Chapter 3

Economic Impacts of Broadband

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Broadband has been increasingly recognized as a service of general economic interest in recent years.[1] Broadband's economic significance can be put into context by referring to similar changes in other areas of infrastructure, such as road, rail, and electricity. Each of these infrastructure services transforms economic activities for citizens, firms, and governments; enables new activities; and provides nations with the ability to gain competitive and comparative advantages. Though many of these advantages were unforeseen when original investments were made, they quickly became an essential part of economic lifestyles and activities. A similar assumption about the expected transformative benefits of broadband on economic and social variables has led many governments to set ambitious targets for its deployment.

In making a case for public policy on broadband, many studies have sought to identify and measure broadband's economic benefits. Though some of these studies have found a positive relationship between broadband access and economic development, most of them have been restricted to developed economies and their firms and communities, and to qualitative arguments and case studies. This chapter attempts to fill the gap on the macroeconomic evidence of broadband's impact, in both developed and developing countries.

This chapter has three sections. The first reviews the literature on the economic impacts of broadband—by enhancing the knowledge, skills, and networks of individuals; raising private sector productivity; and increasing community competitiveness. This section also explores broadband's role as an enabling technology in increasing investment payoffs in other sectors, transforming research and development (R&D), facilitating trade in services and globalization, and improving public services to enhance national business environments and competitiveness. The second section introduces a cross-country empirical model for analyzing broadband's impacts on economic growth using data from 120 developing and developed countries. Undertaking this quantitative analysis can provide policy makers with an assessment of the potential benefits of broadband and its impacts on the overall economy. The final section summarizes key results and implications for developing countries. The main conclusion is that broadband has a significant impact on growth and deserves a central role in country development and competitiveness strategies.

This chapter is not intended to debate the technological, regulatory, and content aspects of broadband or to analyze its social and political impacts—an important but complex issue often surrounded by controversies and subject to local cultural contexts. The awareness clearly exists in the academic literature and among industry leaders that broadband is associated with different classes of impacts, ranging from enhanced social networks and interactions to increased political activism and the spread of democracy through the grassroots organization of political movements and the spread and control of information. This broader

framework has an indirect impact on economic variables, even though it is not explicitly analyzed in this chapter. Policy and regulatory recommendations on how to facilitate access to and leverage the potential of broadband are also beyond the scope of this chapter; these are in part addressed in chapter 4 of this report.

Existing Literature

Some broadband applications and attributes are available with narrowband (dial-up links), raising the question of whether the benefits of broadband are more than marginal relative to the status quo (Bauer, Muth, and Wildman 2002). Over time, though, the advantages of broadband over narrowband are evident (Saksena and Whisler 2003):

- Progression from "e" (electronic) to "u" (ubiquitous) access: omnipresent, always on, and always aware of the user's location
- Higher connection speeds, which contribute to the spread of Internet protocol (IP) networks
- Enhanced cross-platform security to protect private communications and critical data, as well as embedded security among different platforms, applications, and environments
- Reduced costs for businesses through lower telecommunication costs (relative to the cost of leased lines) and transaction costs (for example, through enhanced customer relationships)
- Enhanced multimedia applications (for example, increased access to online video content)
- Increased development of complementary products (such as outsourcing) due to the global nature of networks and information services, as well as encouragement of global, real-time, and transparent competition.

Understanding the economic benefits of broadband involves several complexities. One is that a critical mass of broadband penetration—a common feature of network infrastructure—has been reached in only a small number of countries, and only quite recently. In this context, many facts are still evolving.

Another issue is that the literature tends to confound benefits with applications or attributes and the activities they enable, such as telecommuting and e-government (electronic government; Firth and Mellor 2005). This creates an impression that the benefits of broadband are unambiguous and does not take into account the investment costs involved—especially if public funding is required.

A third issue is that some of the reports and studies cited in the literature were commissioned by parties with direct commercial or policy interests in the industry's success—for example, telecommunications providers, associations of commercial firms, and government agencies with mandates to promote broadband. Moreover, impacts can take many forms, and causal links are often difficult to disentangle and analyze individually. Hence, findings may need to be interpreted with caution. Still, it is useful to examine how individuals, firms, and communities interact with broadband and how broadband enables transformational changes with each of these three players, as well as how broadband impacts the overall economy.

Individuals and Their Roles in Economic Processes

One crucial impact of broadband is its growing role in improving human capital, a necessary condition for economic growth and competitiveness. The benefits of broadband diffusion for individuals—such as better and more diverse access to information—have been documented in the literature. Broadband users spend up to 64 percent more time on the Internet than do dial-up subscribers (Saksena and Whisler 2003). An analysis of click-stream data on Internet use in 10 U.S. cities, comparing one group with dial-up access with a second group having broadband access, shows that content-intensive and socially interactive sites were used more often by those with broadband access (Rappoport, Kridel, and Taylor 2002).

Individuals can acquire skills (increasing their marketability as workers) and develop social networks through broadband-enabled Web applications, facilitating peer-to-peer communities and their integration with the economy. Blogs (online diaries), wikis (Web sites where users can contribute and edit content), and the like have created new, decentralized, dynamic approaches for capturing and disseminating the knowledge needed for individuals to become better prepared for the knowledge economy (Johnson, Manyika, and Yee 2005). It is also believed that broadband can enhance a city's or a country's appeal to the "creative class" of knowledge workers and attract human capital amid intensifying global competition for talented workers (Dutta and Mia 2008).

