CENTER FOR GLOBAL DEVELOPMENT **ESSAY**

# Solow's Return: Inventions, Ideas and the Quality of Life

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February 2011

www.cgdev.org/content/publications/detail/1424863

**ABSTRACT**

Robert Solow's model of exogenous growth driven by the global diffusion of technology is out of fashion because it ill fits the empirical evidence. Today, economic growth is considered endogenous, and institutions are seen as central to the long-term growth process. An increasing body of literature suggests institutions both have deep historical roots and are difficult to change. At the same time, non-income measures of quality of life, including health and education, do see strong patterns of global growth and convergence. This suggests institutions may be less important to progress in broader quality of life, with a larger role for the factors that drive endogenous change. There has been a rapid global diffusion of "invented" technologies and ideas central to the quality of life from vaccines and oral rehydration therapies to ideas of hygiene and the importance of education. This suggests governments and donors alike should give greater attention to supporting the development and diffusion of technology while creating the demand for the services which underpin the quality of life.

This essay is adapted from material in *Getting Better: Why Global Development Is Succeeding—And How We Can Improve the World Even More* (Basic Books). It overcomes at least one significant weakness in that material: properly recognizing the considerable intellectual debt this work owes to Richard Easterlin. Many thanks to Nancy Birdsall for comments.

The Center for Global Development is an independent, nonprofit policy research organization that is dedicated to reducing global poverty and inequality and to making globalization work for the poor. CGD is grateful for contributions from the William and Flora Hewlett Foundation in support of this work.

## Introduction

Robert Solow's model of economic growth is distinctly out of fashion amongst economists, and no wonder—it does a pretty terrible job of explaining postwar patterns of income performance around the world. But, as Richard Easterlin has suggested, Solow's old bottle might do for new wine. Broader measures of the quality of life do fit patterns predicted by a Solow-type model.[1] This paper discusses the course of global change in income and quality of life and why a Solow-type model might be more relevant to explaining the second than the first. And it points to the policy conclusions which follow from an exogenous model of quality-of-life change.

## Solow's Theory and Economic Growth

Perhaps the first recognizably modern theory of economic growth was the model developed independently by Sir Roy Harrod of Christ Church, Oxford, in 1939 and seven years later by Harvard's Evsy Domar.[2] This theory posited a linear relationship between investment and growth rates. Invest more in factories, roads, or housing, and your growth rate will go up. The more you invest, the more you grow. But Domar himself argued that his model was not appropriate for determining long-term growth rates, supporting instead a model developed by Nobel Prize winner Robert Solow.[3] Solow's model predicted that long-term growth rates were primarily dependent on technological change rather than investment.

Economists define technology broadly—anything that isn't investment that might affect per worker growth rates. For example, it can include inventions as usually imagined, like the steam engine or the transistor, but also new processes, like the assembly line, or new ways of doing business, like double-entry book-keeping. Solow suggested that as these technologies spread across countries, they would be able to use workers and capital more effectively to produce goods and services. This, he argued, was the secret to growth.

Solow also assumed that technology spread across countries at a constant rate. Every year, the gap between advanced and nonadvanced countries in terms of technological prowess shrunk by the same amount. This suggested growth was a natural state, if you will. All a poor country had to do to get richer was to sit there while the inevitable flow of technology from rich countries increased productivity and output. Later economists termed Solow's growth model "exogenous," meaning that the dominant force behind growth came from outside countries in the form of these constant technology flows. His model suggested that government policies or the social or geographical status

[1] Easterlin 2004.

[2] Harrod 1939; Domar 1946.

[3] Solow 1956.

of a country played a comparatively limited role in retarding or speeding technology flow, and so a limited role in fostering economic growth.

Solow did think that investment mattered to growth in the medium term. Especially in countries with many people, limited infrastructure, and few factories—a.k.a. poor countries—Solow's model suggested that investment would improve economic performance. Relatively poor countries saw higher returns to investment in the form of economic growth, he argued. As a result, poor countries would grow faster than rich ones until they were rich as well: the model predicted global income convergence. After convergence had occurred, the world as a whole would grow at pretty much the same speed, determined by the rate of global technology advance.[4]

Solow's model was elegant. But it didn't fit the realities of economic growth. The world has experienced considerable divergence rather than convergence in incomes across countries.[5] In 1950, the poorest country for which we have data (Guinea Bissau, a small former Portuguese colony on the coast of West Africa) had an income of $289. The richest country in the world (the United States) had a GDP per capita of $9,561.[6] By 2003, Congo-Zaire's $212 per capita ranked it as poorest. The richest was still the United States, with a per capita income of $29,037. The richest-poorest gap between countries grew over 400 percent, from around 33-fold in 1950 to around 137-fold today.

Growth economists have adapted Solow's model to deal with the problems of stagnation and divergence. They now assume that the rate of technological progress is not exogenous to the economic system but that it is different for each country. Technology is an "endogenous variable," with an adaption rate that varies depending on factors such as policy or institutions or levels of education or health or trust in a society (the variable depends on the economist's proclivities). This adapted model allows for poorer countries to grow more slowly than rich ones indefinitely, at least until the factor(s) restricting the diffusion of technology are removed.

