White Paper

# The Economics of Network-Powered Growth

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*This paper is one of three addressing network-powered growth. Click on the following links to access the other papers: "Network-Powered Growth," by Peter Gruetter and Fred Thompson, and "Next-Generation Clusters: Creating Innovation Hubs To Boost Economic Growth," by Anne Lange, Doug Handler, and James Vila.*

## Executive Summary

This paper assesses the evidence and finds strong support in the economic literature for the notion that network technology has the potential to boost economic growth permanently, sustainably enriching poorer societies.[1]

The drivers of economic growth have been difficult for economists to determine; some countries prosper, while others decline or remain poor. Yet economic analysis shows that differences in total factor productivity—the know-how, processes, and technologies with which capital is utilized—rather than capital intensity are the main determinants of cross-country differences in productivity and economic growth.

Thomas Malthus posited that finite resources would constrain humans' ability to supply rising demand from growing populations. But his theory has not been borne out; knowledge and innovation have helped us do more with the resources we have. The role of policy in driving technological innovation is still subject to analytical investigation. Recent endogenous-growth theory has focused on the factors that drive technology in an attempt to understand technology's role in economic growth. They build on the notion that an increase in knowledge has the potential to positively impact capital productivity. The concept of "knowledge capital" can be treated as similar to physical capital, but is dependent on a number of factors such as cumulative R&D expenditures and capital investment.

In the endogenous growth framework, new equipment also enables new ideas and innovation in technologies. For example, investing in computers induces bright ideas on how to use them. Investment in physical and knowledge capital drives increasing returns to scale in production, where more knowledge begets increased output and liberates resources for further investment: a virtuous growth spiral in which future output becomes "path-dependent." This paper examines the evidence for endogenous growth and argues that network technology has the potential to promote such a virtuous growth path in countries at all stages of development:

1. For the purpose of this paper, network technology means a mix of wired and wireless connectivity and network services, enabling high-speed delivery, processing, and dissemination of data, as well as interactive sharing and real-time communication. This can include Internet; audio, video, and automated real-time sensing that monitors, measures, and responds to data. Network technology enhances the effective provision and delivery of private and public services as well as spatial and environmental measurement and monitoring.

- In wealthier, innovator countries, network technology enhances the uptake of knowledge, allowing accelerated innovation, invention, and economic growth. Network technology increases returns from investment in human and physical capital and R&D. It does this by reducing the transaction costs of accessing and exchanging ideas, and by promoting collaboration across countries and disciplines. It also helps reduce start-up costs for small enterprises, which are the dynamos of innovation and productivity growth.
- In poorer, developing countries, network technology affords an opportunity to access the latest knowledge and processes to a degree unprecedented in the history of mankind. It is therefore uniquely placed to transform the way poorer economies (which traditionally use outmoded technologies and processes) operate, so they can share in the dynamics of endogenous, innovation-led growth.
- In all countries, especially in the developing world, network technology can encourage inclusive, efficient, and transparent governance by enabling more accountable, rules-based institutions. Economic studies increasingly show that rules, governance, and policies—like technological capital and knowledge capital—are the engine of total-factor productivity and prosperity.

This paper presents mounting evidence to suggest that countries with good institutions, checks on government that limit corruption and graft, and environments that encourage social inclusion, creativity, and enterprise tend to 1) attract investment and 2) benefit from learning, experience, and innovation. By contrast, there is compelling evidence to conclude that per-capita incomes of poor countries are curtailed directly because of shortcomings in institutional governance.

Because the private sector does not take into account the increasing returns from knowledge spillovers, effective government, and other positive "externalities," it will consistently underinvest in R&D, knowledge generation, and knowledge sharing. This means that governments must step in to support growth by providing additional incentives to make these critical investments. It also requires governments to transform the rules and governance of promoting knowledge and innovation by enabling inclusive, stable, and transparent societies. Few means for inducing dynamic returns on investment and enabling innovation through good governance hold as much promise as network technology.

## Introduction

Economists have long sought to explain the reasons for economic growth. Why do some countries prosper while others decline? What are the domestic-policy, cultural, and regional causes of economic success? Why did Southeast Asia (which had a fraction of Africa's average per-capita gross domestic product [GDP] for most of the 20th century) see a fivefold increase in per-capita GDP at the end of the century, while African per-capita GDP remained mostly stagnant? Economists have also struggled to understand why GDP is so spatially concentrated and unevenly distributed. The European Union currently accounts for 32 percent of world GDP, the United States accounts for another 29 percent, and Japan an additional 11 percent.[2] Add Canada, New Zealand, and Australia to the list, and these countries account for more than 75 percent of global output. Yet they are home to less than 25 percent of the world's population.[3]

## 1. Resource Intensity—Where Malthus Got It Wrong

To frame the discussion in a historical context, one needs to go back at least as far as Thomas Malthus. In a series of papers in the early 19th century, Malthus posited a world of finite resources (especially land) that were unable to supply demand from growing populations. In fact, the world's population has doubled and redoubled since Malthus' day, while income and demand have grown even faster. Over the same period, world GDP expanded more than 1,000 percent, despite the reality of fixed resources.

The world turned out to be one in which intensive—not extensive—use of resources drove economic-output growth. As economist Paul Romer notes, "We don't really produce anything. Everything was already here, so all we can ever do is rearrange things." Technological innovation has meant that we continue to invent new and better ways to rearrange things and find more efficient use of fixed resources. Indeed, the continued prevalence of poverty has more to do with governance and the distribution of gains than limits on production. There is no reason the same efficiency gains cannot be applied to spur future sustainable growth and resolve environmental constraints such as global warming in an equitable and efficient manner—but these gains are unlikely to happen without collaborative action and a strong policy lead.

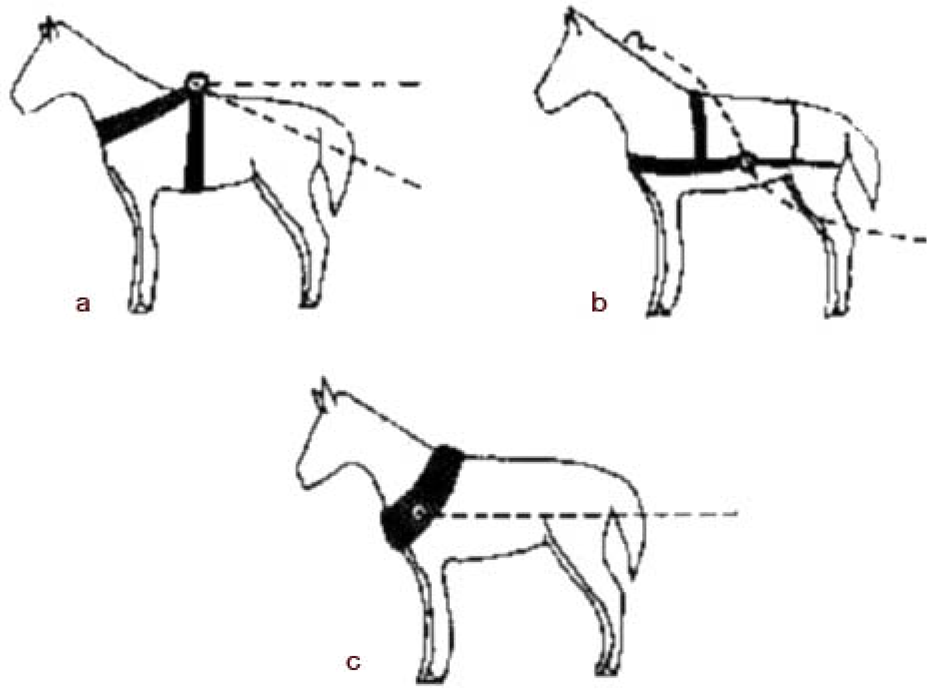
Genius, creativity, and risk taking are sporadic or episodic. By contrast, nurturing and developing ideas require enabling institutions, which might be in the public or private sectors, in civil society, or perhaps from some combination of all three. This has been a consistent feature associated with pre- and post-Enlightenment scientific development and subsequent industrialization.

A classic historical example of the importance of innovation is the horse harness. Figure 1 shows three forms of horse harness: "a" depicts the inefficient throat-and-girdle harness used in antiquity; "b" shows the breast strap employed in the early Middle Ages; and "c" illustrates the shoulder collar introduced in the later Middle Ages. This example

2. International Monetary Fund, World Economic Outlook Database, April 2010.
3. In fact, these dollar market price figures overstate the distribution of GDP as a measure of purchasing power, as lower prices in poorer countries mean each dollar goes further.

shows how it took *12 centuries* to increase agricultural output through use of a plough that does not choke the animal when pulled. Innovation stepped up during periods of stability, commerce, and information exchange. The growth-creating roles of steam, the telegraph, electricity—and more recently, the Internet—were nurtured in enabling environments. In the 21st century, the evidence seems to suggest that network technology has the potential to improve vastly the uptake of inventions the world over, enhancing humanity's propensity for further innovation.[4]

Figure 1. Given Finite Resources, Technological Innovations Can Improve Productivity. Development of the Shoulder Collar (c) Allowed Farmers To Produce More Food Using the Same Resources.




Source: Needham, 2005

**1.1 Knowledge in the Classical Model.** The role of Internet connectivity as a driver of access to knowledge and ideas in the modern age is not disputed among those who daily communicate, trade, and learn online. But the role of learning and knowledge in advancing economic and social well-being has been subject to analysis for several decades. As long ago as the end of the 19th century, Alfred Marshall posited the idea that growth was driven by more than just access to raw materials and the availability of labor.[5] He thought that individuals might learn from one another, thereby creating spillover effects that boost economy-wide production. Until then, classical economics assumed constant returns to scale and diminishing returns, where adding more machines to a person, or more people to a machine, lead to a less-than-proportional increase in output.

4. The interaction between innovation and inventions tends to mean efficiency improvements are subject to jumps, with bursts of innovation, diminishing marginal returns, and then further busts of innovation.

