Economics; Gender and Place; Gender, Economics of; Gender Ideology: Cross-cultural Aspects; Islam and Gender; Labor Markets, Labor Movements, and Gender in Developing Nations; Land Rights and Gender; Lone Mothers in Nations of the South; Nation-states, Nationalism, and Gender; Poverty and Gender in Developing Nations; Reproductive Rights in Developing Nations; Rural Industrialization in Developing Nations and Gender

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J. L. Pyle

Economic Growth: Measurement

Economic growth is the sustained increase in welfare of an economy—nation, region, city—together with the ongoing changes in that economy's industrial structure; public health, literacy, and demography; and distribution of income. In the long run, as this economic transformation evolves, so do social, political, and cultural norms. Societies change profoundly and multidimensionally, as economic performance improves.

To measure economic growth is to quantify this increase in welfare and to endow with numerical precision these large-scale economic and social changes. Given the breadth of possibilities, it is impossible to undertake this measurement exercise without guidance—what can be pared away, what is essential—from *some* view on the causes of growth (see, e.g., *Economic Growth: Theory*).

This article sets down some key (measurement) facts concerning economic growth, and documents how they have evolved, if at all, over time. In doing this, the article attempts also to illustrate the historical interplay between two lines of research, measurement of and theories about economic growth, each influencing the other.

1. National Income

The panorama above of profound social and economic changes can be simplified dramatically by concentrating on just a single key economic variable, income per capita. (We will return in Sect. 8 below to issues of broader structural transformations).

Income per capita is the per head measure of the total value of all goods and services produced in an economy. Taking national income—measured by either gross national product (GNP) or gross domestic product (GDP), or its regional counterpart—and dividing it by population in the appropriate nation or region gives a convenient first measure on the state of economic well-being. Since total income is the same as total output, this measure might sometimes be usefully replaced by output per worker, or *labor productivity*, where the denominator is then the size of the labor force; or, even output per worker-hour, where the measure then takes into account the time spent working by the labor force.

In some detailed analyses, these alternatives can provide different useful insights into economic performance—different countries, at different times, have had their labor force markedly different from their population, or have had workers and firms make different choices on the length of their workday. However, for the kind of long-horizon, large-scale developments that are typically of interest in economic growth, these differences are inessential. Potentially more important is whether this one measure can suitably proxy for the wide spectrum of different variables of concern in economic growth.

Across countries, per capita income is positively correlated with a broad range of alternative indicators for economic performance—including life expectancy, (the negative of) infant mortality, and adult literacy

(Ray 1998). Thus, economists and many other social scientists have focused, primarily although not exclusively, on growth in per capita income as the preferred first measure of economic growth more generally.

One obvious and crucial shortcoming in this, however, is that income per capita, by definition, says nothing about income inequality. Thus, a potential tension between economic growth and income inequality arises, on top of an analytically-driven hypothesis that rising average incomes might be associated with a widening of the income distribution. We will return to this below in Sect. 7.

2. *Early Work*

Economic growth—significant, sustained increases in welfare—is a relatively recent occurrence (Maddison 1982, Romer 1986). While steady improvements in the lot of humanity over the last 50,000 years had been noted, most of those came tortuously slowly.

The Netherlands began the eighteenth century as the leading economy in the world. But economic growth here was neither sustained nor pronounced. Almost a century afterwards, labor productivity in the Netherlands was 6 percent *lower* than in 1700.

In 1785 the UK had risen to become the new world leading economy. However, despite immense strides in technological progress due to the Industrial Revolution, the UK's labor productivity grew by only 0.5 percent per year from 1785 through 1820. From then through the beginning of the twentieth century, the UK remained the world's economic powerhouse. But in this time UK labor productivity grew by only 1.4 percent per year. Only after the US overtook the UK following the end of the nineteenth century, did the world begin to see the kind of long-run, sustained growth rates that are now typical: US labor productivity grew at 2.3 percent from 1890 through 1979.