In particular, a set of endogenous models which focus on institutions has (broadly) won out, with institutions seen by some as "sticky technologies." Not least, Paul Romer, a father of endogenous growth theories, suggests that process technologies are the key to growth. He argues that Wal-Mart's management of inventory data has had a bigger impact on economic growth than inventions such as the transistor, for example.[7]

There is strong evidence to support Romer's contention that process technologies are more important to per capita income growth than so-called traditional invented technologies. In particular, traditional invented technologies aren't sticky; they flow across borders. Transistors (followed by

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[4] This is an oversimplification because the original neoclassical model actually allowed for steady state growth rates to vary across countries.

[5] Pritchett 1997.

[6] Yemen, Oman, and Kuwait, all small countries with very high reported per capita incomes related to oil wealth, are excluded from the 1950 sample. The data is from Maddison 2001.

[7] Perkins and Perkins 1999.

microchips) have spread to every country in the world, and very rapidly. Take transistors in televisions and microchips in computers. Over one-half of households in the developing world own a television, and there are 219 million computers in low- and middle-income countries. Per dollar of GDP, developing countries have far more televisions, computers, and Internet users than rich countries.[8]

Similarly, you can be stuck in a traffic jam the world over, and some of the worst are in poor countries (Kabul, for example, has hideous traffic). Of course, poor countries have less in the way of assets than rich countries. That is what it is to be poor. But they don't have less in the way of access to technologies embedded in goods than one would expect given their income level. Figures 1 through 4 (all figures at end of document) show the number of air passengers, mobile phone subscribers, motor vehicles, and kilowatts of electricity consumption per million USD of GDP across countries against their income per capita. As can be seen, poor countries and rich see similar usage rates for these technologies on this measure. If anything, poor countries see slightly higher usage.

Furthermore, countries that are as poor as they have ever been have increased their access to technologies over time. That is obvious given that no country in the world had *any* air passengers, motor vehicles, power plants or mobile phones in 1850, for example, and yet many countries little richer than they were in 1850 have stocks of all four technologies today. But it is a process that continues. Take the example of mobile phones in Africa. Figure 5 suggests that the number of telephone subscribers at a given income level in an African sample of countries has increased more than 10-fold between 1980 and 2005. Cars, cell phones, and computers don't appear to be like the kind of sticky technologies that must be behind income per capita growth.[9]

On the other hand, there are no Wal-Marts in Malawi. Televisions and computers, along with cars and telephones, work pretty similarly worldwide. Inventory control and production management systems do not. They are highly context-specific. It takes the same skills to fix a television in New York or Nairobi; it is likely to take considerably different skills to be a good inventory manager. Furthermore, improvements in process technologies have to take account of the existing institutional context. This suggests a long-term and context-specific path of improvement in process technologies, or "stickiness" that would account for income divergence.

Institutions such as inventory management techniques, regulatory structures, or regime type might be central to the growth story. But the type of institutional innovation which spurs growth in a particular country at a particular time may be highly context dependent. And given the interlocking nature of process technologies, it may be difficult to predict the impact of altering a particular process technology in a particular setting. This was, pretty much, the insight that won Douglas North his Nobel Prize in 1993, for what was termed "new institutional economics." Still, North suggested

[8] Fink and Kenny 2003.

[9] The same is true of Internet users although poor countries do still have fewer secure Internet servers per unit of GDP.

that a strong network of property rights, market systems, and decentralized, democratic decision-making structures underpin economically successful regimes.[10] Some more recent offshoots of this theory have suggested a large role for economic and social networks that promote trust, highlighting the importance of things such as the equitable distributions of income and efforts to overcome ethnic divisions.[11]

The role of institutions and the importance of historical development of those institutions has led economists to look for the origin of institutional structure. As a result, Acemoglu, Johnson, and Robinson have produced a theory of institutional development based on different experiences of colonization.[12] Nathan Nunn of the University of Toronto takes the argument over the causes of economic growth even further back, prior to colonization. He argues that Africa's poor growth performance is at least in part the result of the extent of the slave trade. Countries containing areas where slave exports were at their highest see some of the weakest modern-day economies.[13] Bill Easterly and colleagues up the ante a little further by suggesting it all dates back to technology stocks in the year 1,000.[14] But Jared Diamond has already trumped explanations that truck in mere millennia by suggesting it all depends on the shape of the continent your ancestors were born on. Diamond argues that the West triumphed over the Rest because Europe sat at the end of a continent broader than it was long, so containing much larger contiguous ecological areas compared to the landmasses of Africa or the New World.[15]

In short, Solow's optimistic view of growth-promoting technologies as things that flow easily has been replaced by a view of such technologies as institutions that change slowly and have deep historical roots. The good news is that the story of growth, convergence, and the technologies that matter look very different when we examine other elements of the quality of life than income. Here, Solow's model lives on.

## Progress and Convergence in Quality of Life

For example, with regard to health, global statistics covering the second half of the 20th century suggest particularly powerful convergence even as average world life expectancy increased from 51 to 69 years. We can look at convergence of outcomes by studying the quality of life achieved by the bottom 20 percent of the world's countries compared to the top 20 percent of countries. In 1950, the 20 percent of countries with the lowest life expectancy only averaged life spans about half as

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[10] North 1992.