5. Marshall A. (1890), "Principles of Economics," Cambridge University Press, http://www.econlib.org/library/Marshall/marP.html

Under the classical assumption, capital accumulation would ultimately be "self-defeating," as adding more capital would yield diminishing returns but rising capital depreciation as machines age and break down.[6] Additional saving and investment would achieve only a temporary increase in growth. Finally, because investment yields greater returns at a low level of capital, classical theory also suggested that poor economies would grow faster and catch up with rich economies—a proposition commonly termed "convergence" that (critically) can be empirically tested.

In the mid-1980s, a series of new economic models (broadly grouped under the heading "endogenous-growth models") challenged this received wisdom and focused on the impetus of technological progress. These models built on the notion that knowledge had the potential to take advantage of capital productivity. Output and growth are functions not just of the number of people and amount of capital, but the processes, techniques, and technologies with which this capital is used. This element is termed total-factor productivity (TFP).

With the understanding that knowledge generates TFP, and that TFP generates growth, attention began to shift to asking which factors might generate knowledge. The debate over the relative contribution of policy, institutions, trade, and geography to the generation of growth and to explanations of cross-country differentials has become a primary point of contention within the growth and development literature.[7]

**1.2 Working Limited Resources More Efficiently.** With Malthus discredited, the search began for an understanding of what precipitates improvement in resource efficiency. For a long time, the exogenous-growth model developed in part by economist Robert Solow (1957) provided the conceptual basis for thinking about the economics of technological change. He argued that the unexplained element of increased productivity in his econometric analysis of U.S. data on economic growth was due to technological progress. This became known as the "Solow residual." The treatment of this residual, however, has often been confused and inappropriate. By definition, it represented little more than the unexplained component of an accounting identity. The growth-accounting model does not in itself provide information to support a behavioral relationship, or to make inferences and projections.

The challenge was therefore to develop a model that explained the role of technological change and its impact on growth. But this was not easy. The further economists went in attempting to explain growth, the more they expanded the frontier of ignorance. For example, where once we asked what produces growth, now we ask what is the reason for the different vintages of machines, what creates the higher quality of the labor force, what underlies the way similar technologies are used in different countries or factories, and what stimulates uptake and penetration of broadband? Although such inquiries do represent analytical progress, they tend to shift the discussion "upstream," and do not nec-

6. This is because the marginal product of capital is assumed to fall as each additional machine works with a fixed amount of labor and knowledge, whereas the rate of depreciation increases in proportion to the capital stock. Increasing investment would be needed to cause a net increase in the capital stock, until at some point more and more resources would be poured into keeping the capital stock stable.

7. The economic growth literature abounds with papers explaining growth on the basis of four or five factors, often taken singularly, such as human capital (Lucas, 1993; Barro, 1998; Young, 1995; Goldin and Lawrence, 2001; Benhabib and Spiegel, 1994); technology (Kuznets, 1966; Landes, 1969; Mokyr, 1990); natural resources (Shaban, 1987; Walker and Ryan, 1990); trade (Lockwood, 1954; Pomeranz, 2000; Galor and Mountford, 2003); and population density (Das Gupta, 1994). Market-friendly reforms are also often seen as necessary conditions for sustainable growth. Easterly and others, however, note that such economic reforms in low-income countries failed to deliver the promised economic growth during the 1980s to 1990s (Easterly, 2001). See Easterly and Levine (2003) for a comprehensive outline. For the sake of brevity, only a selection of these references is listed in full at the end of this paper.

essarily identify causal factors behind growth-enhancing behavior that can be directly influenced by policy.

## 2. The Role of Investment and Learning in Generating Knowledge

The recent endogenous-growth literature, surveyed by Aghion and Howitt (1998), has been built on the concept of knowledge capital. This was perhaps most famously articulated by Paul Romer in 1986, though Aghion and Howitt (1992) reached the same conclusions independently. These economists rediscovered the "Y=AK" endogenous-growth model, in which production (Y) is dependent on knowledge (A), a function of physical capital (K).

Previously, Solow (1960) and Kaldor (1962) argued that increased capital-intensive investment embodies new machinery and new ideas as well as increased learning and experience to further economic progress. Learning was regarded as a function of the rate of increase in investment. In the Lucas (1988, 1990) model, productivity gains in one firm spilled over into the economy as a whole, itself a function of social interaction and information technology. Network connectivity has the power to increase the rate at which knowledge spillovers spread among sectors and across innovation silos. Similarly, Romer emphasized investment in "knowledge capital," generating new ideas, products, and services: "…as we learn more, it's getting easier to discover new things, so somehow knowledge is building on itself. Newton had this great evocative phrase that he can see farther because he 'stood on the shoulders of giants.'" The treatment of the knowledge stock is therefore similar to that of physical capital, but it is assumed to be dependent on cumulated R&D expenditures rather than capital investment.

The essential element of endogenous growth is that knowledge increases the productive potential of factors so that traditional diminishing returns are overcome. Where once adding more machines to a person might have led to a less-than-proportional increase in output, now the gains from learning, experimentation, and innovation derived from using more machines might allow output to expand at least proportionately. The speed of learning, experimentation, and innovation—as well as replication and leapfrogging of technologies—is likely to be influenced by the reliability of connections among people, ideas, and experience. Complex, robust, and intelligent networks that connect data, information, and people may enhance the uptake of knowledge spillovers. The theory also suggests that increasing a country's saving rate to fund investment in physical and human capital now has the potential to prompt a one-off, temporary increase in the level of income (as in the classical model), and also to raise a country's potential growth rate. This opened up the possibility of raising permanent growth, and put economic policy back on the map.

Endogenous-growth theories had a crucial impact on the policy world. Suddenly, investment in schools, hospitals, and R&D offered the potential to boost long-term growth and provide an upward spiral to economic success. The policy world snapped up the new theory with relish. Although at first it seemed to describe accurately the economic history of the world, the empirical evidence to support the new theory was found to be more complex and less compelling than might have been expected. Before examining the empirical literature in more detail, it is important to understand how the theory of endogenous growth is based on a series of market failures concerning the use and dissemination of knowledge and the incentives to innovate in a world with possible increasing returns to scale.

Carlota Perez refines the discussion by showing evidence of how technological revolutions induce major social and economic changes.[8] She notes that much of Asia made the leap to economic success because technological revolutions allowed such leaps. This, she argues, has happened several times in history. The United Kingdom, Germany, the United States, Australia, and Canada all made similar leaps, thanks to what she describes as "the Internet of the time"—steamships, transcontinental railways, and the transoceanic telegraph. But each of these regular revolutionary changes in technology is highly specific. The nature of the potential for growth is different each time because of the characteristics of the new technologies. For that reason, each revolution brings "a paradigm shift in the direction of innovation and the criteria for competitiveness." But she argues that technologies will provide only "available potential"; "it will be the social forces and their institutions that will define what part of the new opportunity space will be deployed and how." She concludes that, "It is up to government, business, and society to agree on the convergent actions to bring forth the best of the possible futures."

## 3. Government and Growth—Addressing "Externalities"

The presence of increasing returns from knowledge spillovers means that—left to itself—the market will underinvest in R&D and knowledge formation relative to the social optimum. Because firms do not individually take the knowledge externality into account in their investment plans, this provides a role for government to support growth. This is due to positive spillovers from an incomplete ability to appropriate the private gains from knowledge. In general, ideas are non-excludable and nonrival (nonrivalry means that consumption of the good by one individual does not reduce availability of the good for consumption by others).[9] Many people can use ideas, which can be found in books, journals, or online. Many firms or people can use the same formula or designs at the same time, or duplicate them in the production process. In the classical model, this explains why all countries can, in the long run, catch up with the technology leaders by riding free on the available knowledge.

In the endogenous-growth framework, new equipment enables new ideas and better technologies. For example, investing in computers induces bright ideas on how to use them. This fuels increasing returns to scale in production, where investment in knowledge begets increased output and resources for further investment; a virtuous-growth spiral in which future output becomes "path-dependent."[10] Investing in network connectivity can enhance the speed at which new ideas in one sector can be adopted in another, or in which radically novel or disruptive ideas can be applied to make old processes obsolete. While the exact specifications of such models varied, most emphasized the importance of innovation and the spread of information.[11] In essence, Malthus' problem was that he failed to account for human ingenuity.

8. Perez (2009); see also www.carlotaperez.org
9. Obvious exceptions include patents and "informal" knowledge such as traditional know-how.
10. See "Special Issue: Endogenous Technological Change," *Energy Journal*, April 1, 2006.
11. Sala-i-Martin (1996) is one of many economists to emphasize education as a possible cause.

Many types of infrastructural investment—such as broadband networks—are subject to such externalities, while also bearing the characteristics of natural monopolies. Here, economies of scale can be fully realized only if industry ownership is concentrated and competition is limited. But monopolists tend to undersupply and overprice their products, inhibiting the adoption of innovative products—a phenomenon exacerbated by the lack of competitive pressure to innovate and the scope of managerial inefficiency. Natural monopolies warrant government regulation, especially where the alternative—breaking up or deregulating the monopolies—loses important cost savings associated with scale economies.

A final externality arises where integrated networks are required to make a technology valuable. Such network externalities arise when someone joining a network does not take into account the benefits that accrue to others from the expansion of network membership. As a result, there is a tendency for the social benefits of investing in network expansion to exceed the private benefits considered by potential new members, especially when the network is just being set up to take advantage of a new technology. When the network itself is a source of dissemination of knowledge and ideas, then the impact of the network effect is enhanced. Without public intervention, the market underinvests in expanding the network because suppliers cannot monetize the social gains. As a result, the public sector may need to regulate the behavior of network members once they have been encouraged to join. Integrated communications networks and energy distribution networks tend toward natural monopolies, but are also key propellers of multifactor productivity.