Broadband diffusion enables individuals outside the boundaries of traditional institutions and hierarchies to innovate to produce content, goods, and services. The role of network users in the innovation process increases as they generate or contribute to new ideas (user-led innovation, or "the democratization of innovation"; von Hippel 2005) and collectively develop new products (such as open source software). But few of the above claims have been empirically substantiated in the literature.

Firm Efficiency and Productivity

Most studies looking directly at the impacts of broadband tend to be conducted at the firm level. Evidence of broadband promoting firm growth has been fairly well documented in developed countries, particularly its ability to lower costs and raise productivity. Internet business solutions have enabled private companies to cut costs (by $155 billion in the United States and a collective $8.3 billion in France, Germany, and the United Kingdom) and increase revenues (by a collective $79 billion in France, Germany, and the United Kingdom)—suggesting that the companies focused their Internet solutions on growth rather than just on cost savings (Varian and others 2002).

For example, British Telecommunications (BT) had about 8,500 workers who worked from home using broadband in 2004, a setup that provides significant financial benefits to the company. On average, each worker saved the company accommodation costs of about £6,000 a year; had a productivity rate increase of 15–31 percent (averaging 20 percent); and took an average of only 3 days of sick leave a year, compared with an industry average of 12 days. All this added up to annual savings of more than £60 million for the company. BT has also extended flexible working arrangements to its engineers. The latest data from a trial of 3,000 engineers show that service quality has risen by 8 percent. The engineers in the trial worked an average of two hours less per week but earned more, and BT was saving money through the elimination of overtime payments (Broadband Stakeholder Group 2004).

Such improvements in performance depend on firms' ability to conjoin their technological, business, and organizational strategies. When fully absorbed, broadband drives intensive, productive uses of information and communication technology (ICT) and online applications and services, making it possible to improve processes, introduce new models and structures, drive innovation, and extend business links (box 3.1). Forman, Goldfarb, and Greenstein (2005) distinguish between "IT (information technology) using" and "IT enhancing" firms, and find that the changes broadband delivers to firm behavior generally lie on a spectrum—with the highest productivity increases appearing in firms that commit most intensively to integrating broadband, or IT in general, with new business processes.

On one end of this spectrum are firms where broadband diffusion is affecting their entire industries. Broadband connectivity and speed remove the need for proximity to customers and facilitate hyper-differentiation of customers and choice, in line with the popularization of "long tail" marketing strategies of niche products (Allaire and Austin 2005). For example, broadband is revolutionizing the print, movie, music, gaming, and advertising industries by enabling direct involvement by users in creating digital content (through the emergence of Web 2.0, Wikipedia, Facebook, YouTube, Blogger.com, and MySpace, among others) and high-speed downloads, and peer-to-peer distribution and interaction, reducing transaction costs and saving time for customers and producers (Heng 2006). Between 2000 and 2003, DVD sales rose $14.1 billion in the United States, of which 9 percent—$1.3 billion in revenues and $630 million in profits—was attributed to online sales enabled by increased broadband connectivity (Smith and Telang 2006). Developing broadband networks has been a key strategy for the Japanese animation industry to maintain its international competitiveness and remain a global market leader (Government of Japan 2003).

Export-oriented firms also benefit considerably from broadband use. Broadband lowers the costs of international communications and improves the availability of information, enabling companies to access foreign markets more easily and become more competitive. Clarke and Wallsten (2006), in a study of 27 developed and 66 developing countries, found that a 1 percentage point increase in the number of Internet users is correlated with a boost in exports of 4.3 percentage points and an increases in exports from low-income to high-income countries of 3.8 percentage points. Although this study was not broadband-specific, it is safe to infer that broadband would have an even bigger positive impact.

Broadband is also particularly important for firms in information-intensive service sectors, such as financial markets, insurance, and accounting. For example, some

Box 3.1 Broadband's Effects on Firms' Behavior to Increase Competitiveness

A number of examples show how broadband can help transform processes, business models, and relationships in the private sector.

- A study involving business and technology decision makers from 1,200 companies in six Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, and Mexico) showed that broadband deployment was associated with considerable improvements in business organization, including speed and timing of business and process reengineering, process automation through network integration, and better data processing and diffusion of information and knowledge within organizations (Momentum Research Group 2005).
- A 2005 study by McKinsey highlighted the growing importance of broadband to companies' competitiveness through new ways of structuring work. Modern companies build distinctive capabilities based on a mix of talent and technology; they specialize in core activities and outsource the rest. Broadband helps allocate activities more efficiently between workers tackling complex, highly dynamic tasks and more traditional, transactional workers. It is also a key component in raising the productivity of employees whose jobs cannot be automated, and in doing so cost-effectively (Johnson, Manyika, and Yee 2005).
- Companies that adopt broadband and ICT to transform their supply chains prompt other companies in their value and distribution chains to adopt new technologies and interoperable IT systems (Atkinson and McKay 2007). For example, the automobile industry's entire technology-intensive supply chain is linked through broadband networks and high-power computing. Broadband networks are essential to engineering design service firms to test and implement design options directly with car and parts manufacturers.
- Studies in the United Kingdom indicate that enterprises using broadband are more likely to have multiple business links. For example, they use e-mail and the Internet to raise the quality and lower the costs of gathering market intelligence and to communicate with suppliers and business partners. Enterprises with more links tend to have higher labor productivity (Clayton and Goodridge 2004).