[11] Putnam 1993; Fay 1993; Grenato, Inglehart and Leblang 1996; Seabright, 1997.

[12] Acemoglu, Johnson, and Robinson 2001.

[13] Nunn 2008.

[14] Comin, Easterly, and Gong 2010.

[15] Diamond 2005.

long as those in the top 20 percent. By 1999, the poorest performers saw life expectancy two-thirds as long as the strongest performers. That is clear evidence of dramatic global improvements concentrated in the developing countries that were furthest behind.[16]

Again, with regard to education, in 1900, the bottom fifth of countries—the laggards in terms of human capital—saw education rates that suggested the average adult had been in school for less than two months. Of course, this reflected the fact that the great majority of adults had never set foot in a classroom at all, and education was the privilege of a small elite. In contrast, the top fifth of countries in 1900 already had average human capital stocks of over seven years, suggesting the considerable majority of citizens had completed primary schooling, at the least. The gap between leaders and laggards in 1900 was huge: a 40-fold difference in average educational levels.

Since then, leading countries have extended access to secondary and tertiary education, and the average number of years that citizens of those countries spend in school has nearly doubled to 13 years. But education rates in laggard countries have exploded. Average human capital levels increased 19 times over the course of the century as basic education evolved from a luxury to ubiquity. Progress was particularly rapid in the period between the end of the Second World War to the end of the 1970s, but even the so-called lost development decades of the 1980s and 1990s saw average years of education in these laggard countries increase from around one year and four months to two years and eight months. Laggard countries are still behind, of course, but from having around 1/40 of the human capital stocks of leader countries in 1900, they had about one-quarter by the year 2000.

And as predicted by a Solow-type theory, there is a strong pattern of change common across countries to global quality of life outcomes. The importance of this pattern in health can be illustrated by use of a very simple model. The model predicts country mortality today based simply on the level of mortality yesterday (or ten years ago, or fifty years ago) and a constant (global) rate of progress. It makes no reference to different rates of economic growth, or health financing, or education rates, or policy choices—or war, famine, or plague—across countries. It predicts future mortality purely on the basis of current mortality and the average rate of global change.

When we look at actual change in levels of infant mortality for 68 countries over 1950 to 2000 compared to the change predicted by the model, the two are very close. The average decline in infant mortality over the period is 73 percent, and pretty much every country saw a dramatic decline. The average error on our 2000 predictions based on 1950s mortality data and global change alone is only 11 percent, just a little over one-seventh of the average change. This one-seventh error rate in the model accounts for the combined impact of differing geography, institutions, policies, and rates of economic growth across countries. It also accounts for weaknesses in the data, which are considerable. The other six-sevenths of mortality change in these 68 countries can be accounted for by a global pattern of decline.

[16] Kenny, 2005.

Related to the finding of similar rates of progress over the long term around the world is that country variations from this trend rate of progress tend to be short-lived. There is a very weak relationship between the relative speed of a country's improvement in health over time. Relatively strong performance in improving health today is absolutely no guarantee of strong relative performance tomorrow. If anything, strong performance one decade is associated with somewhat weaker performance the next, that is, the data provide evidence of reversion over time toward the rate of change predicted by the simple model of global progress.[17]

A similar finding of a strong global pattern of change applies to other areas of the quality of life. With regard to developments in education, Michael Clemens finds evidence of a global pattern behind increased enrollments. He describes an S-curve of progress in which slow initial progress in expanding enrolments from very low levels in the first 30 years of the transition toward universal education is followed by rapid progress toward ubiquity. This slows once again as countries reach toward 100 percent enrollment rates. The pattern of transition suggests that a country which reaches 50 percent net enrollment today will reach 70 percent enrollment after 22 years and 90 percent after 58 years.[18] Around 90 percent of the variation in net primary enrollment in all countries for the postwar period can be accounted for by this common global pattern of transition, argues Clemens.

Once more, Daron Acemoglu and colleagues find a similar pattern of change when they look at the move toward greater respect for civil rights and democracy.[19] And Bill Easterly's study of 70 different measures of the quality of life covering health, education, rights, the environment, and access to infrastructure found that a global pattern was the driving explanatory factor for progress in nearly all of them over the past 30 years.[20]

## A Process with Limited Relation to Income Change

If broader quality of life is improving and converging worldwide, following a global pattern of improvement, while income is diverging with many countries seeing little if any growth at all, this suggests something about the relationship between the two. Income (and the factors that drive income growth) cannot be driving changes in broader quality of life, especially not in economically stagnant countries. Direct evidence for this has been mounting ever since Samuel Preston first plotted curves associating health outcomes with income levels over time.[21] The average level of health for a given income per capita improves considerably as each decade passes. At an income of

[17] Kenny and Casabonne 2008.

[18] Clemens 2004.

[19] Acemoglu and Robinson 2006.

[20] Easterly 1999.

[21] Preston 1975.

$1,000, expected infant mortality fell from 199 per thousand births in 1900 to 140 in 1940 and 73 in 2000.[22] This suggests that a country that saw absolutely no income growth over the entire century would still have experienced a near two-thirds decline in infant mortality over those 100 years (see figure 6).