As Aghion and Howitt (1998) argue, these theoretical developments revitalized the economic literature on growth, leading to insights for the analysis of business cycles, sustainable development, international income distribution, and renewed awareness of the fundamental role of innovation in macroeconomic growth. Other stimulants of increasing returns include the propensity for skilled workers to group with other skilled workers in the formation of high-value clusters,[12] and the ability of patents to secure a stream of rents (the stream of earnings from property) from incremental innovation. The authors further developed these ideas to incorporate "Schumpeterian" growth—the idea otherwise known as "creative destruction"—which implies that firms search in an uncertain world for innovations that qualitatively improve production technology and make previous technologies obsolete. Unlike incremental innovation, disruptive innovation of this sort requires rethinking and reorganizing processes, redesigning networks, and changing behaviors. To the extent that increasing returns to scale can be realized, the ability of innovation to capture monopoly profits (albeit temporarily) is enhanced. As Joseph Schumpeter identified, temporary profits can enable monopolists and oligopolists to cover the relatively high costs and risks associated with R&D.[13]

The presence of increasing returns to scale means that higher growth can be generated by investing in capital stock, skills, and ideas. In direct contrast to the classical model,

12. Another driver is complementarities among goods.

13. Schumpeter (1942).

this implies that investment returns will be highest in rich countries; poor countries will tend to be mired in poverty traps while rich countries continue to break away from the pack in economic progress. This theoretical implication has been the subject of much empirical analysis, which we discuss below.

**3.1 The Role of Governance and Rules in Promoting Knowledge and Innovation.** There is another element of innovation and knowledge increasingly seen as central to driving growth: innovation in rules and governance in both the public and private sectors. Paul Romer points out that innovation is not limited to technologies; it also applies to rules, governance, and policies, all of which—like technological capital and knowledge capital—impell total factor productivity.[14] Poor policy innovation is usually associated with inefficient uptake of, and innovation in, physical and knowledge capital. Research and innovation in governance, policies, and frameworks for the execution of innovative, evidence-based policies are prerequisites to strong growth. The rules that govern society require innovative, fresh responses to problems as they emerge. For example, the response to climate change (perhaps the most pervasive social challenge today) will require a mix of carbon prices, emissions standards, regulations, and targeted inducements to develop, demonstrate, and deploy new technologies.

Evolving rules that govern how people interact with one another and the economy determine the framework of incentives available to capture the gains from *knowledge-led growth*. Social rules often hold back the potential introduction and exploitation of new technology. As Romer shows, new technologies are potentially harmful if not accompanied by rules that make growth sustainable—for example, rules that limit pollution, soil degradation, and overfishing.

Basic rules are essential for individuals to interact commercially. These include property rights and protection of the individual from coercion—what Robert Nozick (1974) terms the minimal state of the "night watchman." But for societies to thrive, the state must also have a role in enhancing opportunities, offering a higher quality of life that attracts skilled labor in an open economy. Rules must be extended to the provision of universal education, sanitation, water, congestion, building standards, transport networks, and urban planning. But because social provision usually requires the transfer of income to the state through taxation, the legitimacy of any social contract is a vital part of good governance.

A framework of rules is vital for success, and can be enforced by law or even by social custom. They can include many noneconomic attributes of well-being, including the need to preserve good health, the environment, and work-life balance. The evidence for the role of governance in promoting economic success is addressed below. Romer concludes, however, that the Internet will ultimately speed up innovation in physical technologies, making him optimistic on sustainable growth. Resource constraints will become more apparent as global living standards rise, but he argues this will not stop progress. The price mechanism may accelerate experimentation, innovation, and progress in finding some solutions to environmental crises. The need for complex communications and other infrastructure investment necessary to make communities work collaboratively means the ability of network technology to address governance externalities is greatly enhanced.

14. For details of Paul Romer's ideas on charter cities, see http://www.chartercities.org/blog/

## 4. The Empirical Evidence: What Drives Knowledge and Growth?

**4.1 Macroeconomic Evidence.** At first sight, the evidence in favor of endogenous growth is overwhelming; the knowledge stock has clearly expanded to the extent that empirically, diminishing returns to investment in physical and human capital have not materialized. In this obvious sense, the classical model appears to be refuted. The very existence of resources in fixed, limited supply should have vindicated the possibility of diminishing returns, but they did not. The neoclassical model, for reasons explained above, also predicts what Robert Lucas famously referred to as a "strong tendency to income equality and equality in growth rates…which simply cannot be seen in the world at large."

Although capital has flowed to some fast-growing, developed world economies, especially in Southeast Asia and South Korea (as predicted by the classical model), in general it has tended to reside within the rich world, where the bulk of technological innovation occurs. Evidence of poverty traps abounds, particularly in Africa, which has been both the poorest and slowest-growing region. Danny Quah (1996) found evidence of twin peaks in global income distribution, suggesting a distinct cluster of incomes around rich and poor, with few countries managing the leap from one to another.

Over the second half of the last century, the rich world continued to receive the bulk of gross capital inflows; the richest 20 percent of the world's population received about 90 percent of the gross capital inflows. The poorest 20 percent of the world's population received a mere 1 percent of gross capital inflows.[15] More recently, however, signs of convergence have been identified, especially with rapid economic development in India and China. Neither neoclassical nor endogenous-growth theories predict the striking fact that while most developing countries have been falling further behind in relative and even absolute income terms, a subset of these countries has grown much faster than developed countries. In the final quarter of the 20th century, the three fastest-growing countries were all developing countries (China, South Korea, and Thailand), and they grew on average more than 12 times as fast as the three countries with the highest per-capita incomes (Canada, Switzerland, and the United States).

**4.2 Does Geography Destine Countries To Fail…?** At the macroeconomic level, it is harder than it appears to identify the relationship between knowledge capital and physical capital. Physical capital accumulation is assumed to embody new knowledge, but differentiating between physical and knowledge capital and their relative contribution to productivity remains problematic. Krugman and Young (1995) argued that growth accounting could explain the bulk of the economic success of Southeast Asia and South Korea on the basis of capital accumulation, rather than a material rise in the growth of total factor productivity. They concluded that the Asian boom was due to perspiration rather than inspiration, and was unlikely to be sustained.

Many commentators argued that poor countries are held back not by lack of knowledge, but by the relative propensity for people in different countries to innovate and apply knowledge effectively. This depends on numerous other factors such as a country's

15. See Lucus (1990) and Easterly (2001a).

climate, propensity to war, disease (such as malaria, AIDS, and TB), culture, religion, and historical legacy. These may create poverty traps for reasons not associated with endogenous growth. A number of authors attempted to account in more detail for independent, non-knowledge-related factors. Sachs (2001, 2003), Bloom and Sachs (1998), and Gallup et al. (1998) found evidence that tropical location directly hinders economic development due to climate and higher rates of disease. One of the best determinants of economic performance, Sachs argues, is distance from the equator.

**4.3 ...Or Is It Institutions that Matter?** A number of authors such as Easterly and Levine (2003) and Acemoglu et al. (2001) argue that geography matters only through institutional development. They questioned the importance to economic development of geographic endowments like tropical climates, landlocked locations, ecological geography, diseases, or cash crops, and concluded that institutions and policies determine the extent to which these factors do affect development. Once country- and region-specific characteristics were taken into account, there was strong evidence for the classical model of convergence, whereby countries tend to converge on a steady-state output level. This process was dubbed "conditional convergence," and was taken by some to undermine evidence of endogenous growth.

Acemoglu et al. (2001) argue that during colonization, the governments of Europe established solid institutional environments protecting property rights in climates with low settler-mortality rates, and set up extractive institutions with weak property rights in climates with high settler-mortality rates. They provide empirical evidence that suggests the legacy of these past institutional characteristics is still present in today's societies, promoting or stifling economic development.[16] In response, Sachs (2003) argued that geography has a direct effect on development, after controlling for different institutional histories, when using malaria rates as the geographical variable.

This may sound like a dry academic debate, but the implications of these findings are vital. Countries seeking a better society cannot change their geographies, but they can change their system of governance. The data itself provides a partial explanation for the disagreements. Knabb (2005) argues that the results of these regressions are hugely sensitive to the sample employed. Removing one or two key countries from samples of more than 50 countries can completely change the conclusions, and the author reran many of the key studies to prove it.

**4.4 Government Strongly Influences Innovation and Growth.** It should be no surprise that the evidence at a macroeconomic level seems inconclusive. If boosting saving and investment was such an obvious enabler of growth, the empirical relationship would have been spotted a long time ago. In actuality, the world is a more complex place. The causal links among knowledge, wealth, and good governance will be multidirectional and mutually reinforcing, making it difficult to identify an independent trigger for success.

16. Hall and Jones (1999) provide additional evidence in support of this hypothesis, and Easterly and Levine (2003) find that geography and trade (a proxy for policy) are no longer statistically significant after controlling for variables among institutions.

Some economic historians, such as Mokyr (1990), North (1990), and Rosenberg and Birdzell (1985) have concluded that differences in governance and institutions are key to explaining economic success. Some even argue that factors such as codified rule of law also explain why the Industrial Revolution took place in the West rather than in other parts of the world, and why certain countries continue to be more innovative. A growing number of studies also emphasize that the structure of incentives facing agents in an economy are a crucial determinant of an economy's performance.[17] Rodrik (2004), for example, emphasizes five institutions important for growth and innovation—those institutions that protect property rights, provide regulatory oversight, promote more economic stability, and provide social insurance and conflict management. These studies supply evidence for the central importance of a country's institutions and economic policies in explaining why most developing countries fail to grow any faster than high-income countries, while at the same time, other developing countries (especially in Southeast Asia) have broken from the pack and grown faster than the rich countries.

Governance structures that limit firms' and individuals' uncertainty about property rights and contract enforcement appear to be preconditions for innovation, enterprise, and growth. Factors that limit innovation include the risk of expropriation and confiscation as well as the forced nationalization of foreign enterprises. They also include the risk that government or powerful interests will repudiate contracts. A tradition of law and order reflecting the degree to which citizens are willing to accept the authority of established institutions is also shown to influence innovation, enterprise, and wealth creation. Sound political institutions, a strong legal system, and provisions for an orderly succession of power (democratic or otherwise) also promote growth.

Some who have looked at the political and bureaucratic processes by which politically powerful groups enrich themselves find that corruption—especially when inconsistently applied—amounts to a significant dissipation of resources.[18] Eyeballing the top 20 and bottom 20 ranked countries in the Corruption Perceptions Index[19] makes clear the correlation between economic failure and corruption (see Table 1).