98 percent of small and medium-size enterprises in Australia's finance and insurance industries use broadband (Australian Communications and Media Authority 2008). Increases of 25 percent or more in the number of claims processed each day have been documented by U.S. insurance companies that have adopted wireless broadband (Sprint 2006). Other examples include consulting firms, marketing, real estate, travel and tourism, advertising, and graphic design.

As wireless broadband applications become increasingly mature, the health care sector and small businesses are reaping big gains, especially from the mobility aspects such as not having to staff a head office, more ready access to corporate information, field service automation, and sales force automation. In 2005, productivity improvements because of the use of mobile broadband solutions across the U.S. health care industry were estimated to be worth $6.9 billion (Entner 2008).

Community Competitiveness

Deploying broadband networks at the community and municipal levels has become an important factor in allowing local businesses to grow and remain competitive. An often-cited 2005 study by the Massachusetts Institute of Technology of a broad range of U.S. communities where broadband had been deployed since December 1999 found that it benefits economic activity in ways consistent with the qualitative stories told by broadband advocates. Between 1998 and 2002, U.S. communities that were among the early adopters of mass-market broadband experienced faster growth in employment, number of

Table 3.1 Impacts of Broadband on Economic Activities in U.S. Communities

Indicator	Results
Employment	Broadband added 1.0–1.4 percentage points to the growth rate in the number of jobs during 1998–2002.
Number of businesses	Broadband added 0.5–1.2 percentage points to the growth rate in the number of firms during 1998–2002.
Housing rental rates (proxy for property values)	Rates were more than 6 percent higher in 2000 in zip codes where broadband was available by 1999.
Industry mix	Broadband added 0.3–0.6 percentage point to new business creations in IT-intensive sectors in 1998–2002.
	Broadband reduced the share of small business (those with fewer than 10 employees) by 1.3–1.6 percentage points in 1998–2002.

Source: Gillett and others 2006.

businesses, and businesses in IT-intensive sectors, as well as higher market rates for rental housing, than communities where broadband was adopted later (Gillett and others 2006; table 3.1).

Other studies of community-level broadband experiences include the following:

- A case study of a municipal fiber network built in 2000–01 in South Dundas Township, Ontario (Strategic Networks Group 2003)
- A study comparing Cedar Falls, Iowa (which launched a municipal broadband network in 1997) with its otherwise similar neighboring community of Waterloo (Kelly 2004)
- A study comparing per capita retail sales growth in Lake County, Florida, with 10 other Florida counties selected as controls based on their similar retail sales level prior to Lake County's broadband rollout (Ford and Koutsky 2005).

All these studies found that broadband connectivity had positive impacts on job creation, company and community retention, retail sales, and tax revenues. A more recent survey conducted for Industry Canada of subscribers to two remote, rural broadband networks in British Columbia found that about 80 percent of business respondents believed that they would be at a major disadvantage if they did not have broadband access (Zilber, Schneier, and Djwa 2005).

Even in rural areas of developing countries, broadband diffusion is making existing markets function better by reducing information asymmetry and creating a range of economic opportunities for communities—contributing to income diversification and rural nonagricultural employment as well as increasing incomes from agricultural jobs. In recent years, communities in developing countries have launched broadband-enabled services and applications to give local populations access to new markets and services and facilitate information exchange and value creation between buyers and sellers of agricultural products (box 3.2). Before that, many of these opportunities had been available only in the largest or wealthiest communities.

The Overall Economy

Broadband is not just an infrastructure. It is a general-purpose technology that can fundamentally restructure an economy. Thus, examining the overall economic impact is a logical way to assess the implications of broadband diffusion because it takes a more comprehensive view than looking only at impacts on individuals, firms, or communities.

The first generation of country-level studies on broadband appeared before the technology had been significantly adopted even in developed countries. In a study commissioned by Australia's National Office for the Information Economy (replaced by the Australian Government Information Management Office in 2004), Allen Consulting Group (2002) estimated that broadband would add 0.6 percentage point to Australia's gross domestic product (GDP) growth rate each year through 2005. According to 2003 estimates by Accenture, next-generation broadband has the potential to contribute $500 billion to GDP in the United States and from $300 billion to $400 billion in Europe, and was likened to water and electricity as the "next great utility" (Saksena and

Box 3.2 Broadband's Role in Raising Rural Incomes in Developing Countries

Experience shows that access to broadband networks has had a positive impact on rural incomes in developing countries. In India, the E-Choupal program was started in 2000 by ITC, one of India's largest agricultural exporters. The program operates in traditional community gathering venues (*choupals*) in farming villages, using a common portal that links multimedia personal computers by satellite. Training is provided to the hosts, who are typically literate farmers with a respected role in their communities. The computers give farmers better access to such information as local weather forecasts, crop price lists in nearby markets, and the latest sowing techniques. Collectively, these improvements have resulted in productivity gains for the farmers. E-Choupal also enables close interaction between ITC and its rural suppliers, which increases the efficiency of the company's agricultural supply chains, eliminates intermediaries, and improves terms of business. The fact that ITC pays a higher price than its competitors for exportable products has encouraged farmers to sell their increased output to the company. By 2008, E-Choupal had reached millions of small farmers in more than 40,000 villages, bringing economic and other benefits. It aims to reach 100,000 villages by 2010.