Similarly, countries with a GDP per capita of $300 in 1999 have a predicted life expectancy of 46 years, the same life expectancy as predicted for a country with an income of $3,000 in 1870. Meanwhile, countries with a GDP per capita of $3,000 today have almost exactly the same life expectancy as would have been predicted for a country with a GDP per capita of $30,000 in 1870. In other words, the income associated with a given life expectancy has fallen 90 percent over 130 years.[23]

With regard to education, an analysis of the data suggests that a country with a GDP per capita of $800 in 1930 would typically have a 9 percent enrollment rate while a country with the same GDP per capita in 2000 would expect an 84 percent enrollment rate. The evidence for 2000 suggests effectively no relationship between income and enrollment at a GDP per capita of $1,000 or above (see figure 6).[24] More broadly, mounting evidence suggests a weak or secondary relationship between income change and changes in quality of life across countries over time covering variables from democracy and civil rights through health, education, and infrastructure.[25]

## The Technologies and Ideas behind Quality of Life

Income growth appears endogenous, then, strongly dependent on country-level factors (even if these factors are institutions, which are hard to change). Conversely, other measures of the quality of life display features that suggest a strong influence of exogenous factors common across countries. In turn, this suggests that the factors which drive the exogenous model—the global diffusion of invented technology and ideas—might play a large role in quality-of-life outcomes.

Such a model surely fits the evidence quite well. It is not just cars, planes, and computers that have spread worldwide. And the mobile phone is far from the only technology whose spread has considerably outstripped what would be expected if usage was determined by income levels alone. The range of technologies that are available and used by many of the world's poorest people today that were far less ubiquitous 50 or 100 years ago is considerable. Beyond medical technologies such as vaccination, the list would include building materials such as cement, corrugated iron, steel wire,

[22] Kenny 2008a. It should be noted here that with greater coverage of the countries suffering severe AIDS epidemics, the figure and following results would look less positive. But with higher-quality data, change over time might look even more dramatic.

[23] Kenny 2005.

[24] Kenny 2008b.

[25] Easterly 1999; Kenny and Casabonne 2008.

piping, nails, and tools; household items including plastic sheeting and containers; synthetic and cheap cotton clothing; transport technologies from rubber soles through bicycles; infrastructure services including all-weather roads and buses; water pumps, radios, televisions, and butane and paraffin for lighting; and pens, papers, and books. On the side of ideas, the germ theory and its implications, the concept of democracy and the value of literacy for both boys and girls have gained considerably greater acceptance in countries rich and poor. These technologies and ideas have had a considerable impact on a range of measures of the quality of life, and they have spread worldwide.

For example, the diphtheria, pertussis, and tetanus (DPT) vaccine has spread dramatically across the world over the last 30 years. In 1980, many developing countries had immunization rates considerably below 20 percent. Figure 8 suggests that, especially for poor countries, there has been a dramatic uptick in vaccination rates so that a country with an income of about $1,000 per capita would have a vaccination rate near 80 percent, more than twice the rate predicted in 1980.[26] Again, nonprofessionally administered oral rehydration salts as a treatment for diarrhea only became widely accepted after the refugee crisis connected with Bangladesh's war of independence in 1971, yet survey evidence suggests that around two-fifths of diarrhea cases in the developing world are now correctly treated with fluids and continued feeding, and the link between income per capita and levels of correct treatment is weak (figure 9).[27]

Oral rehydration and vaccination are two examples that the most effective health technologies are very cheap and very simple. The Bellagio Child Survival Group, a group of medical experts assembled by the leading British medical journal, *The Lancet,* in 2003 to discuss this issue, concluded that fully one-third of the ten million child deaths in low-income countries that still occur each year could be prevented with the use of oral rehydration therapy alongside breast feeding and insecticide treated bed nets.[28] Bed nets cost around $5. Oral rehydration therapy involves a simple solution of sugar and salt in water. Breastfeeding takes time and maternal nutrition, but otherwise it is free. It is certainly considerably cheaper than baby formula. A full regime of oral antibiotics costs $0.25, and antimalarials are similarly priced.[29]

Health evidence from household survey data covering 278,000 children across 45 developing countries also supports the importance of ideas—or the demand side—of health. This evidence, compiled by Peter Boone of the London School of Economics and Zhaoguo Zhan of Brown University, suggests that the prevalence of common diseases that kill children has little predictive power for child mortality. Instead, actions taken by parents to help sick children are the most significant factors

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[26] Data from World Development Indicators (2010). PPP GDP per capita in 2005 USD and DPT immunization rates for all countries with data.

[27] Data from World Development Indicators (2010). PPP GDP per capita in 2005 USD and ORT rates average for each country with available data 2000–2008.

[28] Boone and Johnson 2008.