3. *Kaldor's Stylized Facts*

The concept of GNP was only developed in the early twentieth century, not for measuring economic growth, but for assessing the state of a national economy. Not long after, Kaldor (1961) observed that the ongoing growth in per capita national income came with several empirical regularities:

(a) Income per capita grows steadily over long stretches of time;

(b) Factor income shares—the fractions of total income accruing to the labor force and to physical capital—show no secular trend;

(c) The ratio of total national income to the aggregate stock of physical capital—the total value of machines, highways, bridges, buildings, physical infrastructure—remains roughly constant.

These observations, typically labeled *Kaldor's stylized facts*, constitute a first important growth measurement that economists sought to understand and to explain.

According to Kaldor's measurements, while economic growth occurs, its benefits divide up in a stable way between rewards to capital and labor—no one factor input, taken as an aggregate, benefited more than another from economic growth. Moreover, since capital's income share can be viewed as the stock of capital multiplied by capital's rate of profit, Kaldor's stylized facts also implied that the profit rate is, in the long run, constant.

4. *Physical Capital Accumulation*

The most successful of the different explanations for Kaldor's growth observations was given in Solow (1956). This immensely influential work produced a widespread conventional wisdom that was simultaneously a profoundly important policy implication. The line of work, however, then led to yet further measurements (Solow 1957) whose later reinterpretation would eventually overturn the original consensus.

Conventional wisdom following Solow (1956) had investment—the accumulation of physical capital—constituting the critical engine of growth. Solow (1956) assumed that total output obeyed a *production function* taking values that increased with the quantities of physical capital and labor employed in the economy. Because no well-behaved function can give at all times a perfect fit relating output, capital, and labor, Solow (1956) hypothesized further an unobservable residual to the production function relation, a residual that he interpreted as exogenously evolving *technical progress* or, more simply, technology. Together with some other reasonable assumptions on the behavior of savings (and therefore investment), labor force growth, and technology's impact on the effectiveness of labor and capital, the model generated outcomes successfully reproducing Kaldor's stylized facts.

The result envisioned had economic growth in two conceptually distinct phases. First, there is the long-run steady state, where the capital-output ratio is constant, and growth in per capita income occurs entirely from technical progress. Second, there is transition to the steady state: along this transition path, physical capital accumulates rapidly due to relatively high investment, driving up the economy's growth rate as the economy itself converges towards its long-run, steady-state growth path. If the second phase were that more relevant to the real world, as many supposed, then accumulating physical capital—building machines, factories, roads, and bridges—constituted the engine of economic growth. Policymakers from Joseph Stalin in the Soviet Union through Lee Kuan Yew in Singapore through leaders in developing country after developing country took this implicit advice to form a cornerstone of their development plans. Encouraging savings—voluntary or forced—became key to economic progress.

In Solow's work, technology bore two different meanings. One, because by assumption it influenced the effectiveness of factor inputs, technology was also labeled *total factor productivity* (TFP)—it improved the productivity of all the factor inputs in an economy. Two, because it emerged as a residual in the production function accounting exercise, it was also viewed, derisively, as a 'measure of our ignorance' (on the part of the modeller). Early research on growth measurement, therefore, took one of its goals to be the minimization of this residual, the idea being that the smaller TFP became, the more successfully one had explained economic growth.

Measurements undertaken by Solow (1957) showed that for the US over the first half of the twentieth century, almost 90 percent of economic growth was due to TFP, with only the remaining one-tenth accounted for by capital accumulation. Taken at face value, this surprising empirical finding sharply contradicted the conventional wisdom and policy advice many had taken to follow from Solow (1956). The hoped-for reconciliation was that by measuring accurately enough the factor inputs—accounting for improvement in quality of capital and labor—this Solow residual would be diminished.

By contrast, more modern work (Sect. 6 below) favors the first interpretation of TFP, that is, that it is correctly viewed as enhancing the productive potential of an economy. Thus, economies with large TFP are considered high-growth, high-performance economies. The research focus has shifted from trying to minimize measured TFP to trying to understand its evolution, typically in terms of its being driven by science and research and development (R&D).