Another program, launched by the Songtaaba Association, has allowed female agricultural producers in Burkina Faso to become economically empowered through broadband. Songtaaba, an organization manufacturing skin care products, provides jobs to more than 3,100 women in 11 villages. In order to provide its members with regular access to useful information and improve the marketing and sales of their products, the association set up telecenters in two villages equipped with cell phones, Global Position System, and computers with high-speed Internet connections. The telecenters, managed by trained rural women, help the association run its businesses more efficiently. The organization also maintains a Web site that offers its members timely information about events where they can promote or sell their products. In the two years following the establishment of the telecenters and the launch of the Web site in 2005, orders have increased by about 70 percent, and members more than doubled their profits.

Sources: Agenda 2007; Bhatnagar and others 2002; ITC 2008; M. S. Swaminathan Research Foundation 2008; Shore 2005; UNCTAD 2006a.

Whisler 2003). Criterion Economics reached a similar conclusion, estimating that universal broadband access in the United States could account for $300 billion–$500 billion of GDP by 2006 (Crandall and Jackson 2001).

Some sources—including the Organisation for Economic Co-operation and Development (OECD; 2001)—have supported broadband's importance in terms of its potential and actual impacts on the overall economy, while others have suggested that the macroeconomic impacts of broadband are still to come (Galbi 2001). In the early 2000s broadband was still rare. All of these first-generation studies were hypothetical and forward-looking, and had little evidence on which to base their analyses.

More recent studies have analyzed actual broadband experiences. The Republic of Korea is often cited as a country where economic and employment growth resulted from proactive broadband policies (box 3.3). Broadband seems to have played a significant role in transforming Korea's overall economy and improving its global integration and competitiveness.

Broadband is also believed to play an important role in enabling innovation and R&D, important factors that contribute to sustainable economic growth. Broadband-enabled combinations of ICT and other technologies—such as biotechnology and nanotechnology—are considered essential to generating inventions and innovations in numerous fields (Carlaw, Lipsey, and Webb 2007). For example, according to the Commonwealth Scientific and Industrial Research Organization, broadband networks are transforming astronomy by allowing telescopes to be operated remotely. VLBI (very long baseline interferometry)-over-broadband is a new technique being tested and used

Box 3.3 The Republic of Korea's Experiences with Broadband

Korea is a well-known leader in broadband. Its government has both catalyzed rapid rollout of broadband infrastructure and facilitated the uptake of broadband services by citizens, businesses, and the public sector. In 2007, 99 percent of the country's households had access to high-speed Internet. About 90 percent subscribed to broadband, with half enjoying connection speeds of 50–100 megabits per second. Korea was ranked first in the International Telecommunication Union's (ITU's) Digital Opportunity Index that year.

In 1995, as part of its Information Infrastructure Plan, the Korean government stated its vision for nurturing a knowledge-based economy and identified robust broadband as the first step. It implemented its broadband strategy through a combination of deregulation, facilities-based competition, and privatization of the incumbent telecommunications provider Korea Telecom. The government also invested in the construction of backbone networks and provided subsidized loans to telecom operators to facilitate the development of local access networks. In 1995–2005, public investments totaled $900 million, triggering $32.6 billion in private investment.

The government also implemented broadband promotion policies designed to stimulate Internet use and aggregate demand among the population. In 2000, the government set up the Internet Education to Ten Million People Project, aimed at providing IT literacy training for all citizens. In addition to the training and awareness raising, the government vigorously promoted e-business incubation and IT use in public administration (e-government). Such policies and programs led to an explosion in demand.

The rapid deployment of broadband provided important opportunities for Korea's ICT industry. Some 300,000 jobs have been created in ICT, and the sector is growing three times faster than the rest of the economy. Particularly fast-growing areas of the sector include development of search engines and local content. In addition, Korea has developed a competitive advantage in certain niches of the ICT industry—such as online gaming, where Korean companies are the biggest global players.

Broadband has played a significant role in transforming Korea's overall economy and improving its global competitiveness. Korea's media, automotive, and banking industries have benefited from the introduction of broadband, changing their business models and production and supply chain management. According to the National Statistics Office, Korea's e-commerce market more than doubled between 2002 and 2006, from $178 billion to $414 billion. Moreover, a much larger share of the population in Korea accesses news information through broadband than in Europe, Japan, and the United States. This helps develop a well-informed population that is ready for global integration and competition. ITU (2005) attributes the rising share of ICT as a share of GDP in Korea in part to the country's early leadership in the broadband field, both fixed and mobile. In 1992, Korea's ICT industry contributed around 2 percent of its GDP, a percentage close to the world average. However, a decade later, ICT's share of GDP in Korea had risen to around 4.6 percent, almost twice the global average.

