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Economic Letter

Technological Progress Is Key to Improving World Living Standards

by Enrique Martínez-García

Technological progress appears to have shifted around 2001, when the median emerging economy's growth rate accelerated and surpassed that of advanced economies.

A country able to increase the output of final goods and services faster than its population grows can improve its citizens' standard of living. However, the speed with which such change occurs can vary greatly.

Technological progress is the key to a country's long-term increase in its material well-being, the work of Nobel laureate Robert Solow and economist Trevor Swan showed in the 1950s. The contribution of factors of production, such as capital or labor, is only temporary.[1] The Nobel Prize-winning work reshaped our understanding of why countries such as the United States exhibit sustained labor productivity growth, while others such as Niger and Zimbabwe become impoverished. Technological progress also might hold a key to understanding persistent differences in the rates of improvement in the standard of living among countries.

Technological progress appears to have shifted around 2001, when the median emerging economy's growth rate accelerated and surpassed that of advanced economies, data from 120 countries for 1990–2011 indicate. This change was accompanied by a declining rate of capital-driven growth in advanced countries as investment expanded in some emerging nations. These patterns are not uniform across emerging countries, since significant technological gaps persist. The net result: In spite of large gains by many emerging countries, there was no broad-based catch-up in the standard of living around the world.

Improving Living Standards

The standard model based on Solow and Swan's work shows labor productivity growing either through factor accumulation—as an economy adds more units of capital per worker, a process known as *capital deepening*—or through technological progress. Technological progress refers to gains in the efficiency with which the inputs needed to make goods and services are used.

The law of diminishing returns to capital, which can be traced back to classical economists such as David Ricardo (1772–1823), holds that adding successive units of capital while keeping the number of workers unchanged results in ever-narrowing increases in output per worker.

For example, suppose a textile factory holds its employment steady while adding a second sewing machine that increases overall production by 80 percent. A third machine might further boost total output by an additional 60 percent. In short, adding more and more machines (capital) to the factory, using the same number of workers (labor), increases output less and less. Output per worker (labor productivity) increases but at a diminishing rate because

the workers find it increasingly difficult to operate all the machines simultaneously and at full capacity.

Investment becomes less attractive when the law of diminishing returns to capital takes hold and capital per worker rises. The Solow–Swan model tells us that only technological progress, and not capital deepening, can sustain the growth of output per worker over the long run, offsetting diminishing returns on capital.

Measuring Productivity

The Conference Board Total Economy Database allows exploration of productivity growth internationally and what influences it. The database contains annual measures of labor productivity and total factor productivity for most countries from1990 until 2011—the last full year covered in the 2013 database release. The 120 countries analyzed represent 99 percent of global output (gross domestic product, GDP).[2]

Real GDP measures the market value of a country's aggregate output of goods and services, correcting for inflation. Real GDP data are also expressed using purchasing-power-parity exchange rates, which adjust for differences in relative price levels across countries, so that valid cross-country comparisons can be made. Purchasing-power-parity-adjusted real GDP (what we'll call real GDP), however, does not fully account for unpaid work in the home and other informal or nonmarket activities, the incidence of which varies across countries.

Labor productivity, or real GDP per worker, is conventionally used to measure the material well-being of the average citizen in different countries, because output growth alone may be insufficient to raise the living standards of an expanding population. Labor productivity also correlates well with other welfare indicators, such as life expectancy and years of schooling.

Technological progress gauges the efficiency with which the various inputs are combined and used to produce output. Technological progress is measured as the total productivity of inputs, or *total factor productivity* (TFP). It is obtained by dividing output (real GDP) by a combination of the labor and capital inputs used to produce it. The labor and capital inputs are weighted according to their relative importance in production.[3]

Using the definitions of labor productivity and TFP, we can derive an expression showing the relationship between labor productivity growth and TFP growth. For a typical advanced economy,

$$\%\Delta\text{Labor Productivity} = \%\Delta\text{TFP} + \tfrac{1}{3}\times\%\Delta\ \text{Capital-Labor Ratio},$$