Growth is also supported by increased openness to trade and foreign investment, developed and well-regulated financial institutions, and deep and credible markets with consistent product-market regulation.[20] Finally, in poor countries, social support to enable opportunities in the form of health, life expectancy, nutrition, education (especially among women), and R&D also expand the TFP envelope of poor countries and raise steady-state growth, allowing them to catch up with richer societies.

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17. These include Barro (1996); Sala-i-Martin et al. (2004); Olson (1996); Olsen et al. (2000); Clague et al. (1995); Acemouglu et al. (2001); and Tradico (2008). Others not listed at the end of this paper include North (1990); Jones (1981); Knack and Keefer (1995); and Nugent and Lin (1995). In parallel, a growing literature emphasized the role of human development indicators such as life expectancy, infant mortality, and literacy on growth; see Easterly (1998), or regular reports of the United Nations Development Programmme (UNDP).

18. See Tullock (1967) and Posner (1975).

19. See http://www.transparency.org/policy_research/surveys_indices/cpi/2009/cpi_2009_table

20. Even with trade openness, the evidence is far from clear: see Sachs et al. (1995), Rodriguez 2007, and Wacziarg et al. (2003).

Table 1. Corruption Perceptions Index 2009

| Top 20 | | | | Bottom 20 | | | |
|---|---|---|---|---|---|---|---|
| Rank | Country/Territory | Score | Surveys Used | Rank | Country/Territory | Score | Surveys Used |
| 1 | New Zealand | 9.4 | 6 | 162 | Congo Brazzaville | 1.9 | 5 |
| 2 | Denmark | 9.3 | 6 | 162 | DR Congo | 1.9 | 5 |
| 3 | Singapore | 9.2 | 9 | 162 | Guinea-Bissau | 1.9 | 3 |
| 4 | Sweden | 9.2 | 6 | 162 | Kyrgyzstan | 1.9 | 7 |
| 5 | Switzerland | 9.0 | 6 | 162 | Venezuela | 1.9 | 7 |
| 6 | Finland | 8.9 | 6 | 168 | Burundi | 1.8 | 6 |
| 7 | Netherlands | 8.9 | 6 | 168 | Equatorial Guinea | 1.8 | 3 |
| 8 | Australia | 8.7 | 8 | 168 | Guinea | 1.8 | 5 |
| 9 | Canada | 8.7 | 6 | 168 | Haiti | 1.8 | 3 |
| 10 | Iceland | 8.7 | 4 | 168 | Iran | 1.8 | 3 |
| 11 | Norway | 8.6 | 6 | 168 | Turkmenistan | 1.8 | 4 |
| 12 | Hong Kong | 8.2 | 8 | 174 | Uzbekistan | 1.7 | 6 |
| 13 | Luxembourg | 8.2 | 6 | 175 | Chad | 1.6 | 6 |
| 14 | Germany | 8.0 | 6 | 176 | Iraq | 1.5 | 3 |
| 15 | Ireland | 8.0 | 6 | 176 | Sudan | 1.5 | 5 |
| 16 | Austria | 7.9 | 6 | 178 | Myanmar | 1.4 | 3 |
| 17 | Japan | 7.7 | 8 | 179 | Afghanistan | 1.3 | 4 |
| 18 | United Kingdom | 7.7 | 6 | 180 | Somalia | 1.1 | 3 |
| 19 | United States | 7.5 | 8 | | | | |
| 20 | Barbados | 7.4 | 4 | | | | |

Source: Transparency International, 2009

There is strong evidence to conclude that the per-capita incomes of poor countries remain a mere fraction of what they could be, primarily due to shortcomings in governance.[21] Olson et al. find that the quality of institutions and economic policies explains a significant part of the variation in growth rates across countries. Some studies, such as Clague et al. (1995) and Keefer and Knack (1995), also find that the quality of governance and institutions is important for explaining rates of investment.

Clemens (2002) concluded that 85 percent of wealth bias between rich and poor, whether caused by market failure or not, is domestic in origin. He argued that poor-country lenders are deterred from investing in poor countries to nearly the same degree as rich-country lenders. In other words, investors at the National Stock Exchange in Mumbai face much the same incentives to invest in India as do their counterparts on Wall Street. Imbs (2008) concluded that countries with poor property rights and underdeveloped financial markets are vulnerable to excessive foreign debt, have a propensi-

21. Olson et al. (2000) assume a Cobb-Douglas production function in each country to draw out differences in TFP and used a fixed-effect panel to relate cross-sectional country heterogeneity (assessed through fixed-country dummies) to governance.

ty to default, and collapse in all but concessional financial inflows. By contrast, exit from excess indebtedness is accompanied by improved governance and institutions.

**4.5 Does Good Governance Cause Innovation and Growth?** It is unlikely that cultural characteristics—rather than institutions—make people in some countries more innovative and willing to take growth-enhancing risks. The evidence that cultural characteristics are the key drivers of poor governance and low growth is not strong. Hall and Jones (1999) found that when correcting for factor inputs (types and vintages of machines, education of workforce), workers in poor countries tend to be three to five times less productive than those in the United States. Yet when these same workers migrate, they quickly earn salaries comparable to those of workers in their adopted countries.[22] Something seems to be holding back productivity in poor countries, and it appears unrelated to the amount of capital stock available. These natural experiments indicate that variation in real per-capita income across countries (where citizens of the richest countries are 40 times richer than those of the poorest) cannot be explained by differences in personal culture (Olson, 1996).

No test can definitively determine causality. There are likely to be covariance and corelationships with causality flowing in interrelated directions. For example, it is possible that the quality of governance is the *result* rather than the *cause* of productivity growth. (In fact, it is likely.) Rich countries with a history of rule of law and civil liberties tend to respect property, invest in education, and demand responsive government. It is likely that poor governance is both the result of poverty and an underlying driving cause. Such amplifying feedback mechanisms mean sustained, carefully targeted policy and institutional reform can trigger a reinforcing cycle of good governance and higher productivity.

Breaking into a positive growth and development cycle requires a trigger, and evidence suggests the trigger often comes in the form of a sustained improvement in governance. The changes in governance and economic policy that occurred when Deng Xiaoping reformed Maoist mainland China, the reforms in South Korea shortly after Park Chung-hee replaced Syngman Rhee, and Chiang Kai-shek's economic policy in Taiwan in the early 1960s provide ready examples.

A number of unsavory and heavy-handed political regimes have engendered economic stability for middle-class entrepreneurs and businesses. For example, Indonesia under Suharto and Chile under Pinochet promoted ruthless persecution and extermination of opponents, yet they and subsequent democratic, center-left regimes established a thriving environment for businesses and investment and promoted a burgeoning middle class. In both cases, institutional change preceded—and appeared to cause—growth of productivity or income. Cross-sectional evidence also exists of cultures and institutions exerting different economic influences on culturally similar societies: East and West Germany during the Cold War; North and South Korea; or pre-Deng Xiaoping mainland China, as compared to Hong Kong and Taiwan. These differences cannot be attributed to culture or any preceding differences in income or productivity.

22. The authors control for selection bias by limiting their sample to migrants only.

By contrast, higher incomes in many oil-exporting countries did not spark a transformation of governance. In some cases, large endowments and exports of primary products even appear to be negatively related to subsequent economic growth (Sachs and Warner, 1995b). On discovery of large mineral resources, small economies can suffer from real exchange-rate appreciations as their economies are swamped by capital inflows targeted at extraction. Factor resources are redistributed away from manufacturing exports to low technology-extraction sectors, a phenomenon somewhat inappropriately referred to as the "Dutch disease." Countries with strong institutions tend not to suffer to the same extent—Norway and the Netherlands are examples of economies that continued to prosper even after the discovery of large reserves of North Sea oil and gas in the 1970s and 1980s. By contrast, Taiwan began with few natural resources or capital goods, but grew rapidly over the second half of the 20th century.

In rich democratic societies, policy, culture, and frameworks have a strong influence on the degree of entrepreneurial innovation. The evidence suggests that countries that encourage the growth (as well as allow for the demise) of small firms tend to foster a more innovative environment than those that tend to emphasize support of mature corporations.

Entrepreneurial capitalism with limited restrictions on hiring, firing, and setting up new businesses tends to induce innovation more successfully than corporatist economies with large national champions. Baumol, Litan, and Schramm (2007) find that among developed economies, the United States and some Anglo-Saxon countries nurture innovators more successfully than the economies of continental Europe and East Asia because they encourage dynamic, young, high-growth businesses. It is these businesses, not mature companies, that exhibit the fastest innovation-led growth and push the technology frontier. Such enterprises tend to be the main sources of entrepreneurial activity.

The "United Nations E-Government Survey 2010" presented various roles for e-government in addressing the ongoing world financial and economic crisis. It concluded:

> *"The public trust that is gained through transparency can be further enhanced through the free sharing of government data based on open standards. The ability of e-government to handle speed and complexity can also underpin regulatory reform. While technology is no substitute for good policy, it may give citizens the power to question the actions of regulators and bring systemic issues to the fore. Similarly, e-government can add agility to public service delivery to help governments respond to an expanded set of demands even as revenues fall short. The costs associated with telecommunication infrastructure and human capital continue to impede e-government development. However, effective strategies and legal frameworks can compensate significantly, even in least developed countries. Those who are able to harness the potential of expanded broadband access in developed regions and mobile cellular networks in developing*

*countries to advance the UN development agenda have much to gain going forward.”*[23]

Unlike geographical conditions, governance and institutions are not set in stone. This means all countries have the potential to embark on the road to prosperity. In fact, the lesson to be learned from the empirical findings is that investment and knowledge formation can drive economic and technological progress in an enabling environment, with reliable property rules and consistent incentives for individuals and firms to take commercial risks. There is substantial evidence that countries can improve their ability to respond to investment and innovation, provided they adopt policies consistent with their successful uptake. By contrast, a good school, an R&D grant, or investment in broadband infrastructure will be wasted on a society where individuals are too scared to leave their homes, or where personal gain is contingent not on productivity, but on favoritism, corruption, and graft.