Sources: Authors' analysis; Ahonen and O'Reilly 2007; ITU 2005; Kelly, Gray, and Minges 2003; Korea National Statistics Office 2007.

in Australia, Europe, and the United States to process data from telescopes, allowing for new experiments and inferences that would not have been possible without high-speed broadband networks.[2] In the area of bioinformatics, the government of India has invested in the Biotechnology Information Systems Network (BISnet), a broadband network linking 57 research centers using a high-speed computer network, to tap synergies between ICT and biotechnology (Government of India 2005).

Broadband, as well as the digitalization of scientific content, also has a transformative effect on innovation processes. It allows around-the-clock R&D and concurrent development on multiple phases and projects in different locations. New forms of ICT-related innovation processes

are emerging and fundamentally changing how science and research are conducted. Broadband enables faster diffusion of codified knowledge and ideas, linking science more closely to business. It also lowers barriers to product and process innovation, fosters startups, improves business collaboration, enables small businesses to expand their R&D and collaborate with larger R&D consortiums, and encourages greater networking among the community of researchers (Van Welsum and Vickery 2007).

Many developing countries expect public investments in broadband—for education, health care, and the overall economy—to pay off. In 2006, the government of the Arab Republic of Egypt, in partnership with the private sector, installed a WiMax network to connect two public schools, a mobile health care center, a municipal building, and an e-government services kiosk in rural Oseem.[3] In April 2008, the government of Brazil formalized an arrangement with five fixed-line operators to build a broadband network to connect public schools in 3,440 municipalities by the end of 2010 (*Gazeta Mercantil* 2008). Even though the evidence in terms of measurable outcomes such as improved educational achievements and medical treatment results is not yet conclusive, there are numerous case examples pointing to the potential transformational impact of broadband connectivity on the effectiveness and efficiency of health and education service delivery (box 3.4). The greatest impact may be achieved in remote areas without direct access to critically needed medical specialists and qualified teachers.

Moreover, many governments believe that broadband is becoming increasingly important for globalization. This is beginning to have a fundamental impact on how economies work and on the global allocation of resources—especially for developing countries, due to their greater integration in global value chains than ever before (OECD 2008).

Box 3.4 Broadband-Enabled Telemedicine

The use of broadband-enabled telemedicine is widespread, both in developed and developing countries, yet there are few high-quality studies assessing its diagnostic efficacy and outcome capabilities. Many studies do not separate new opportunities offered by telemedicine from evaluations, which is required to adhere to standards of high-quality evidence. The best evidence for the effectiveness of telemedicine is in medical specialties for which verbal interactions are a key component of the patient assessment and when medical results comparable to in-person encounters can be achieved.

In remote areas without direct access to critically needed medical specialists, broadband networks allow health professionals to care for patients living in different rural locations using videoconference facilities. In such cases, even if the evidence of improved medical outcome is not proven, rapid diagnosis and treatment, reduced costs and travel time for patients, and decreased medical errors are tangible benefits, especially in the context of the ever-falling costs of broadband connectivity solutions.

The Aravind Eye Hospital in the southern Indian state of Tamil Nadu provides such a case in point. Using a wireless broadband network with speeds 100 times faster than a dial-up network, the hospital was able to connect five of its rural clinics in 2004 to provide eye services to thousands of rural residents. With high-speed links to the hospital, the clinics screen about 1,500 patients each month through a Web camera consulting with an Aravind doctor. This videoconferencing system enabled patients to have minor eye problems diagnosed and resolved locally; only those with more serious problems had to travel long distances to a hospital. Hence, patients were able to save on unnecessary travel time and cost, and avoided the corresponding loss in income. The hospital's study also showed that 85 percent of the men and 58 percent of the women who had lost their jobs due to sight impairment were reintegrated into the workforce after treatment. Thereby, the hospital was also able to address the shortage of rural doctors through this broadband system, and the pilot project proved so successful after just 17 months that plans have been made to implement a similar system in 50 clinics serving half a million patients each year.

Sources: Authors' analysis; University of California Berkeley 2006.

Broadband enables economic integration and encourages greater international competition in sectors and jobs that were previously uncontested. Rapid broadband diffusion and increasing speeds and bandwidth, along with the ongoing liberalization of trade and investment in services,[4] have increased the tradability of many service activities—especially business services—and created new kinds of tradable services. The availability, quality, and affordability of broadband services are now important factors for international investors when deciding whether to invest in a specific country. Developing countries with better ICT infrastructure attract more offshoring, outsourcing, and foreign investment (Abramovsky and Griffith 2006) and, as a result, trade more (UNCTAD 2006b).

The boom in broadband-enabled IT services and their clear contribution to GDP, employment, and exports have been well documented (see chapter 7). In India, software exports jumped from less than $1 billion in 1995 to more than $32 billion in 2007; the software industry now accounts for more than three-quarters of the country's services exports and employs 1.6 million people. Other developing countries, such as China, Costa Rica, the Philippines, and some small Caribbean islands, have benefited from the global outsourcing of IT services (Li 2003; World Bank 2008a). Because traded services are often transmitted through high-speed data networks, the advantage of broadband over narrowband is evident in this case. For example, electronic delivery of software, testing, and remote product updating, as well as training and technical assistance for customized software, cannot be performed without broadband.