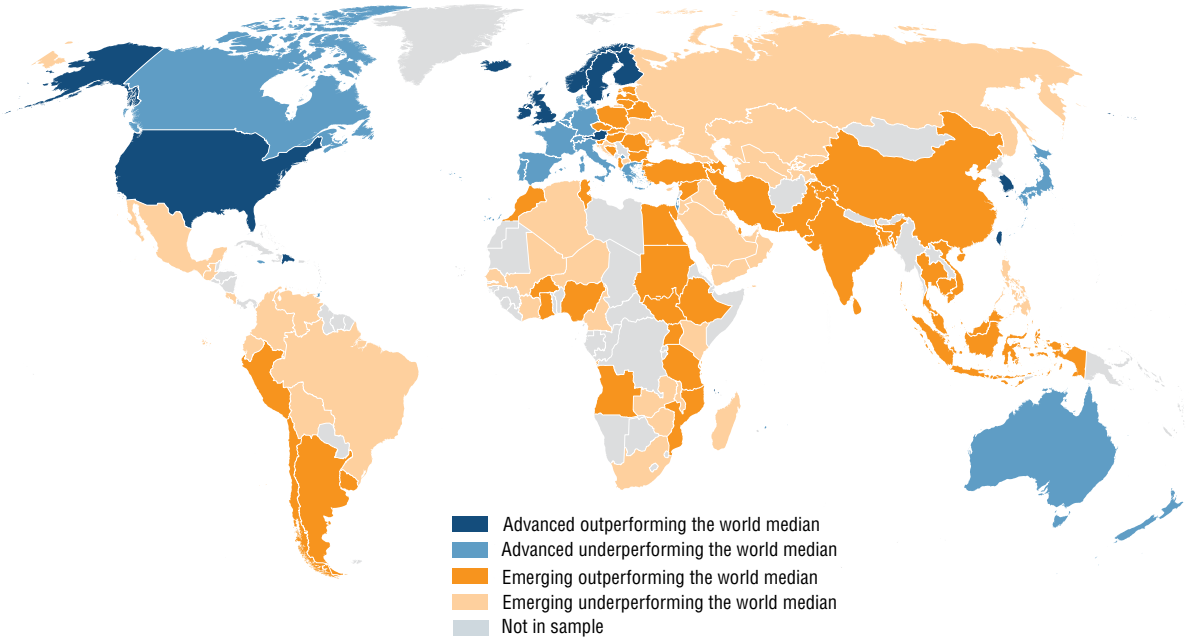
where the %Δ expression denotes percentage changes/growth rates. The fraction (⅓) multiplying the percentage change in the capital-labor ratio is the long-run share of capital income in national income. (The particular value of ⅓ used in this illustration is typical of an advanced country such as the U.S.)

This equation says that labor productivity growth is a combination of TFP growth (technological progress) and the weighted contribution of growth in the capital-labor ratio (capital deepening). For example, if labor productivity grows by 2 percent and the capital-labor ratio grows by 3 percent, the growth in TFP equals 2% – ⅓ × 3% = 1%. In the long run, Solow–Swan show that the contribution of capital deepening will decline, so long-term labor productivity growth and rising living standards can only come from sustained growth in TFP.

Productivity Catch-Up

If technologies are common and economic and social institutions (demographics, saving rates, laws, education and economic policies) are similar, then Solow–Swan anticipates that living standards in

Chart 1 The Geography of Labor Productivity Gains, 1990–2011



SOURCES: 2013 release of the Conference Board Total Economy Database; author's calculations.

emerging countries should eventually catch up with those of advanced economies. As this occurs, labor productivity in emerging countries such as China and India should grow faster than in advanced countries. This occurs through capital deepening—high levels of investment boosting the capital-labor ratio toward what is found in advanced economies.

Labor productivity differences among countries may arise because of varying economic and social institutions. However, as long as countries share the same technology, the Solow–Swan model says these differentials won't persist in the long run because they result from temporary differences in capital deepening.[4]

Crucially, Solow–Swan assumes countries have access to and adopt identical technology to allow achievement of a common TFP growth rate. Historically, this has not been the case. Technological progress appears to vary with the level of economic development—that, in turn, carries implications for long-run labor productivity growth.

To examine the catch-up phase, average labor productivity growth for each country from 1990 to 2011 was examined (*Chart 1*). Countries that outperformed the world median are separated from those that did not. Countries are also distinguished by their level of development, based on the Conference Board's classification of advanced (blue) and emerging (orange) countries.

Labor productivity grew unevenly without broad-based growth convergence. In some emerging countries (dark orange), it grew faster than in the typical country, while in some advanced economies (light blue) it grew slower. Because evidence of broad-based catch-up is lacking, the role of technological progress (TFP growth) in these labor productivity variations merits further attention.