Another important idea arose from this early work on measuring economic growth: convergence, or the tendency for economies not already on the steady state path to approach it. Stated more fully, the Solow (1956) model implies that capitalist economies where capital and labor are rewarded their *marginal products*—the contributions each make, on the margin, to final output—are economies that are stable around their steady states. If an economy is not already at steady state, it has a tendency to go there. Economies relatively poor have a tendency to converge to, or catch up with, those relatively rich.

5. *Rich and Poor*

Difficult as it initially was to compile systematic national income accounts for even the advanced countries, obtaining comprehensive and comparable data across countries was an order of magnitude more complex. This task has only recently been accomplished (Summers and Heston 1991) to a degree where researchers can now meaningfully compare incomes and therefore economic growth across countries.

Because different countries collect and report income data in their individual, respective currencies, cross-country comparisons can be made only after converting national incomes to a common basis. To achieve this, one possibility is to use official current exchange rates to convert national–currency figures into numbers denominated in some single currency. However, such exchange rates are highly volatile, and need not always accurately reflect the purchasing power, or the command over real resources, of the respective national currencies. Importantly, currency exchange rates cannot reflect the prices of nontradeable goods and services. To the extent that nontradeables are relatively lower-priced in poorer countries, conversion using official exchange rates *underestimates* the incomes of relatively poor countries, and thus exacerbates the true gap between rich and poor.

As just one example, consider the following. Even though between 1985 and 1990, Asia was the world's fastest growing region, its share of world GDP—calculated using official exchange rates—fell from 8 percent to 7 percent. The reason for this is that Asian currencies depreciated sharply against the US dollar in this 5-year period. In this instance using exchange-rate adjusted national incomes disguised (and indeed misled on) actual changes in economic performance.

Summers and Heston (1991), in collaboration with the United Nations, constructed rescaled national incomes for a broad cross-section of countries. They used a *purchasing power parity* (PPP) correction to overcome the measurement difficulty just described. Taking into account prices on close to 700 individual items—traded and nontraded—across different countries, and then adjusting for differential spending patterns, the Summers–Heston data provide the most reliable indicators to date, allowing comparison of economic growth across countries. These data now constitute the professional standard, and have been used in over 1,000 empirical studies on economic growth.

Allowing cross-country comparisons has opened up striking new questions in both the measurement and theory of economic growth. Using 1993 official exchange rates, Switzerland was the world's richest economy; Tanzania, the world's poorest. The ratio of per capita incomes between them approached an incredible 400. By contrast, when PPP-corrected and averaged across the last five years of the 1980s to smooth out short-run fluctuations, the ratio between richest and poorest economies (now the US and Chad, respectively) falls to a little over 40. This latter number accords better with less formal evidence and with casual observation on differing costs of living. However, even though PPP correction has reduced the dramatic disparity between rich and poor across the world, the divide obviously remains considerable.

The Summers–Heston data reveal the following: between 1960 and 1989 world per capital income grew by 2.25 percent per year. Averaged over the five years 1960–64, per capita income at the bottom 10th-percentile point (in the cross-section of countries) was 0.22 times the world average, with the 90th-percentile point 2.70 times the world average (Quah 2001). The 90 : 10 ratio was, therefore, 12. Almost three decades later, averaged over 1985–89, per capita income at the bottom 10th-percentile point had fallen to 0.15 times the world average while the 90th-percentile point had risen to 3.08 times the world average. The 90 : 10 ratio thus nearly doubled over this period of high average growth worldwide. More detailed study of the growth dynamics in this post-Second World War cross-section of countries has revealed, not just a widening of income disparities across rich and poor, but also an emerging polarization, with the middle-income group of countries dwindling in number (Quah 1997a).

This finding, that in the post-War era, poor economies do not obviously catch up to the rich, has its interpretation disputed by research arguing that, provided one conditions on the appropriate indicator variables—investment and schooling, in particular—then convergence does occur. That kind of convergence, however, is no longer between rich and poor, but is convergence of each economy towards its own specific steady state growth path (Barro and Sala-i-Martin 1992, Levine and Renelt 1992). Hundreds of auxiliary variables have been suggested in these cross-country growth and convergence studies as appropriate alternative or additional conditioning variables (see, e.g., the compilation of studies in Durlauf and Quah 1999).