At the same time, governments have increasingly leveraged broadband to have efficient, reliable, cost-effective public services that contribute to an attractive business environment and national competitiveness. Many good examples of e-government applications are in place today (see chapter 5). Ghana and Singapore, for example, have been successful in using broadband in customs and trade facilities (box 3.5).

Cross-Country Growth Analysis

The literature review above suggests that the presumed economic impacts of broadband are real and, in many cases, measurable. But most results have been restricted to developed economies, their firms and communities, and to case studies. Because broadband's benefits are pervasive, the best way to look at its impact is by focusing on economic growth, despite the complications that such an effort entails.

This section uses an endogenous growth model (Barro 1991) to test the impact of broadband penetration on the average growth rate of per capita GDP between 1980 and 2006. Such a macro-level econometric analysis makes it possible to control for other factors that may have similar impacts on growth, and thus explores the effects of broadband access specifically. In addition, a cross-country analysis sheds light on developing countries where empirical evidence is lacking. Annex 3A provides more details on the definition of variables, methodology, results, and limitations of the analysis.

The average growth rate of per capita GDP between 1980 and 2006 was used as the dependent variable and regressed onto the following variables, selected as representative of conditioning variables in the growth literature:

- Per capita GDP in 1980 (GDP_{80})[5]
- Average ratio of investment to GDP between 1980 and 2006 (I/Y_{8006})
- Primary school enrollment rate in 1980 ($PRIM_{80}$) (a proxy for human capital stock)[6]
- Average penetration of broadband and other telecommunications services between 1980 and 2006 for developed (BBNDH) and developing (BBNDL) countries (a proxy for technological progress and the focus of this analysis)
- Dummy variables for countries in the Sub-Saharan Africa (SSA) and Latin America and Caribbean (LAC) Regions.[7]

Data for all the ICT-specific variables are from the ITU (2007) and World Bank (2008b). The sample consisted of 120 countries, the majority of which are developing countries.

Table 3.2 summarizes the results from the growth regression, which are consistent with the literature on endogenous growth: the average growth rate of per capita GDP between 1980 and 2006 was negatively correlated with initial GDP per capita (GDP_{80}) and positively correlated with the average share of investment in GDP (I/Y_{8006}). Consistent with the convergence implication of the neoclassical growth model, the coefficients on these variables were significant.

The coefficient on average broadband penetration for high-income countries (BBNDH) was positive and significant. This result suggests a robust and noticeable growth dividend from broadband access in developed countries: all

Box 3.5 Broadband-Enhanced Trade Facilities in Ghana and Singapore

Ghana. In 2003, Ghana introduced the GCNet customs system as an ICT-based solution to foster trade development and facilitation and ensure effective mobilization of customs revenues. The electronic data interchange system links all the main players in the clearing process, enabling quick online processing of customs clearance documentation and facilitating clearance of goods through ports. Among other features, the system allows around-the-clock submission of customs documents, provides a one-stop platform for processing and verifying trade documents, and enables systematic monitoring of consignment movements. Within its first 18 months, GCNet increased customs revenues by 49 percent and substantially reduced clearance times.

The system's backbone is a private broadband communication network that consists of a fiber-optic broadband link between the GCNet office and the Customs, Excise, and Preventive Services Department, and is complemented by radio links and leased lines to the department's offices throughout Ghana. By increasing the speed, reliability, and transparency of the clearing process and revenue accrual, broadband contributes directly to the country's competitiveness and economy.

Singapore. SingaporeONE was launched in 1998 to connect citizens, firms, and the government in a single broadband network. A public-private consortium, 1-Net Singapore, was formed to run SingaporeONE's backbone. Infocomm@SeaPort is one of the programs that uses SingaporeONE's broadband capacities. It was launched in 2007 to enhance the capabilities and efficiencies of Singapore's ports and improve the port community's infrastructure. One of its first projects is WISEPORT, a mobile wireless broadband network providing low-cost, high-bandwidth, secure access within 15 kilometers of Singapore's southern coastline. By the end of 2008, all ships in Singapore will have access to mobile wireless broadband, allowing real-time and data-intensive communications between the ships and their customers and business partners. The parties involved will be able to perform multiple tasks remotely, including regulatory filings and real-time access to navigational data. This network is aimed at maintaining Singapore's competitiveness relative to other growing ports in the region.

Sources: de Wulf and Sokol 2004; Ghana Shippers' Council 2008; Keng and others 2008.

Table 3.2 Growth Regression Separating Effects of Broadband Penetration

Variable	Coefficient	t-Statistic
GDP_{80}	–0.100	3.86
I/Y_{8006}	0.164	5.46
$PRIM_{80}$	0.001	–0.18
BBNDH	0.121	2.87
BBNDL	0.138	–1.96
SSA dummy	–1.018	2.19
LAC dummy	–0.655	–1.55
Constant	–1.726	–1.83

Source: Authors' analysis.