[29] Boone and Zhan 2006.

determining differences in child survival. Boone and Zhan estimated that improvements in treatment-seeking and education among parents might reduce child mortality by roughly 32 percent. Across the 45 countries, children whose mothers believed fluids should be reduced during diarrhea episodes faced a 15 percent greater risk of death than a child whose mother was better informed. Educated parents exposed to media, as well as those living in communities where others knew the correct response, were both more likely to know how to treat diarrhea events and thereby save lives. Allowing for these factors related to knowledge and education, household income played a marginal role in determining health outcomes for the quarter-million-plus children across 45 countries in the study.[30]

Similarly, Michael Clemens notes that the evidence of the last half century suggests that the diffusion of demand for educational services—the spread of the idea that education matters—has the key role in explaining outcomes.[31] Deon Filmer of the World Bank suggested the importance of demand versus supply factors in explaining outcomes by looking at enrollment rates of children in 21 developing countries to see if children who lived closer to schools were more likely to attend. At the time, average school enrollment in the rural areas of the study countries was 50 percent. He estimated that if every rural household was right next door to a school, this would increase enrollments by three percentage points, to 53 percent.[32] Community-level enrollment rates and parental education do a far better in explaining enrollment decisions because the key factor is convincing parents that an education is of value to their children.[33]

## Conclusion

We have seen that the hope and expectation of early economic growth models was that the technology behind growth would flow to seek a common level—like water. Technology would spread without regard to distance and borders. The medieval would not cohabit with the modern. In turn, this would create a powerful force for income convergence.

Again, we've seen that hope was optimistic. The process technologies, institutions such as laws and inventory management systems, that appear central to raising incomes per capita flow less like water and more like bricks. But ideas and inventions, the importance of ABCs and vaccines for DPT, really might flow more easily across borders and over distances. They may be a little more like water—or at least Jell-O—than like bricks. The comparatively easy flow of innovations central to quality of life helps to account for the considerable evidence of strong global patterns of change in

[30] Boone and Zhan 2006; see also Dearden, Pritchett, and Brown 2003.

[31] Clemens does report a secondary influence of income levels on the speed of the education transition and notes that numerous studies suggest wealthier parents are more likely to send their children to school.

[32] Filmer 2004.

[33] Regalia and Castro 2007.

quality of life. It also might help to explain the process of global quality-of-life convergence even without income convergence as well as the improvements in health and education in Africa even absent any substantive income growth at all.

If the exogenous growth model works better with measures of health and education than it does with income, this suggests the policy conclusions linked to a Solow-type model might have more relevance in quality of life than they do in the case of economic growth. All countries have moved toward a greater government role in the provision of quality of life, suggesting that government actions may have a part in explaining the global rate of change in quality of life. At the same time, the exogenous model suggests that there must be an upper limit not only to the importance of different rates of income growth but also different speeds of policy or institutional change in explaining relatively fast or slow progress in the quality of life over time across countries.

That said, the evidence on the importance of the supply of technologies and demand for quality of life to outcomes suggests the potential for government approaches that support rollout of services: such as subsidies and extension for new technologies, conditional cash transfers, and social marketing to promote demand.

At the global level, donors have focused much of their recent attention on attempting to strengthen institutions in developing countries to promote growth. Growth matters, and institutions are key, but changing institutions is clearly a slow and difficult process (perhaps especially for outsiders)[34] while quality-of-life improvements do not necessarily require income growth. Aid has already had a considerable part to play in improvement in global health, supporting the eradication of smallpox and the spread of vaccines, while combating AIDS. Aid was also central the development and diffusion of new technologies, not least green revolution crops. In addition, donors have also financed a number of conditional cash transfers and other approaches to encourage demand for services. Expanding such programs may be the more straightforward way to influence quality of life worldwide.

[34] Pritchett, Woolcock, and Andrews 2010.

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**Figure 1: Air Passengers per Unit of GDP**