The evidence in Durlauf and Johnson (1995) shows that poor economies do indeed tend to converge to relatively low income levels, and rich ones to high, even after conditioning on savings and literacy rates. This study suggests, therefore, that as economic growth proceeds, then even with conditioning, the polarization into rich and poor described in Quah (1997a) remains empirically relevant.

6. *Ideas—Science and Technology*

Observing that country disparities are large and growing, that is, that convergence is not happening; and that so much of economic growth is due to TFP has motivated some researchers to investigate models of *endogenous technological change*. (One notable exception is Mankiw et al. (1992) who argued that taking into account *embodied human capital*—the quantity of schooling embodied in the labor force—suffices to explain both observations.)

In work on endogenous technology, TFP is no longer taken to be exogenously given. Instead, economic theory is used to shed light on the incentives and forces shaping TFP's evolution (Aghion and Howitt 1998, Grossman and Helpman 1991, Romer 1990). The problem of explaining cross-country disparities then becomes one of understanding the dynamics of cross-country technology dissemination (Coe and Helpman 1995, Helpman 1993). This work predicts that knowledge inputs—scientists and engineers, R&D, patents, knowledge spillovers, ideas—drive economic growth. The key empirical findings are twofold: First, significant spillovers occur across countries, so that worldwide knowledge accumulation drives worldwide economic growth. Second, country-specific knowledge stocks, resulting from that country's own R&D, do matter importantly, and help explain each country's pattern of economic growth.

The hypothesis of knowledge-driven economic growth, while suggested by the logical sequence of earlier measurements and theoretical developments, remains controversial. For one, many observers consider it implausible that the poorest economies—those in sub-Saharan Africa, say, in the latter part of the twentieth century—are poor because they do not do enough scientific research. This, however, is an overly-literal interpretation of knowledge inputs. The ability of people in different economies to absorb and economically exploit scientific developments or even just best-practice production techniques obviously differ. The question then becomes one of incentives to use ideas—why do the very poorest economies not use frontier technologies to raise the productivity of factor inputs? The economics of creating and disseminating ideas, or *intellectual property* more broadly, are subtle; so too, but much less-studied, the economics of using ideas.

However, even in the richest economies, empirical evidence is ambiguous on knowledge-driven economic growth. US scientists and engineers employed in R&D grew five-fold from 200,000 in 1950 to over 1 million in 1990; the growth rate of US GDP failed to increase by anything remotely comparable over this period (Jones 1995).

7. *Inequality*

As measuring economic growth has continued to focus on progressively fewer observable variables, an implicit tension has correspondingly sharpened: if welfare is proxied only by average income, then income inequality—or more generally, the distribution of income across people—might be unobserved worsening to where an average seriously misleads as an indicator for the economic welfare of the population overall.

The Kuznets (1955) curve describes a key empirical regularity between growth and inequality: Cross-sectionally across economies, inequality is low when per capita incomes are low, increases at moderately higher per capita income levels, and finally falls again at the very highest levels of per capita income. Put differently, the relation between inequality and levels of development is an inverted U. This early finding suggested to many researchers the possibility that, indeed, economic growth might disadvantage the very poor, due to increases in inequality.

More recent empirical analyses (Li et al. 1998) have shown, however, that as economies grow, the change in inequality is small: most of the measured variation in inequality is that *across* countries. Over time, inequality can change but much, much more slowly than economic growth varies.

8. Structural Drift

The more recent focus on measuring economic growth using just changes in per capita income has de-emphasized the evolution in industrial structure of economies as growth proceeds. By contrast, research such as that in Kuznets (1966) consistently documented such basic changes. Quah (1997b) has noted that such structural drift continues, away from manufacturing, towards high value-added intangible services.

Over the nineteenth century, as economies grew, their industrial composition shifted away from an emphasis on rural agriculture, and towards manufacturing and urbanization. Economic activity became progressively more markets-based, so that traditional informal, nonmarket work at home was replaced by formal employee arrangements. Education became more institutionalized; foreign commerce increased; and natural resources were relied on progressively less.