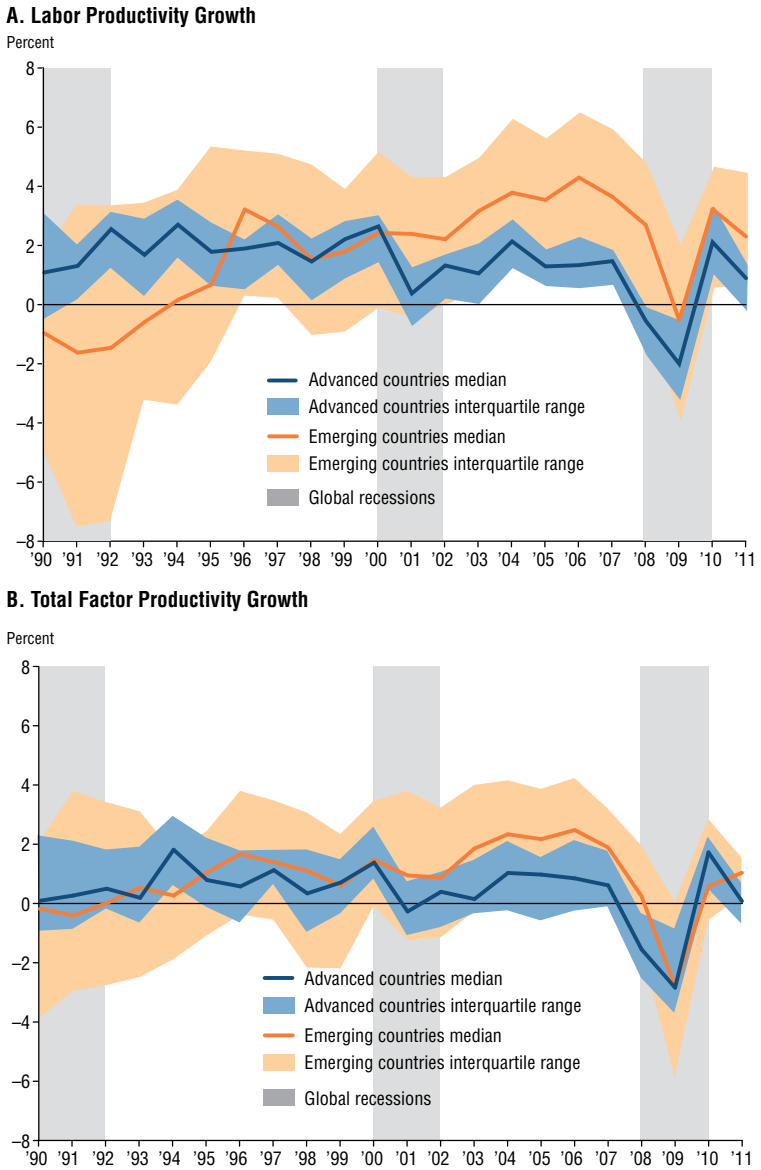
TFP Growth Disparities

Two events were particularly noteworthy in the 1990–2011 period—the collapse of labor productivity in 1990–94 during the transition from centrally planned to market-based economies in Eastern Europe and in the former Soviet Union and, second, the global financial crisis that began in 2007. Nonetheless, labor productivity growth partly reflects the evolution of and the differences in the measured rate of technological progress (TFP growth) and the level of development.[5]

Median labor productivity growth in advanced countries averaged around 1.9 percent annually in 1990–2000, declining to 1.3 percent in 2001–07 and to 0.1 percent in 2008–11 (*Chart 2A*). In turn, average TFP growth hovered around 0.7 percent annually in 1990–2000 (*Chart 2B*). It fell slightly to 0.5 percent in 2001–07, before going negative (contracting) by an average –0.6 percent in 2008–11.[6] Since TFP growth held fairly steady between 1990 and 2007, the decline in median labor productivity growth over this period is mainly due to a lower contribution of capital deepening.

The median emerging country attained 0.7 percent average labor productivity growth in 1990–2000, accelerating to 3.3 percent in 2001–07, surpassing the performance of the median advanced country (*Chart 2A*). However, it fell back to 1.9 percent in 2008–11. TFP growth also sped up from an average of 0.7 percent prior to 2001 to 1.8 percent in 2001–07, before a small contraction, –0.2 percent, in 2008–11 (*Chart 2B*). TFP growth before the global

Chart 2 Growth Slows in Advanced Economies, Picks Up in Emerging Ones Since 2001



NOTE: The plots are based on 30 advanced (blue) and 90 emerging (orange) countries.