The evidence explains why knowledge and innovation tend to cluster in developed economies with strong governance. These countries commit billions of dollars of resources in technological infrastructure, education, skills training, R&D, and providing attractive locations for talent. The role of knowledge in growth is taken for granted. In developing countries, evidence also suggests governments making a credible commitment to economic success attract foreign capital and expertise. Krugman and Young’s findings in the mid-1990s now appear outdated and premature. South Korea, China, and India provide strong examples of how early investment—initially of the capital-intense “quantity rather than quality” variety—can eventually spur growth in domestic technological enterprises by attracting skilled labor and ideas vital to boosting endogenous growth. Together with Malaysia, Thailand, Indonesia, and others, many of these countries provide healthy refutations of Sachs’ infamous equator-proximity effect. Consistent perspiration sooner or later begets inspiration, but it takes time, commitment, and leadership.

**4.6 Microeconomic Evidence Linking Innovation to Growth**. Empirical analysis at the microeconomic level also provides compelling evidence that technical change from learning and experience drives productivity growth. The evidence presented above suggests there are positive spillovers from knowledge, characterizing innovation by increasing returns and imperfect competition. The experience-curve literature provides strong empirical evidence that rates of cost reduction increase with experience, though these vary widely. These uncertainties lead to the conclusion that endogenous technical change is fundamental to economic growth, but the mechanisms by which this happens and the strengths of the effects are not yet clear.

The importance of technical innovation in driving sustainable growth is the subject of increasing academic and empirical investigation. In a groundbreaking special edition of the *Energy Journal*, Köhler, Grubb, Edenhofer, and others showed how, in a world of induced innovation, policy incentives such as prices or regulations to develop new technologies could lead to accelerated learning, experience, and the exploitation of

23. http://www2.unpan.org/egovkb/global_reports/10report.htm

scale economies in low-carbon energy that would make such technologies fully competitive with fossil fuel equivalents.[24] Of course, a switch to renewable technologies is likely to crowd out induced innovation in established fossil-fuel technologies. Nonetheless, scope for learning and spillovers is arguably larger in new technologies than in established ones. In other words, a low- or zero-carbon world may cost no more in terms of output or growth than a high-carbon, business-as-usual world, reflecting the post-Malthusian role of knowledge in increasing resource intensity.

An early and temporary policy push to support R&D may be sufficient to induce a virtuous spiral of innovation and creativity. A recent paper by Acemoglu et al. (2009) explains how endogenous growth and induced innovation favor an early push to support sustainable technologies. As long as these sustainable technologies are ready substitutes for existing "dirty" technologies, this will increase their market size. This triggers a virtuous cycle of innovation and profit through learning and experience. Because of virtuous-growth dynamics, virtuous cycles are relatively insensitive to issues like the discount rate used to determine preferences across time. The paper recommends a "jump-start" policy to spark path-dependent, dynamic innovation, which can be progressively withdrawn once economies of scale have been established.

This contrasts markedly with the slow policy-ramp approach recommended by Nordhaus and others, where technological progress is assumed to be exogenous, that is, independent of investment, learning, and experience. The conclusion is intuitive—to achieve enduring and dynamic innovation to meet prestated goals, policymakers must start with bold, clear, and credible policy signals to generate scale economies, and not vague, long-term commitments. This greatly reduces the long-run resource cost of the policy. Aghion suggests that by symmetry, this conclusion should be applicable to network technology investment, which would reduce resource inefficiency and generate innovation, but require up-front investment.

## 5. How Network Technology Spurs Innovation and Growth

The network externality and public-good characteristics of network technologies mean the social returns for smart-network technologies are likely to be greater than the private gains. This implies the need for public intervention and resources to secure the socially optimal provision of networked technology infrastructure. Some of these externalities and the role of network technology as a growth-enabling utility are outlined in sections 4.2 to 4.6. Section 4.1 starts by assessing the contribution of information technology to expanding the technological frontier in rich countries.

**5.1 Network Technology Helps Push the Technology Frontier.** It is now widely recognized that information and communications technology (ICT) was critical to the dramatic acceleration of rich-world labor-productivity growth from the mid-1990s. Robert Solow famously quipped in the mid-1980s, "You can see the computer age everywhere except in the productivity statistics"—a dilemma that became known as the "Solow Paradox." It was only after the massive ICT investment boom of the late 1990s that productivity

24. See Kohler et al. (2006) and a special issue of *Energy Journal*, April 1, 2006.

increases in the ICT-*producing* sectors were identified as important sources of growth. Brynjolfsson et al. were among the first to use new data to address the paradox. They found a significant positive relationship between ICT investments and productivity.[25]

A recent comprehensive study of U.S. input-output data sought to locate precisely the contribution of ICT.[26] Jorgenson found that that the first phase of ICT-led productivity growth did indeed come from ICT manufacture, induced by the increasing power of processors and falling ICT prices. Declining prices in the ICT sector led to capital deepening as sectors incorporated new technologies. After the dot-com crash of 2000, the productivity-growth contribution from ICT shifted from manufacturers to service providers (especially finance, legal, and other business services) as office software and the Internet increased the efficiency of output following significant reorganization of production around ICT. This allowed new knowledge spillovers relating to processes and technologies to spread across sectors aided by the rapid expansion of network communication. As a result of this, Jorgenson argued that underlying private-sector productivity growth was likely to remain at around 2.5 percent per year over the period of 2005 to 2015—a pace that is only moderately under the average for 1995 to 2005. He expected about half of the projected growth in U.S. TFP to come from ICT (including networked technology), which will continue to drive productivity increases in ICT users (see Table 2).[27] Similar results have been reported in the European Union, and Fornfeld et al. (2008) found that, accounting for simultaneity problems, intense broadband application has the power to contribute 75 percent to GDP growth.[28]

A study by the World Bank of the impact of broadband worldwide[29] found that the coefficient on average broadband penetration for high-income countries was positive and significant. The World Bank study specified an endogenous-growth model and estimated the impact of broadband penetration on the average growth rate of per-capita GDP across 120 countries. The results were consistent with the literature on conditional convergence. The average growth rate of per-capita GDP between 1980 and 2006 showed a significant negative correlation with initial per-capita GDP and a positive correlation with the average share of investment in GDP.

25. See Brynjolfsson et al. (1998, 1999).

26. See Jorgenson (2007).

27. An interesting question relates to network technology's contribution to the growth of unmeasured added value. The National Accounts do not capture all value added in society. Paid housework, childcare, and gardening form part of GDP, but the same activities undertaken by householders for free do not. Contributions to Wikipedia or free videos on YouTube are similarly not measured in the National Accounts, but do add value. In many cases, the network is both a source of intermediate output (knowledge on Wikipedia or Google being used to inform business) and final output (free videos on YouTube or directions on Google). In the latter case, where the network supplies a final good, its value may not be appropriately measured in National Accounts.

28. See also Rincon-Aznar and Vecchi (2004).

29. Qiang et al. (2009).

**Table 2.** U.S. Output and Labor Productivity Projections

| | Projections | | |
|---|---|---|---|
| | Pessimistic | Base-Case | Optimistic |
| | | Projections | |
| Private Output Growth | 2.12 | 3.25 | 3.76 |
| Average Labor-Productivity Growth | 1.36 | 2.49 | 3.00 |
| | | Common Assumptions | |
| Hours Growth | 0.76 | 0.757 | 0.76 |
| Labor-Quality Growth | 0.15 | 0.149 | 0.15 |
| Capital Share | 0.42 | 0.423 | 0.42 |
| Reproducible Capital-Stock Share | 0.81 | 0.809 | 0.81 |
| IT-Output Share | 0.05 | 0.046 | 0.05 |
| | | Alternative Assumptions | |
| TFP Growth in IT | 8.05 | 9.52 | 10.77 |
| Implied IT-Related TFP Contribution | 0.37 | 0.43 | 0.49 |
| Other TFP Contribution | 0.14 | 0.45 | 0.59 |
| Capital-Quality Growth | 0.86 | 1.72 | 2.05 |

**Notes:** In all projections, hours growth and labor-quality growth are from internal projections for 2005-2015, capital share. Reproducible capital-stock shares are 1959-2005 averages, and the IT output shares are the 1995-2005 average. The pessimistic case uses 1973-1995 average growth of IT-related TFP growth, non-IT TFP contribution, and capital-quality growth. The base case uses 1990-2005 averages, and the optimistic case uses 1995-2005 averages.

Source: Jorgenson, 2007

The results hinted at a noticeable growth dividend from broadband access in developed countries. The study suggested that the per-capita GDP growth of a high-income economy with 10 percent broadband penetration tends to be 1.21 percentage points higher than the global average. This potential growth increase is substantial, given that the average growth rate of developed economies was just 2.1 percent between 1980 and 2006. The growth benefit from broadband associated with developing countries was similar to that of developed economies—about a 1.38 percentage point increase for each 10 percent increase in penetration.[30] In 2006, 3.4 percent of the population in low-income countries and 3.8 percent in middle-income countries had broadband, compared with 18.6 percent in developed economies.

A further study by Nathan Associates (2009) using country-specific Cobb-Douglas production functions for Southeast Asia further corroborated the initial World Bank findings. Another study by LECG (2009) on the impact of broadband in the Organisation for Economic Co-operation and Development (OECD) specified an augmented Cobb-Douglas production-function model and estimated the effects of broadband penetration on productivity growth across 15 OECD countries. It also found positive and statistically significant effects of greater broadband penetration.

30. The coefficient was statistically significant at 10 percent, but not at 5 percent, perhaps reflecting that broadband is a recent phenomenon in developing countries and penetration has not yet reached a sufficient size to generate statistically significant aggregate effects.

It is too early to draw definitive conclusions from these studies, given the ever-present problems of causality and specification inherent in endogenous-growth models. As a consequence, the quantitative results probably overstate the impact of broadband as a contributor to GDP growth. The specification of the independent variable is likely to pick up the impact of variables that co-vary with both income and technological investment. The difficulty in correctly accounting for causality and the need to instrument for the influence of ICT is acknowledged in the Appendix to Chapter 3 of the World Bank paper. Nevertheless, despite its shorter history, broadband seems to have a higher growth impact relative to communications technologies such as fixed and mobile telephony and the Internet, the impact of which have been assessed using identical methodologies.