9. Where Next?

Measuring economic growth is an intricate and subtle exercise. It has a scope that can be large and unmanageable. In practice, the history of measuring economic growth has been one of intimate interplay with economic theorizing, leading from improvements in the accuracy and relevance of growth data, to hypotheses on the critical sources of economic growth, to explaining deep changes in the structure of national economies.

Total factor productivity, previously a measurement residual to be minimized, has since been reinterpreted, and has emerged as the key driver for economic growth. Ideas—scientific and engineering knowledge, R&D, expertise—constitute the prime candidates for explaining TFP, but the supporting empirical evidence remains weak.

See also: Development, Economics of; Development: Social; Development: Social-anthropological Aspects; Economic History, Quantitative: United States; Modernization, Sociological Theories of; Time Series: General

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D. Quah

Economic Growth: Theory

Growth theory was developed in the 1950s and 1960s, and some early growth models are collected in Stiglitz and Uzawa (1969). After a lull in the 1970s, the arrival of better data in the 1980s prompted a burst of activity during which economists refined their models so that they could better answer question like: Why did growth take off two hundred years ago and why in England and then the West, and why do Africa, Latin America, and most of Asia lag so far behind? And, what measures will improve things, especially in the poor countries? It is mostly the new crop of models that will be surveyed here.

1. Growth

What determines the rate at which our standard of living grows? Economic theory has settled on three broad categories:

(a) the progress of science and productive knowledge;

(b) the growth of individual skills; and

(c) incentives.

Incentives impinge on every economic decision, of course, including the decision to accumulate knowledge and skill. Still, (a) and (b) are listed separately because science and skills have evolved, in part, spontaneously or accidentally as people went about their business or pursued their curiosity.

1.1 Science

The world's wealth grows thanks mainly to the growth of knowledge. As with anything else, when adding to knowledge, there is strength in numbers. Even before the fifth century BC and the beginnings of science, early stone tools, farming, the domestication of animals, the wheel, and other inventions spread not by parallel and independent invention, but by imitation. If I was alone in the world, I would have to do my own inventing. But if there are two of us and you have invented the wheel already, I don't need to reinvent it, I can just copy your design. In copying you, moreover, I do not deprive you of your wheel—we both can make a wheel even though you alone came up with the idea. Thus, knowledge is a form of social capital that grows when anyone adds to it, and a bigger world will grow faster simply because more people will think up more new ideas. From the first stone tools to the steam-engine, electricity, and the computer, the mass of the people who derived some use from new ideas have had no part in coming up with them. So, if the overriding constraint on growth is scientific progress, a more populous world is one in which living standards will rise at a faster rate.

Arrow (1962) argued that we get new ideas when we use our old ideas, and that invention is incidental to normal production activity. He called this process 'learning by doing' and he assumed that the process operates in the machine-producing industry: The more machines we make, the better at it we get. The learning process operates at the level of the industry as a whole in that each producer learns from the experience of all other producers.

Because it relies exclusively on learning by doing, however, Arrow's growth mechanism contains only a small part of the engine that drives modern growth. After all, how many of our big inventions were made fortuitously at the workplace? Even when it is an accident—penicillin and the Post-it note, for example—a discovery usually occurs, instead, in the research lab. Moore's law, the observation that the speed of computers doubles every two years, is driven by research on the computer chip, and not by the mere fact that the world produces a lot of chips. Of course, if we made a greater number of chips, we would probably also be choosing to do more research to make them faster; the rate of production and the rate of growth of chip-quality would, in this sense, be positively related, but it would still be the research scientist and not the production worker whom we would have to thank for that quality growth.

Romer (1990) recognizes the importance of research. In his model, the more researchers we have, the faster we can invent, and the faster we grow. As in Arrow's model, then, here too a bigger economy grows faster. This positive effect that the scale of the world has on growth holds up well historically. Kremer (1993) finds that the rise in the world's population has, at least until around 1900, gone hand in hand with a rise in the rate of growth of income per head. The industrial revolution thus took place only when people came up with enough ideas—e.g., the steam engine—that then kicked off the industrial era.

1.2 Skills

Science cannot be all there is to growth and development. For one thing, large parts of the world

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