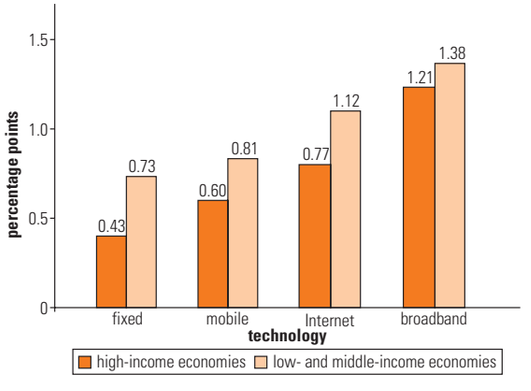
Note: BBNDH = average broadband penetration for high-income countries between 1980 and 2006; BBNDL = average broadband penetration for middle- and low-income countries between 1980 and 2006; GDP_{80} = per capita gross domestic product (GDP) in 1980; I/Y_{8006} = average ratio of investment to GDP between 1980 and 2006; LAC = Latin America and the Caribbean Region; $PRIM_{80}$ = primary school enrollment rate in 1980; SSA = Sub-Saharan Africa Region.

else equal, a high-income economy with an average of 10 broadband subscribers per 100 people would have enjoyed a 1.21 percentage point increase in per capita GDP growth. 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 that broadband provides for developing countries was of similar magnitude as that for developed economies—about a 1.38 percentage point increase for each 10 percent increase in penetration. But the coefficient on average broadband penetration for middle- and low-income countries (BBNDL) 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 critical mass to generate aggregate effects as robust as in developed countries. 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.

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 (figure 3.1). Thus, current differences in broadband penetration among countries may generate significant long-run growth benefits for early adapters. Moreover, the significant and stronger growth effects of other technologies in developing countries than in developed countries suggest that the growth benefit of broadband in developing countries could be on a similar path.

Figure 3.1 Growth Effects of ICT



Source: Qiang 2008.

Note: The y axis represents the percentage-point increase in economic growth per 10-percentage-point increase in telecommunications penetration. All results are statistically significant at the 1 percent level except for that of broadband in developing countries, which is at the 10 percent level.

Conclusion

Broadband is a significant technological development, providing users with fast, always-on access to new services, applications, and content. Much of the research on the relationship between broadband adoption and its economic impacts has been in the form of qualitative arguments, anecdotes, and limited case studies. Formal empirical studies have focused on developed countries, and firm- and community-level studies in those countries confirm the high potential economic gains from broadband—including higher productivity, lower costs, new economic opportunities, job creation, innovation, and increased trade and exports.

Filling the gap in assessing the macroeconomic impact of broadband and in empirical evidence for developing economies, this chapter represents a first attempt at macroeconometric analysis and validation of the positive impacts that broadband, as a proxy for the more pervasive role of networks, can have on economic growth. The empirical findings here suggest that broadband's benefits are major and robust for both developed and developing countries, although the significance is higher for the former, which have a longer track record of broadband diffusion. As the number of broadband subscribers increases and the applications supported by broadband reach a critical mass, the benefits could show the same statistical significance in developing economies, as with all other communications technologies.

Whether this great potential to contribute to growth and competitiveness is realized will depend on whether governments understand the opportunity and ensure that supportive conditions are in place through regulatory and policy reforms as well as strategic investments and public-private partnerships. Realizing the benefits of broadband also requires development of new content, services, and applications, as well as increased human capacity to adapt the technology in economic activities. Broadband clearly deserves a central role in national development strategies.

As this chapter indicates, several areas for future research would be fruitful. First, once longer periods of data are available on broadband penetration, a subperiod analysis could be conducted, thus establishing multiple data points for each economy in an endogenous growth regression. This

approach would make it possible to study individual dynamics, give information on the ordering of events, and control for individual unobserved heterogeneity, addressing the endogeneity issue better. Second, it may be useful to look at how broadband affects key variables that are good for growth, such as trade, foreign investment, education, and innovation. Third, the microeconomic foundations of broadband's impact should be further explored with specific reference to developing countries. The current largely anecdotal analysis needs to advance to systematic impact evaluation. The effect of broadband on the creation and expansion of social and political networks could also be explored further in both developed and developing countries.

Annex 3A: Statistical Note

Initially, the four-equation simultaneous model (namely, the output equation or economywide production function; demand function for telecommunications; equation determining investment in telecommunications infrastructure; and equation relating investment to increased rollout) used by Röller and Waverman (2001) was considered to analyze the broadband impact on growth. However, this approach uses annual data, so errors or missing data cause significant difficulties.[8]

The Barro cross-sectional endogenous growth model was then used to look at long-term average growth rates. Waverman, Meschl, and Fuss (2005) used a similar model to test the impact of mobile telephony on economic growth in developing countries. This endogenous technical change approach, which uses period averages and initial values, is therefore less prone to data errors. Given the poor data availability in a large number of developing countries, this model may prove more successful in obtaining sensible estimates.

The following equation was used to test the impact of telecommunications penetration, including broadband, on the growth rates:

$$GDP_{8006} = \alpha_0 + \alpha_1 * GDP_{80} + \alpha_2 * (I/Y_{8006}) + \alpha_3 * TELEPEN_{8006} + \alpha_4 * PRIM_{80} + \alpha_6 * SSA + \alpha_7 * LAC + \mu.$$

Applying the same regression specification to various telecommunications services makes the results very comparable.