It is likely that the network has been a catalyst for expanding the knowledge frontier. This goes beyond its ability to relay and disseminate ideas and information. The interactive exchange of ideas over the network allows knowledge to evolve as the network of experts engage, communicate, and develop ideas. The network significantly facilitates the process of expert discussion, peer review, and dialogue. Public policymakers, entrepreneurs, and businesses then innovate, execute, replicate, and commercialize the latest ideas.

Network technology reduces the startup costs of small, dynamic firms by immediately raising their access to information and expertise. A study by the National Institute of Economic and Social Research in the United Kingdom found that impact of network ICT on productivity is roughly twice as high in the services sector as in the manufacturing sector, and that 90 percent of the firms in the services sector improve their productivity by 9.8 percent when using e-commerce.[31] This enables successful entrepreneurs (often with liberal arts or science training rather than business degrees) to start dynamic new enterprises that tend to galvanize innovation and TFP growth.[32] This further enables innovation to expand the technology frontier in advanced economies.

**5.2 Network Technology Enables Diffusion of Ideas and Financing to Less-Developed Regions.** For many developing countries, the primary barrier to productivity growth is not lack of innovation; it is insufficient diffusion of existing ideas, knowledge, and best practices available in the rich world. Network technology facilitates the diffusion of knowledge and breaks down the importance of distance. ICT can also allow global enterprises greater access to cheap financing. Entrepreneurs with limited collateral in remote developing regions often encounter information barriers that preclude banks and venture capitalists from lending on the same favorable terms as in the rich world. By increasing transparency, ICT can provide creditors with more information on the risks to their investment, thereby lowering the required risk premium. The growing success of mobile phone banking in poor rural regions of Kenya and Mexico is a precursor to the power of mobile network technology in broadening the reach of financing.

**5.3 Network Technology Enables Opportunities for Growth and Innovation.** Network technology can help alleviate barriers to business innovation by improving resource efficiency through smart production and distribution systems, just-in-time inventory,

31. See Rincon- Aznar (2005).

32. See Baumol et al.

supply-chain management, and the encouragement of efficient consumption. Network technology has been shown to promote smart monitoring and management at every scale, using a system of global sensors—from satellite and terrestrial to nanosensors—with the potential to measure almost every variable on the planet and promote more efficient usage of fixed resources such as land and water. Policies that support broadband technology can reduce energy consumption. A smart grid can efficiently manage the distribution and consumption of energy and integrate various sources of renewable energy into the power system.[33] Broadband-network technology can reduce travel costs and fuel use associated with business, education, and medical-related travel. Sustainability may exercise just the right pressure on a company's bottom line to spur innovation and competition.[34]

Network technology can improve individual and corporate security while generating accountability and transparency, limiting the misallocation of resources through corruption and graft. Travel substitution and virtual collaboration tools such as high-bandwidth telepresence have already begun to erode the need for costly travel. This trend is likely to accelerate as virtualization and teleworking become increasingly common, with substantial efficiency gains for individuals, businesses, and governments, and social gains for families in preserving work-life balance. There is an also an opportunity to reduce corruption and bribery by using automated regulatory, licensing, and tax-processing systems to replace in-person interactions with government officials.

High-quality, transparent, and inclusive governance is essential to fully enable the power of the market to operate effectively.  Defending property rights; limiting regulation, bureaucracy, and corruption; and reducing business cost promote economic dynamism and innovation. By engaging civil society, network technology can enable inclusive and transparent government. This encourages informed, interactive, and participatory government rather than purely representative democracy (without recourse to frequent and disruptive plebiscites). Network technology not only increases the effectiveness of most branches of public-sector activity, it also enables new opportunities for citizens by providing responsive infrastructures in health, education, transportation, and justice. Changing the relationship between the citizenry and government is never easy, and such change will encounter opposition from many vested interests that stand to lose privileges. But higher uptake of network technology can help embed a more representative system of governance among those societies eager to break the deadlock of poverty. As a means of identifying and overcoming the forces of poor rule-setting, connectivity has much to offer.

Another recent study by the World Bank (2008) found that successful technology diffusion within a country is closely linked to its economic growth, and depends on the quality of governance, infrastructure, property rights, education, social inclusion, and a host of key institutional factors. Although these do not constitute sufficient conditions for sustainable and rapid economic growth, they do seem to be necessary conditions. There are many instances where property rights, open markets, and regulations to address market failures have failed to generate sustainable, knowledge-led growth.

33. See, for example,  Progressive States Network (2010).

34. See Nidumolu et al. (2009).

There are no examples, however, of sustained, rapid economic growth without these basic institutional and political prerequisites.

A note of caution is required. History suggests that transparency need not be a key determinant of economic success, even though it may be associated in the longer run. The recent history of economic development in China and other Asian countries attests to this. Although it is undeniably true that governance—that is, institutions and policies—can encourage enterprise and innovation (for example, through securing rights to profit without arbitrary appropriation), its ability to do so depends on deeper historical and cultural forces. Transparency may or may not be among these causal forces. Indeed, in some countries where good governance conditions do not exist, transparency may even aggravate divisive forces. For example, transparency may promote conflict in heterogeneous and ethnically diverse populations, often delineated by colonial boundaries, which face internal tribal divisions. Such countries, however, are also less likely to take advantage of the power of network technologies to promote other aspects of economic development, such as efficiency gains and access to segmented, globalized markets.

**5.4 Network Technology Addresses "Market Failures."** A key role for government is to harness the power of the market, but also to intervene in the exceptional cases where the market fails to act efficiently. Only public authorities can address market failures where the private sector generically underinvests due to underprovision or asymmetric provision of information. Energy efficiency is an example. The cheapest appliance, home, or vehicle is often not the most efficient in the long run, but consumers are often unable or unwilling to make an informed choice on every purchase. This is why standards and regulations are common in buildings, vehicles, and domestic appliances, helping consumers save money (and reduce waste and environmental degradation). Smart monitoring and management systems are also central to detecting inefficiency, helping locate and price environmental damage and make the process of monitoring and regulating waste successful. Networked technological collaboration tools are one of the key elements propelling the resource-efficient, smart economy.

Technological support across the innovation chain—from research to demonstration and commercialization—also requires public support. This is because knowledge spillovers are hard to capture by privatized innovators, investment lifecycles are often too long, and risks (often policy-related) are too large for the private sector to assume alone. Network externalities and economies of scale (which can lead to monopolies stifling innovation or inadequate and poorly integrated infrastructures, as outlined above) in traditional utilities—and increasingly in broadband connectivity—also need regulation and support.

Knowledge spillovers are not the only source of increasing returns to scale. Spatial economies have long existed in processing industries such as chemicals and refining and assembly-line production. Unlike knowledge spillovers, however, at some point diminishing returns set in. Increasing the size of these plants becomes unfeasible: transport infrastructures are overwhelmed; suitable land for plant and docking facilities cannot be found; problems of pollution and congestion build; and shortages of skilled engineers and technicians emerge. Such constraints are less pressing for "intangible" production of knowledge services.

**5.5 Network Technology Reduces Economic Instability and Systemic Risk.** Integrated systems also have a role to play in improving real-time macroeconomic data and risk management. On one hand, highly integrated networks can exacerbate short-term speculative flows by amplifying "herd" behavior. On the other hand, network technologies can offset the impact of highly connected financial markets in propagating speculative trades and accelerating systemic risk. For example, a transparent and credible mechanistic approach to macroeconomic management can disseminate information efficiency to take the "fizz" out of economic excess and limit unsustainable and destabilizing macroeconomic imbalances. Such a mechanism could apply the brakes through reserve requirements, capital adequacy limits, liquidity ratios, or changes in policy rates, and can be triggered by a mix of macroeconomic and microeconomic variables.[35]

On balance, the evidence suggests that greater stability (especially where this corresponds to low and stable inflation) tends to raise business confidence and promote investment.[36] Instability, however, can promote creative destruction by shaking up markets, weeding out unproductive activities, and bursting speculative markets. A number of authors find that growth and volatility correlate negatively at the country level, but positively across sectors.[37] Imbs (2007) concludes: "Cross-country estimates identify the detrimental effects of macroeconomic volatility on growth, but they cannot be used to dismiss theories implying a positive growth-volatility coefficient, which appear to hold in sectoral data." In particular, he notes, volatile sectors command high investment rates. It is hard to draw unequivocal conclusions, but one interpretation might be that stable inflation and demand are favorable for national growth, whereas protecting sectors from volatile shifts in market tastes and structures diminishes long-term competitiveness and productivity performance.

Only the public sector has the power and size to offset macroeconomic imbalances and counteract large-scale shifts in private-sector confidence and spending. During recessions, public authorities can do this by spending or cutting taxes (thereby borrowing against future taxpayers) to offset risk-averse underspending by firms and individuals. In good times, the reverse is required, with reduced public debt offsetting increased private debt, and tighter regulatory requirements used to guard against speculative bubbles. In downturns, macroeconomic management favors investing in "shovel-ready" infrastructure projects to boost demand and jobs, while leaving a lasting legacy by expanding the economy's long-run growth capacity.[38] Investment in broadband networks serves both purposes and has featured in recent stimulus plans from the United States,

35. On the macroeconomic side, thresholds might be set for saving ratios, consumer debt, current account balances, or asset prices. The key is to help automate an early-warning process and break the link with confidence. Being non-discretionary, such a system is guaranteed not to be right except by coincidence, but at times of speculative excess, it is likely to be less wrong than following the herd and failing to respond to a clearly imbalanced economy.

36. Good institutions are conducive to macroeconomic stability, which in turn positively impacts economic growth, according to Gerry et al. (2008).

