor force participation**

In the short-run, the growth rate of the labor force may differ from population growth due to changes in the participation rate. The labor force participation rate is defined as the percentage of the working age population in the labor force. It has trended upward in most countries over the last few decades due to rising participation rates among women. In contrast to population, an increase in the participation rate may raise the growth of per capita GDP. While trends in participation may contribute to or detract from potential growth for substantial periods, one should be cautious in extrapolating that trend indefinitely.

- **Net migration**

Another factor increasing population growth, especially among the developed countries, is immigration. Higher levels of immigration are a possible solution to the slowing labor force growth being experienced by many developed countries.

- **Average Hours Worked**

The contribution of labor to overall output is also affected by changes in the average hours worked per worker. Average hours worked is highly sensitive to the business cycle. However, the long-term trend in average hours worked has been toward a shorter workweek in the advanced countries.

2.7 Labor Quality: Human Capital

In addition to the quantity of labor, the quality of the labor force is an important source of growth for an economy. Human capital is the accumulated knowledge and skill that workers acquire from education, training or life experience. In general, better-educated and skilled workers will be more productive and more adaptable to changes in technology or other shifts in market demand and supply. An economy's human capital is increased through investment in education and on-the-job training. Education may also have a spillover or externality impact. Increasing the educational level of one person raises not only the output of that person but also the output of those around them. The spillover effect operates through the link between education and advances in technology. Education not only improves the quality of the labor force, and thus the stock of human capital, but also encourages growth through innovation. Importantly, increased education obtained both formally and via on-the-job training, could result in a permanent increase in the growth rate of an economy if the more educated workforce results in more innovations and a faster rate of technological progress. Investment in the health of the population is also a major contributor to human capital, especially in the developing countries.

2.8 Capital: ICT and Non-ICT

The physical capital stock increases from year to year if net investment (gross investment less the depreciation of the capital) is positive. Thus, countries with a higher rate of investment should have a growing physical capital stock and a higher rate of GDP growth. [2]Exhibit 2 shows the level of gross non-residential investment as a share of GDP with the investment share in China and India well above those in the advanced economies.

The correlation between economic growth and investment is high. Countries that devote a large share of GDP to investment, such as China and India, have high growth rates. The data shows why the Chinese economy has expanded at such a rapid rate. Investment spending in China on new factories, equipment and infrastructure as a percentage of GDP is the highest in the world. In recent years, China devoted over 40 percent of its GDP to investment spending.

As we discussed in section 2.3, long-term sustainable growth cannot rely on pure capital deepening. How can we reconcile this notion with the strong correlation between investment spending and economic growth across countries? This is because the impact of investment spending on growth depends on the existing physical capital stock. As with the share of GDP devoted to investment, the stock of capital available per worker varies significantly across countries. Heston (2009) found that in 2000, the average U.S. worker had $148,091 worth of capital compared to $6,270 in India. The wide difference in physical capital per worker suggests that the positive impact of investment spending on growth is very significant in developing countries. Indian workers have relatively little access to machinery or equipment, so adding even a little can make a big percentage difference. In developed countries like the US, Japan and Germany, the physical capital stock is so large that positive net investment in any given year has only a small percentage effect on the accumulated capital stock. For the developed countries, it requires a sustained high level of investment over many years to have a meaningful relative impact on the physical capital stock even though the absolute size of the increase in any given year is still larger than in the developing countries.

Also, the composition of investment spending and the stock of physical capital matters for growth and productivity. Insights from studies attempting to obtain a more accurate measure of TFP show that the composition of the physical capital stock is

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[2] *The impact on growth of per capita GDP will be somewhat smaller if the population is growing since a proportion of net investment simply provides the capital needed to maintain the capital-to-labor ratio.*

very important. These studies suggest that capital spending could be separated into two categories. The first is spending on information, computers and telecommunications equipment (ICT investment). Capital spending on these goods is a measure of the impact of the information technology sector on economic growth. One of the key drivers of growth in the developed countries over the last decade has been the IT sector. Growth in the IT sector has been driven by technological innovation that has caused the price of key technologies such as semiconductors, to fall dramatically. The steep decline in the price of high technology capital goods has encouraged investment in IT at the expense of other assets.

The IT sector has grown very rapidly and has made a significant contribution to increasing the rate of economic and productivity growth. The greater use of IT equipment in various industries has resulted in **network externalities**. The effects of the network externalities are largely captured in TF Prather than observed as a distinct, direct effect. The other category of investment, non-ICT capital spending, includes non-residential construction, transport equipment and machinery. High levels of capital spending for this category should eventually result in capital deepening and thus have less impact on potential GDP growth. In contrast, a growing share of ICT investments in the economy, through their externality impacts, may boost the growth rate of potential GDP.

Exhibit 2
Business Investment as a Percentage of GDP

	Investment Percent of GDP			
	1990	2000	2010	2015
Germany	22.8%	21.5%	19.4%	17.3%
Japan	32.5	25.4	23.2	20.2
US	17.4	19.9	18.1	15.8
China	24.9	35.1	44.0	48.2
India	21.8	24.3	34.9	36.8

Source: OECD Statlinks

2.9 Technology

Technology allows an economy to overcome some of the limits imposed by diminishing marginal returns and results in an upward shift in the production function as we noted in Exhibit2. Technological progress makes it possible to produce more and/or higher quality goods and services with the same resources or inputs. It also results in the creation of new goods and services. Technological progress can also be one of the factors improving how efficiently businesses are organized and managed.

Technological change can be embodied in human capital (knowledge, organization, information, and experience base) and/or in new machinery, equipment and software. Therefore, high rates of investment are important, especially investment in ICT goods. Countries can also innovate through expenditures, both public and private, on research and development (R&D). Since it is measured as a residual, TFP estimates are very sensitive to the measurements of the labor and capital inputs

2.10 Public Capital: Infrastructure

Roads, bridges, municipal water, dams and in some countries, electric grids are all examples of public capital. They have few substitutes and are largely complements to the production of private-sector goods and services. Ashauer (1990) found that infrastructure investment is an important source of productivity growth and should be included as an input in the production function.

As with R&D spending, the full impact of government infrastructure investment may extend well beyond the direct benefits of the projects since improvements in the economy's infrastructure generally boost the productivity of private investments.

Future Work:
In the next paper, we will be applying these models and data to compute the potential GDP for China and India. We plan to present that research in the next issue of this Journal.

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