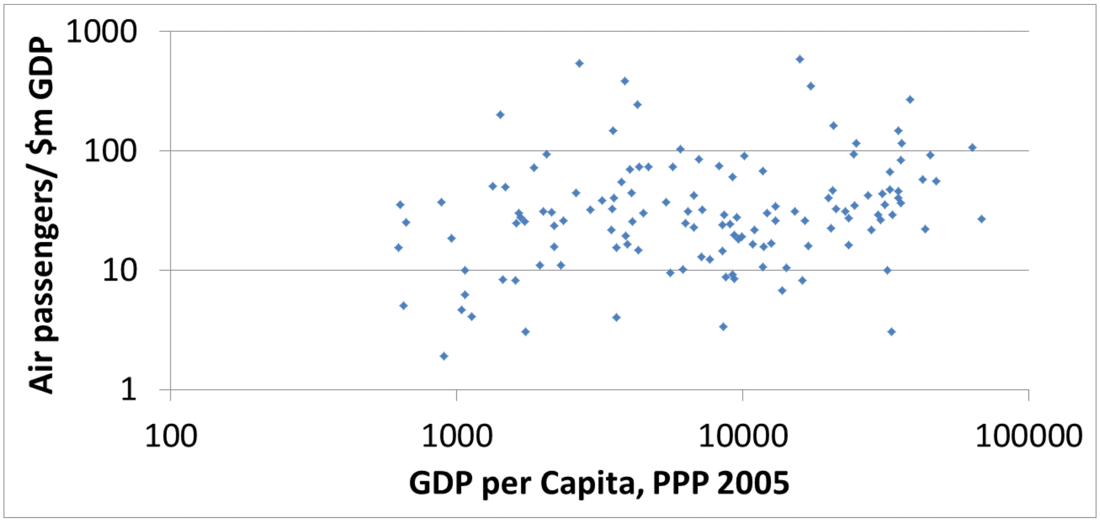


**Figure 2: Mobile Phone Subscribers per Unit of GDP**

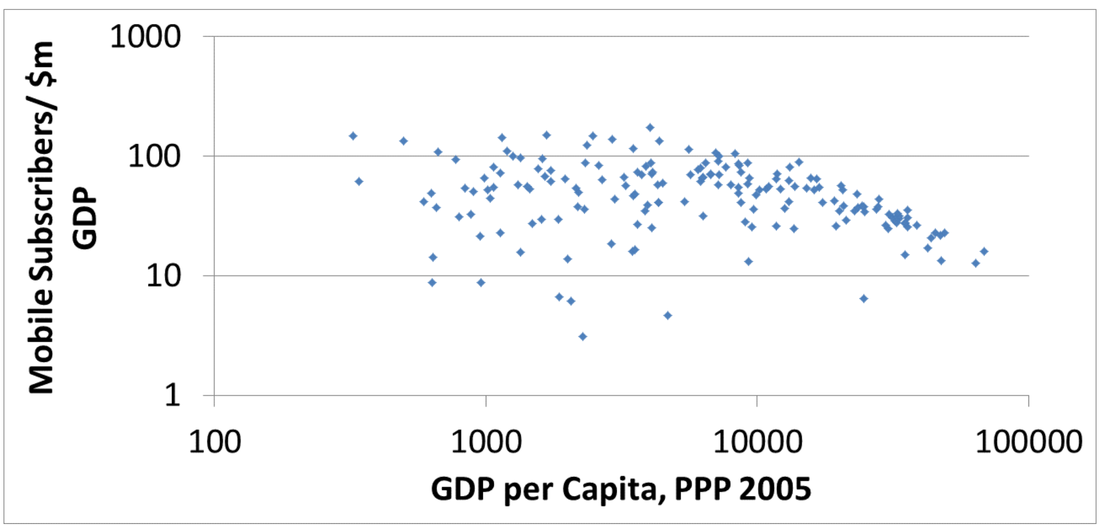

**Figure 3: Motor Vehicles per Unit of GDP**

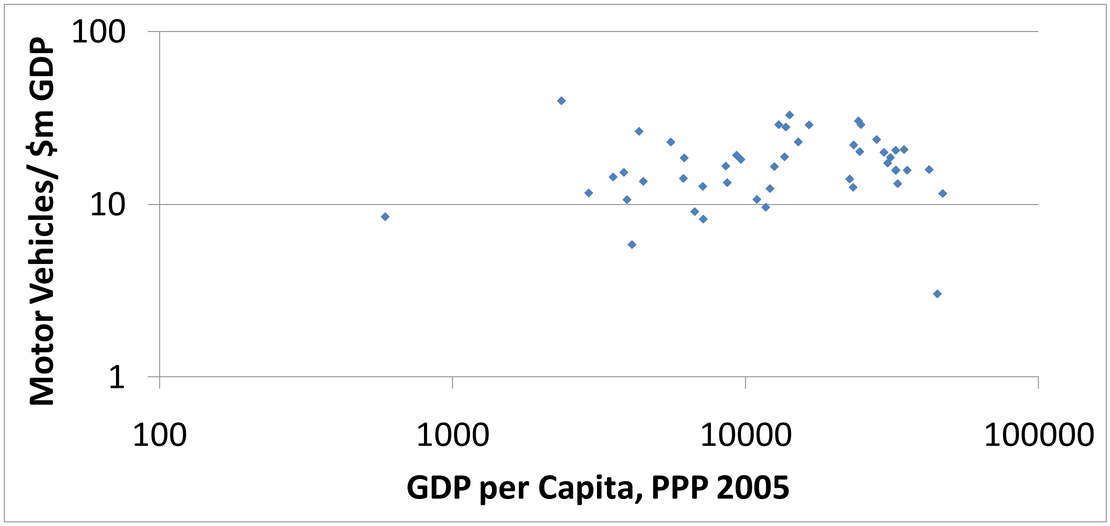


**Figure 4: Electricity Consumption per Unit of GDP**

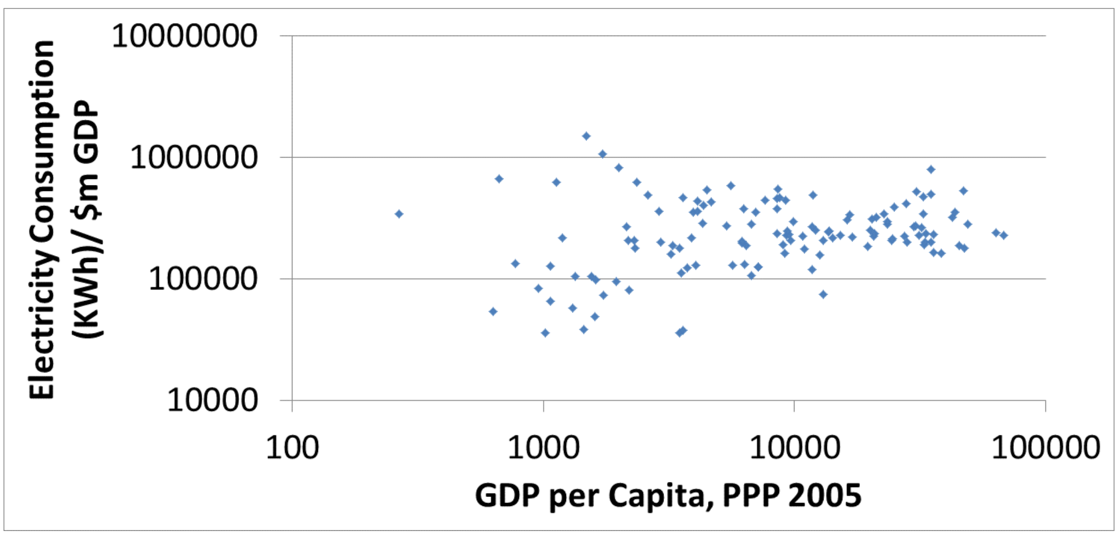