37. See Comin and Philippon (2005) and Comin and Mulani (2007).

38. See Bowen et al. (2009).

as well as Europe, China, and South Korea.[39] On the production side, such networks reduce output variability through better inventory control.[40]

**5.6 Network Technology Alters Spatial-Location Decisions.** Global integration of trade and financial flows has tended to raise the returns of good governance as well as the gains from innovation. This trend will be further strengthened as network connectivity reduces the physical impact of location on GDP by connecting disparate parts of the world with ideas and skills.[41] This has important implications for policymakers seeking to stimulate regional economic growth. The U.S. Department of Labor has indicated that the average young adult today will go through several careers during the course of a lifetime. Since many skilled people will be able to work wherever they live, they increasingly will choose where to live based on quality of life, so investments in factors such as sustainability and culture will be seen as part of a successful economic- growth strategy. Countries and cities will increasingly compete to attract skilled human capital (a process that has already begun). They will need to offer a location that enhances wellbeing, including social and cultural interaction.[42]

The presence of increasing returns on investment in knowledge and learning are likely to lead to the formation of skills and innovation clusters. According to Krugman's powerful 1991 paper, the interaction of increasing returns, trade costs, and factor-price differences will tend to limit trade and promote agglomeration. If knowledge and learning lead to economies of scale in a given sector, those economic regions with the most production in that sector will be more profitable and attract even more production. Instead of spreading out evenly across the world, production will tend to concentrate in a few countries, regions, or cities, which will become densely populated and have higher levels of income. Partially offsetting this trend, network technology has increasingly developed virtual rather than spatial clusters, linking innovators, producers, and stakeholders across the world.

It is not easy to predict when network technology truly will have transformed the spatial-location decision-making process of millions of skilled workers. But it seems probable that because of the network-externality nature of ICT, there will likely be a threshold or critical mass that prompts a jump in virtualization. Communications technologies are only as good as the number of people who use the technology, and at some point, billions of people will be linked to their work colleagues and stakeholders through high-bandwidth video-communications technology, reducing the requirement for physical interaction. It will therefore pay to invest early in ICT infrastructure to avoid being left behind; when the jump happens, it will be rapid. Only those with the infrastructural

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39. See Atkinson (2008), http://www.huffingtonpost.com/robert-d-atkinson-phd/the-right-broadband-stimu_b_152884.html

40. "The Information Technology Revolution," International Monetary Fund, *World Economic Outlook*, 2001.

41. "Economic Viability for American Cities in the Networked World of 2030," Norm Jacknis, Cisco IBSG (forthcoming).

42. The Institute for Urban Strategies recently published its "Global Power City Index (GCPI) 2009," ranking the top 35 global cities according to their capacity to attract talent. Its stated aim is to explore the "comprehensive power of cities to attract creative people and excellent companies from around the world" under conditions of increasingly "severe global competition among cities." GPCI examined New York, London, Paris, and Tokyo from multiple angles, and found them to be the most attractive cities on the basis of six main functions representing city strength (economy, research and development, cultural interaction, livability, ecology and natural environment, and accessibility), four global actors that lead the urban activities in their cities (managers, researchers, artists, and visitors), and one local actor (residents). GPCI is intended to be a useful tool for establishing urban strategies. Interested readers are encouraged to read Richard Florida's various papers on the "creative class" as well as subsequent critiques.

capacity (including planning and governance) will be able to take full advantage of the new workplace.

Virtualization does not mean that physical interaction will diminish in value, offsetting the attraction of economic clusters. Despite the virtualization of knowledge and learning, creative people will want to eat, drink, and interact with other creative people. Academics will want to discuss ideas with other academics. And people in general will want to stay in close proximity to their friends and families.

This means countries, regions, and cities will increasingly compete to attract such skilled talent. Enhancing the physical and cultural environment to attract talent and ideas is becoming essential to long-term economic success for any nation, region, or community. Who produces which differentiated product in which location seems largely arbitrary and is dependent on initial conditions. Silicon Valley, for example, does not owe its existence to natural endowments of factors of production that drive "Ricardian" comparative advantage. As Krugman notes, "God made the Santa Clara valley for apricots, not semiconductors." But once clusters emerge, they develop a competitive advantage in transmitting experience and know-how within the region. Examples outside Silicon Valley include London's financial services sector or Bangladesh's highly competitive garment industry. The development of clusters is "path-dependent" with long-lived inertia—clusters will be where clusters have been. Policy to facilitate smart, connected locations will increasingly influence where new clusters begin.

The ability of network technology to attract talent means that developing countries must try even harder to build an economically effective knowledge base. This will not be easy, and it behooves policymakers to ensure the foundations for success—but it is not impossible.[43] For many years, skilled Indians migrated to the United States and Europe in search of better opportunities and higher standards of living. Today, Indian and Chinese entrepreneurs are returning to their motherlands to set up dynamic, new companies and take advantage of domestic opportunities. Chinese students no longer must travel to the United States and the United Kingdom to obtain the best education. The best British and American schools have opened branches in mainland China, spurring renewed domestic competition for knowledge creation and talent utilization.

## Conclusion

Economic analysis shows that differences in total-factor productivity, rather than capital intensity, are the main determinants of cross-country differences in productivity and economic growth. Because technologies and ideas are generally accessible to all, classical economic theory suggests that all countries should free-ride on best practices, ultimately converging on comparable levels of productivity for any given capital intensity. The evidence, however, finds this is not the case. The income gaps between rich and poor remain wide, with many countries mired in poverty.

There is growing evidence that countries with good institutions, checks on government, and environments that enable social inclusion and entrepreneurial activities tend to 1) attract investment and 2) benefit from learning, experience, and innovation, so

43. "The Economics of Sustainable Urban Development," Dimitri Zenghelis, Cisco IBSG (forthcoming).

that productivity and income accelerate. By contrast, there is compelling evidence to conclude that the per-capita incomes of poor countries are curtailed because of shortcomings in institutional governance. In particular, the evidence suggests:

- The role of ICT (in particular Internet connectivity) has been a driving force of global TFP growth in recent decades—initially in the United States, then in the remaining rich world and developing economies.
- Some countries, especially in Southeast Asia, have managed—or are managing—the transition from poor to rich. Such "miracles" did not happen in a vacuum. They were triggered by good governance and institutions, a rise in domestic saving to fund capital-intensive investment, induced innovation based on new ideas, increasingly connected technologies, and improved learning.
- Knowledge embodied in new capital investment has served to increase the productive potential of factors in fast-growing countries, so that traditional diminishing returns are overcome, fueling a virtuous-growth spiral.

The above suggests that network connectivity has a special relationship with endogenous growth, not only in connecting businesses to a pool of knowledge and promoting the exchange of ideas, but also in allowing civil society to engage with government and access official resources and information. The network's function as an enabler of innovation allows it to generate constant or increasing returns at the whole-economy level. In that sense, it can be treated as a public-investment good akin to education or R&D. The impact of network technology may be especially great in poor countries. This is because connectivity can help poor countries access the knowledge and technologies commonly used in the rich world, while simultaneously improving the quality of governance and institutions that enable citizens to engage in profitable investment, innovation, and material advancement, thus breaking out of poverty.

The presence of increasing returns from spillovers, together with market failures due to monopolistic and oligopolistic competition, mean that left to itself, the market will underinvest in R&D expenditures relative to the social optimum. This raises the returns on well-managed public intervention. Network technology has a role to play in increasing public-sector efficiency, reducing the impact of the public sector on business costs, and limiting regulation and bureaucracy. At the same time, it can generate accountability and transparency, and limit misallocation of resources through corruption and graft. Such an environment is a precondition for businesses to plan and invest with minimal policy and regulatory uncertainty. Connected, transparent, rules-based institutions with credible policies and regulations can reduce uncertainty and establish market incentives for risk-taking, creativity, and entrepreneurship.

The economic literature increasingly identifies governance and knowledge as the key agents of innovation, growth, and prosperity. Among all the available means of inducing dynamic returns on investment and enabling innovation through good governance, network technology offers the greatest potential for benefiting even the poorest of the world's nations.

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## References

Acemoglu D., Aghion P., Bursztyn L., and Hemous D. (October 2009), "The Environment and Directed Technical Change," National Bureau of Economic Research Working Paper No. w15451.

Acemoglu D., Johnson S., and Robinson J. (2001), "The Colonial Origins of Comparative Development: An Empirical Investigation," *American Economic Review*, 91: 1369–1401.

Aghion P. and Howitt P. (1992), "A Model of Growth Through Creative Destruction," Econometrica, Econometric Society, vol. 60(2), pages 323-51.

Aghion P., and Howitt P. (1998), "Endogenous Growth Theory," MIT Press, Cambridge, Massachusetts.

Barro R.J. (1991), "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics,* 106: 407–443.

Barro R.J. (1996), "Democracy and Growth," *Journal of Economic Growth*, 1: 1–27.

Barro R.J. and Sala-i-Martin X. (1992), "Convergence," *Journal of Political Economy*, 100(2), 223-251.

Barro R.J. and Sala-i-Martin X. (1995), "Economic Growth," McGraw-Hill, New York.

Baumol W.J. (1986), "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show," *American Economic Review*, 76(5), 1072-1085.

Baumol W. J., Litan R.E., and Schramm C. (2007), "Good Capitalism, Bad Capitalism, and the Economics of Growth and Prosperity," Yale University Press.

Benhabib J. and Spiegel M.M. (1994), "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data," *Journal of Monetary Economics,* 34: 143–173.

Bloom D., Sachs J. (1998), "Geography, Demography, and Economic Growth in Africa," Brookings Papers on Economic Activity, 2: 207–273.

Bowen, A., Fankhauser S., Stern N., and Zenghelis D. (2009), "An Outline of the Case for a 'Green' Stimulus," Grantham Research Institute, London School of Economics and Political Science.

Brynjolfsson E. and Hitt L. (August 1998), "Beyond the Productivity Paradox: Computers Are the Catalyst for Bigger Changes," *Communications of the ACM*.

Brynjolfsson E. and Yang S. (1999), "The Intangible Costs and Benefits of Computer Investments: Evidence from the Financial Markets," MIT Sloan School of Management.