SOURCES: 2013 release of the Conference Board Total Economy Database; author's calculations.

financial crisis strongly supported the acceleration in labor productivity for the median emerging economy, which also benefited from rising capital deepening. However, even this strong performance did not shield emerging economies from the impact of the 2008 recession.

The overall pattern of dispersion—how broadly the results are scattered around the median—has changed little, especially since the mid-1990s. The distance between the top and bottom 25 percent of the distribution of emerging countries shows they are three times more scattered around the median for labor productivity growth than advanced countries, and twice as scattered for TFP growth. The dispersion of labor productivity growth was 0.9 times that of TFP growth for advanced countries. For emerging countries, labor productivity growth dispersion was significantly higher at 1.3 times that of TFP growth.

If the robust TFP growth of the typical emerging country during 2001–07 resumes, it will speed up the rate of catch-up with the typical advanced economy. In turn, if the observed dispersion in TFP growth rates is the result of persistent technological barriers that prove difficult to overcome, then living standards in poor countries with low TFP growth rates will not converge to those in advanced economies. In these countries, even if the growth of TFP exceeds the population growth rate and long-run living standards rise, their material well-being will still fall behind relative to that of other developing and advanced countries with faster TFP growth.

Long-Lasting Effects

Technological progress is the only source of *sustained* labor productivity growth, while capital deepening's effects should be temporary, according to Solow–Swan. If technologies are freely transferable across borders and if countries operate along a common technological frontier, their rates of TFP growth should also be comparable and differences in labor productivity growth ought to result primarily from short-term differences in per-worker capital accumulation (capital deepening).

The Conference Board's Total Economy Database shows a significant shift in productivity around 2001, evidenced by the slowdown in TFP growth in the median advanced country and the acceleration in the median emerging country. More generally, persistent differences in observed TFP growth across countries and by level of economic development have contributed to sustained differences in labor productivity growth.

Although TFP growth differences cannot explain all of labor productivity growth differences between 1990 and 2011, the Solow–Swan model suggests that the prospects for continued increases in emerging countries' living standards, and for convergence over the long term, crucially depend on what happens to these TFP growth differentials.

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Notes

The author wishes to thank research assistant Valerie Grossman for her assistance.

[1] Robert Solow and Trevor Swan, working independently, are credited with being the pioneers of "neoclassical" growth theory. See "A Contribution to the Theory of Economic Growth," by Robert Solow, *Quarterly Journal of Economics*, vol. 70, no. 1, 1956, pp. 65–94; "Economic Growth and Capital Accumulation," by Trevor Swan, *Economic Record*, vol. 32, no. 2, 1956, pp. 334–61.

[2] The complete Conference Board Total Economy Database is accessible online at www.conference-board.org/data/economydatabase/. The database incorporates the international total factor productivity measures of "Growth Accounting Within the International Comparison Program," by Dale W. Jorgenson and Khuong Vu, *World Bank International Comparisons Project Bulletin*, vol. 6, no. 1, 2009, pp. 3–19.

[3] By definition, labor productivity = Y/L and, using a Cobb–Douglas aggregate production function, TFP = $Y/(K^{1/3}L^{2/3})$, where Y, K and L denote aggregate output, capital and labor, respectively. Then, $\%\Delta(Y/L) \approx \%\Delta\text{TFP} + \frac{1}{3}\%\Delta(K/L)$, where, K/L is the capital-labor ratio. In this example, the aggregate capital and labor inputs have a weight of ⅓ and ⅔, respectively, typical values for an advanced economy. In the Total Economy Database, those values vary by country in line with the capital income share in national income. Different types of capital are also distinguished.

[4] Living standards (labor productivity) in countries with similar technologies and similar initial capital-labor ratios (similar level of development), but with dissimilar economic institutions, may temporarily grow at different rates because they do not converge to the same long-run *level*. However, the Solow–Swan model still predicts that the rate of labor productivity *growth* should be the same in the long run.

[5] The median is used to measure the typical growth rate for advanced and emerging countries, since the median is more robust than the mean (simple average) to outliers. The interquartile range is used to measure dispersion of the growth rates around their central tendency (median). The closer the clustering of growth rates around the median, the smaller is the interquartile range (the difference between the first and third quartiles).

[6] The negative TFP growth in 2008–11 is the result of the Great Recession and accompanying disruption in financial markets, which disrupted the efficient allocation of resources.

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