**Figure 5: Telephone Subscriber per 100 People in Africa, 1980 (Solid Diamonds) and 2005 (Hollow Squares)**

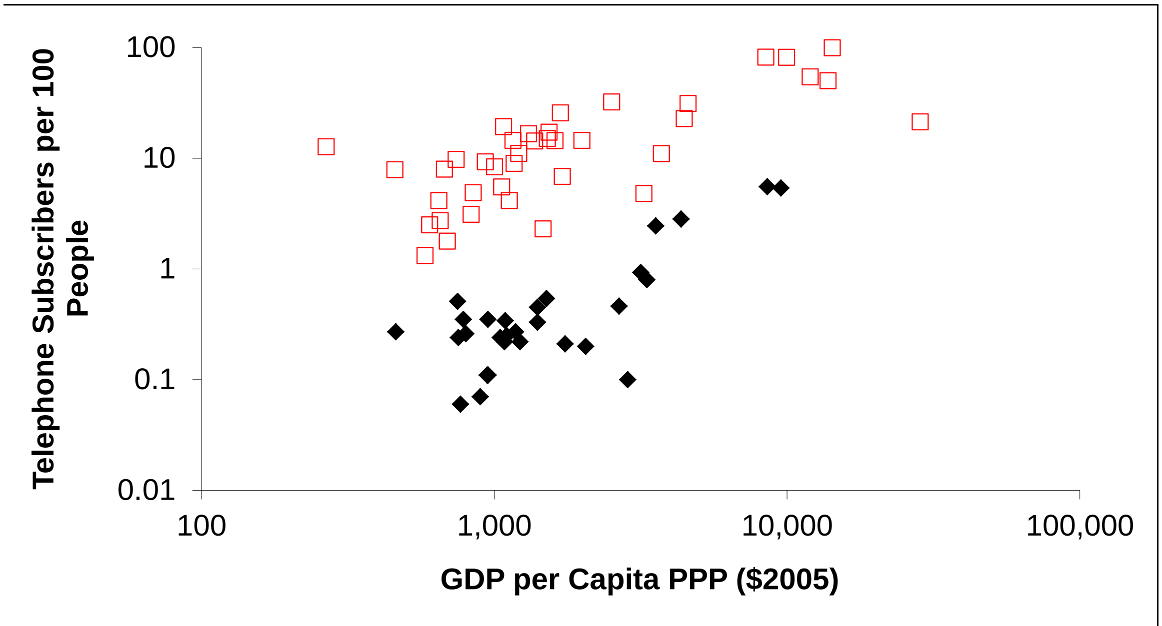


**Figure 6: Infant Mortality Preston Curves for 1900, '20, '40, '60, '80, and 2000**

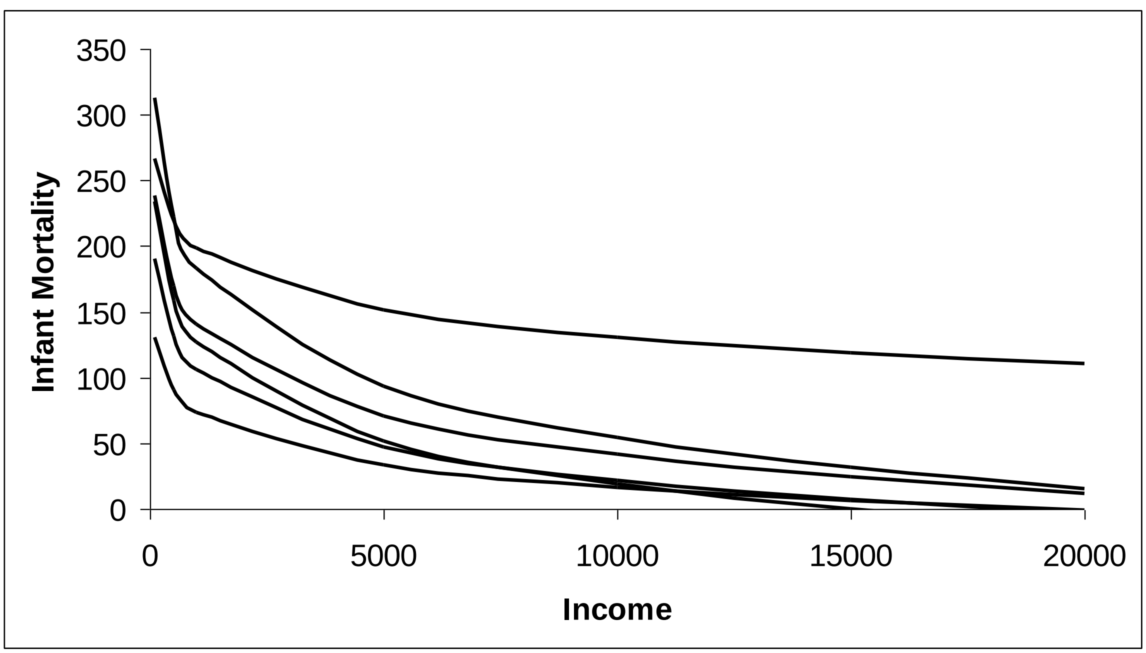