Clague, C., Keefer, P., Knack, S., and Olson, M. (1995, revised 1997), "Contract-Intensive Money: Contract Enforcement, Property Rights, and Economic Performance," University of Maryland, Working Paper 151.

Clemens M. A. (December 2002), "Do Rich Countries Invest Less in Poor Countries than the Poor Countries Themselves?" http://www.cgdev.org/content/publications/detail/2771

Comin D. and Mulani S. (2007), "A Theory of Growth and Volatility at the Aggregate and Firm Level," NBER Working Paper Series, Working Paper 11503, http://www.nber.org/papers/w11503

Comin D. and Philippon T. (2005), "The Rise in Firm-Level Volatility: Causes and Consequences," National Bureau of Economic Research, *Macroeconomics Annual 2005*, pages 167–202.

Tamara R. and Damuth R. (December 2009), "Estimating the Effects of Broadband Penetration on GDP and Productivity in Southeast Asia," Nathan Associates.

De Long J. B. (1988), "Productivity Growth, Convergence, and Welfare: Comment," *American Economic Review*, 78(5), 1138-1154.

Easterly W. (2001a), "Globalization, Poverty, and All That: Factor Endowment Versus Productivity Views," New York University.

Easterly W. (2001b), "The Lost Decades: Developing Countries' Stagnation in Spite of Policy Reform 1980-1998," *Journal of Economic Growth*, vol. 6, p: 135-145).

Easterly W. and Levine R. (2003), "Tropics, Germs, and Crops: How Endowments Influence Economic Development," *Journal of Monetary Economics*, 50: 3–39.

Herper M., ed. (2002), "More Business Thinkers and Transforming Ideas," *Forbes 85th Anniversary Issue*.

Fornfeld M., Delauney G., and Elixmann D. (2008), "The Impact of Broadband on Growth and Productivity," European Commission, DG Information Society and Media, 2008: pp. 7.

Gallup J., Sachs J., Mellinger A. (1998), "Geography and Economic Development," National Bureau of Economic Research Working Paper No. w6849.

Gerry C.J., Lee J.-K., and Mickiewicz T.M. (2008), "Macroeconomic Stability, Governance and Growth: Empirical Lessons from the Post-Communist Transition," Economics Working Paper (89), UCL School of Slavonic and East European Studies, London.

Hall R. E. and Jones, C.I. (1999), "Why Do Some Countries Produce So Much More Output per Worker than Others?" *Quarterly Journal of Economics*, 114: 83–116.

Imbs J. (2007), "Growth and Volatility," J*ournal of Monetary Economics*, October, 54(7).

Imbs J. and Ranciere, R. (2008), "The Overhang Hangover Revised December 2008," World Bank Economic Research Working Paper 3673, Center for Economic and Policy Research, DP 5210.

Islam N. (1995), "Growth Empirics: A Panel Data Approach," *The Quarterly Journal of Economics*, 110: 1127–1170.

Jacknis N. (forthcoming), "Economic Viability for American Cities in the Networked World of 2030," Cisco Internet Business Solutions Group.

Jorgenson D. W., Mun S. Ho, and Kevin J. S, (2007), "A Retrospective Look at the U.S. Productivity Growth Resurgence," Staff Reports 277, Federal Reserve Bank of New York.

Keefer, P. and Knack, S. (1995), "Institutions and Economic Performance: Cross-country Tests Using Alternative Institutional Measures," *Economics and Politics*, 7: 207–227.

Knabb S. D. (2005), "The Contribution of Institutions, Trade, and Geography to the Development Process: How Robust Is the Empirical Evidence to Variations in the Sample?" *Empirical Economics*, Volume 30, Number 2 / September, 393-409.

Köhler J., Grubb M., Popp D., and Edenhofer O. (2006), "The Transition to Endogenous Technical Change in Climate-Economy Models: A Technical Overview to the Innovation Modelling Comparison Project," *Energy Journal*, "Special Issue: Endogenous Technological Change and the Economics of Atmospheric Stabilisation," 17-55.

Kong T. (May 2007), "A Selective Review of Recent Developments in the Economic Growth Literature," Asian-Pacific Economic Literature, Vol. 21, No. 1, pp. 1-33.

Krueger A. (1974), "The Political Economy of the Rent-Seeking Society," *American Economic Review*, 64: 291–303.

Krugman P. (1995), "The Myth of Asia's Miracle," Foreign Affairs, http://www.foreignaffairs.com/articles/50550/paul-krugman/the-myth-of-asias-miracle

Krugman P. (1991), "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99, pp. 483–99.

LECG (2009), “Economic Impact of Broadband: An Empirical Study,” February 2009, http://www.connectivityscorecard.org/images/uploads/media/Report_Broadband-Study_LECG_March6.pdf

Lucas Robert E., Jr. (1988), “On the Mechanics of Economic Development,” Robert E. Lucas, Jr., *Journal of Monetary Economics*.

Lucas Robert E., Jr. (1990), “Why Doesn’t Capital Flow from Rich to Poor Countries?” *American Economic Review*, Papers And Proceedings, 80: 92-96 May.

Marshall A. (1890), “Principles of Economics,” Cambridge University Press, 1890, http://www.econlib.org/library/Marshall/marP.html

Needham J. (2005), “Science and Civilisation in China,” Vol. 4, part 2, Cambridge University Press.

Nidumolu R., Prahalad C.K., and Rangaswami M.R. (2009), “Why Sustainability Is Now the Key Driver of Innovation,” *Harvard Business Review*.

Nozick R. (1974), “Anarchy, State, and Utopia,” Basic Books, New York.

Olson M. (1996), “Big Bills Left on the Sidewalk: Why Some Nations Are Rich and Others Poor,” *Journal of Economic Perspectives*, 10: 3–24.

Olson M., Sarna N., and Swamy A.V. (2000), “Governance and Growth: A Simple Hypothesis Explaining Cross-Country Differences in Productivity Growth,” *Public Growth*, vol. 102, 3-4, pp.341-64.

Perez C. (October 2009), “Long-Run Economic Transformation after The Crisis: Technology, Globalisation and the Environment,” background text for the presentation at the OME International Foresight Forum, Barcelona.

Posner R.A. (1975), “The Social Costs of Monopoly and Regulation,” *Journal of Political Economy,* 83, 807–827.

Progressive States Network, Communications Workers of America, Sierra Club, and the Blue Green Alliance (2010), “Networking the Green Economy: How Broadband and Related Technologies Can Build a Green Economic Future,” http://progressivestates.org/files/greeneconomy/Networking-the-Green-Economy.pdf?q=greeneconomy/report

Qiang C. Z., Rossotto C. M., and Kimura K. (2009), “Chapter 3. Economic Impacts of Broadband,” from “2009 Information and Communications for Development: Extending Reach and Increasing Impact,” the World Bank, Washington, D.C.

Quah D. T. (July 1996), “Twin Peaks: Growth and Convergence in Models of Distribution Dynamics,” *Economic Journal*, Royal Economic Society, vol. 106(437), pages 1045-55.

Rincon-Aznar A., Robinson C., and Vecchi M. (May 2005), “The Productivity Impact of E-Commerce in the U.K, 2001: Evidence from Microdata,” National Institute of Economic and Social Research, http://www.niesr.ac.uk/pubs/dps/dp257.pdf

Rincon-Aznar A., Vecchi M. (2004), "The Dynamic Impact of ICT Spillovers on Companies' Productivity Performance," National Institute of Economic and Social Research, http://www.niesr.ac.uk/pubs/dps/dp245.pdf

Rodrik D. and Rigobon R. (2004), "Rule of Law, Democracy, Openness, and Income: Estimating the Interrelationships," NBER Working Papers 10750.

Rodríguez F. (August 2007), "Openness and Growth: What Have We Learned?" United Nations Department of Economic and Social Affairs Working Paper No. 51.

Romer P. M. (1986), "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, October, 94:5, 1002-37.

Romer P. M. (1990), "Human Capital and Growth: Theory and Evidence," Carnegie-Rochester Conference Series on Public Policy, 32, 251-286.

Romer P.M. (1990), "Endogenous Technical Change,"*Journal of Political Economy*, 98:S71-S102.

Romer P.M. (1994), "The Origins of Endogenous Growth," *Journal of Economic Perspectives*, 8:3-22.

Sala-i-Martin X. (1996), "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence," *European Economic Review*, 40, 1325-1352.

Sala-i-Martin X., Doppelhofer G., and Miller R. I. (September 2004), "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, vol. 94(4), pages 813-835.

Sachs J.D. and Warner A.M. (1995), "Economic Reform and the Process of Global Integration," Brookings Papers on Economic Activity 0(1): 1–95.

Sachs J.D. (February 2001), "Tropical Underdevelopment," National Bureau of Economic Research Working Paper 8119.

Sachs J. (2005), "Institutions Don't Rule: Direct Effects of Geography on Per Capita Income." National Bureau of Economic Research Working Paper 9490.

Schumpeter J. (1942), "Capitalism, Socialism and Democracy," Harper Perennial Modern Classics.

Solow R.M. (1957), "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39:312-320.

Solow, R.M. (1999), "Neoclassical Growth Theory," Taylor J.B. and Woodard M., eds., "Handbook of Macroeconomics," vol. 1A (North-Holland, Amsterdam).

Tradico P. (2008), "The Determinants of Economic Growth in Emerging Economies: A Comparative Analysis," Roma Tre University, Rome.

Tullock G. (1967), "The Welfare Costs of Tariffs, Monopolies and Theft," *Western Economic Journal*, 5: 224–232.

Wacziarg R. and Welch K.H. (2003), "Trade Liberalization and Growth: New Evidence," National Bureau of Economic Research Working Paper 10152, Cambridge, MA.

World Bank (2008), "Global Economic Prospects: Technology Diffusion in the Developing World," in "Global Economic Prospects and the Developing World," http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/02/15/000310607_20080215110511/Rendered/PDF/42097optmzd0REVISED0GEP020081PUBLIC1.pdf

Zenghelis D. A. (forthcoming), "The Economics of Sustainable Urban Development," Cisco Internet Business Solutions Group.



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