Table 3A.1 provides the variable description. The data come from the ITU (2007) and World Bank (2008b). Our econometrics analysis covers about 120 countries for the time period 1980 to 2006 to reflect the long-term growth perspectives.

We also divided the sample into developed and developing economies (the latter including both middle-income and low-income countries according to the World Bank country classifications), created dummy variables, and generated the new variables TELEPENH and TELEPENL (the product of the dummy variables and the telecommunications penetration variables). In this way, we intended to differentiate the

Table 3A.1 Definition of Variables

Variable	Description
GDP_{8006}	Average growth rate of real GDP per capita in US$ over 1980–2006
GDP_{80}	Level of real GDP per capita in 1980
I/Y_{8006}	Average share of investment in GDP for 1980–2006
$TELEPEN_{8006}$	Average telecommunications penetration per 100 people over 1980–2006
FIXED	Number of main lines
MOBILE	Mobile subscribers
INTERNET	Internet users
BBND	Broadband subscribers
H	High-income countries (developed)
L	Low- and middle-income countries (developing)
$PRIM_{80}$	Primary school enrollment rate in 1980
SSA	Dummy variable for countries in the Sub-Saharan Africa Region
LAC	Dummy variable for countries in the Latin America and Caribbean Region

Source: Authors' analysis.

Table 3B.1 Regression for Per Capita Growth

	Dependent variable: GDP_{8006}				
Indicator	–1	–2	–3	–4	–5
GDP_{80}	0.098 (2.82)**	–0.129 (4.62)**	–0.123 (4.49)**	–0.128 (4.46)**	–0.100 (3.86)**
I/Y_{8006}	0.171 (6.02)**	0.177 (6.59)**	0.155 (5.64)**	0.164 (5.96)**	0.164 (5.46)**
FIXEDH		0.043 (4.11)**			
FIXEDL		0.073 (3.18)**			
MOBILEH			0.060 (4.03)**		
MOBILEL			0.081 (3.54)**		
INTERNETH				0.077 (3.69)**	
MOBILEL				0.112 (2.91)**	
BBNDH					0.121 (2.87)**
BBNDL					0.138 –1.96
$PRIM_{80}$	0.003 –0.43	–0.002 –0.36	–0.004 –0.58	–0.001 –0.1	0.001 –0.18
SSA	–1.382 (3.35)**	–0.693 –1.66	–0.859 (2.11)*	–0.903 (2.20)*	–1.018 (2.19)*
LAC	–0.973 (2.35)*	–0.686 –1.68	–0.839 (2.03)*	–0.861 (2.08)*	–0.655 –1.55
Constant	–1.786 (2.09)*	–2.285 (2.82)**	–1.86 (2.31)*	–1.982 (2.43)*	–1.726 –1.83
Number of countries	120	120	120	120	119
R^2	0.44	0.52	0.52	0.51	0.49

Source: Authors' analysis.

Note: The numbers in parentheses are the absolute value of t-statistics. See table 3A.1 for the definitions of variables used in this table.

** Significant at the 1 percent level; * significant at the 5 percent level.

growth effects in developing countries from those in high-income countries. Table 3B.1 presents a summary of the growth regression results.

Because demand for telecommunications services rises with wealth, the impact of increased telecommunications penetration on economic growth and the impact of rising per capita GDP on the demand for telecommunications constitute the so-called two-way causality issue. Especially in the cases of mobile, Internet, and broadband, where data are only available starting 1990 or later (1998 in the case of broadband), penetration rates are potentially endogenous. The growth model approach does not deal with this problem explicitly—we performed a Hausman test to determine whether any reverse causality is present. We used the initial values of telecommunications penetrations as the instruments. The null hypothesis of ordinary least squares being consistent and efficient could not be rejected.

Notes

1. Broadband can be delivered over fixed and wireless networks. This chapter illustrates the benefits achieved by broadband regardless of the type of network delivery.
2. See http://www.csiro.au/news/BroadbandNetworks.html.
3. See "Egypt Unveils First 'Digital Village'" at http://www.egov-news.org/?m=200612&paged=2.

4. Services now account for around two-thirds of output and foreign direct investment in most developed countries, and for up to a quarter of total international trade.
5. Barro (1991) found that, conditional on the initial human capital stock, average per capita GDP growth was negatively correlated with initial per capita GDP. Thus, all else being equal, there should be convergence in income levels between poor countries and rich countries, although this only takes place over long periods.
6. Barro (1991) also found that the initial level of human capital stock was positively correlated with per capita GDP growth, so countries that were initially rich might grow faster than poor countries if there were large differences between their initial endowments of human capital.
7. A common assumption is that countries in the Sub-Saharan Africa and the Latin America and Caribbean Regions have poorer telecommunications sector performance than countries elsewhere. Our results confirmed this assumption for sub-Saharan African countries. However, the negative coefficient of the Latin America and Caribbean dummy—smaller than that of the Sub-Saharan Africa Region dummy—is statistically insignificant.
8. This technical note draws from Qiang (2008).

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