**Figure 7: Education Preston Curves (Solid: 1930, Dashed: 2000)**

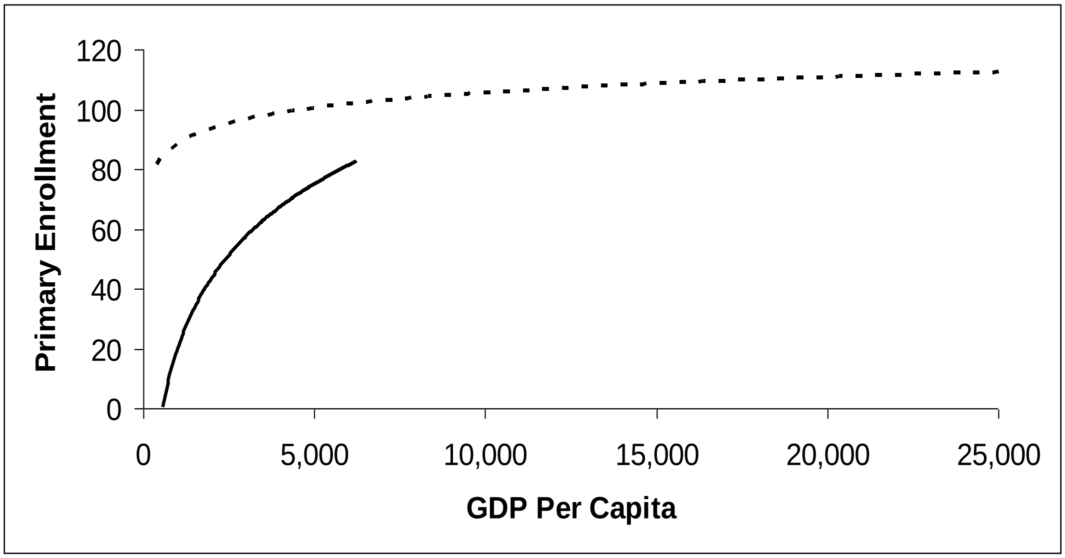


**Figure 8: DPT Immunization against GDP per Capita, 1980, 2005**

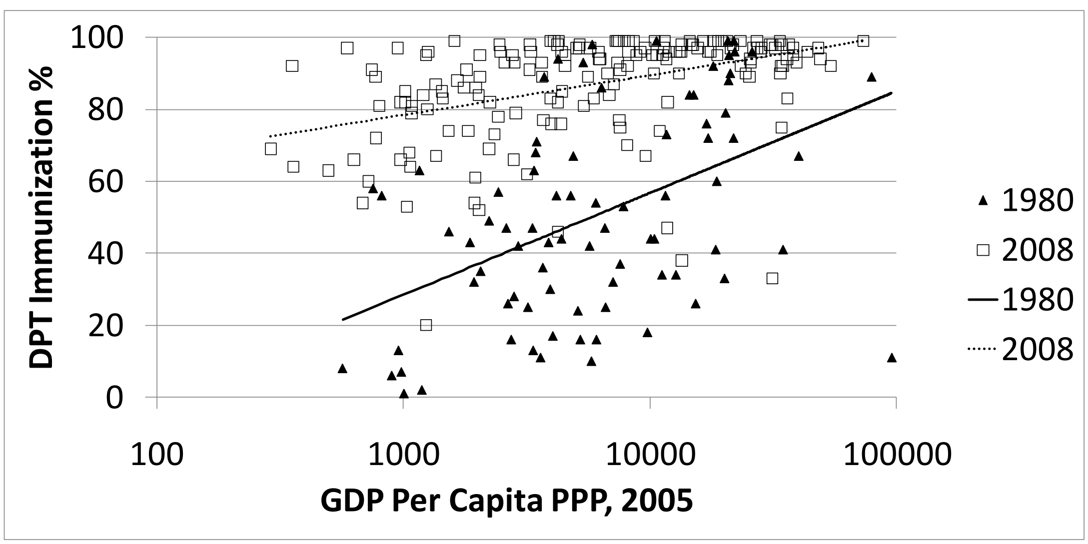

**Figure 9: ORT Response against GDP per Capita, 2005**