3

Globalization and IT Prices, Diffusion, and Productivity

Chapter 1 reviewed why the overall impact of networked IT on the US economy warrants deeper analysis, while chapter 2 examined the globalization of the production of and demand for IT and communications products and services and of demand for them. This chapter puts the two pieces together to show the links between globalization of IT, IT prices, and diffusion of investment in IT. It discusses the macroeconomic trends and cycles in IT investment in the United States in response to globalized IT prices and the resulting acceleration of productivity growth at the macro level. Business transformation, particularly with respect to workplace practices, plays a key role in this process.

This chapter also delves deeper into the pattern of IT investment in the United States. It looks at the uneven pace of diffusion of IT into nontechnology sectors in the US economy and the resulting uneven acceleration of productivity growth that underpins the overall macro behavior. This varying pace of IT "uptake" by different sectors of the US economy is of particular interest, and appears to be related to customer and supplier transactional linkages between sectors of the economy, as well as to sector-specific regulations and the size distribution of firms, among other factors.

Finally, the chapter considers the experiences of other countries, given that they too are affected by the globalization of IT, although few of them have exhibited economic performance as it relates to IT similar to the United States. Comparing outcomes cements some of the findings pertinent to US behavior in the face of globalization and IT prices, the resulting investment in networks, and, importantly, changes in business activities and workplace practices.

Globalization of IT and Implications for Prices

What are the implications for the United States of all this globalization of IT production and sales? In short, the globalization of IT hardware production, trade, and sales has made these prices lower than they otherwise would have been. The IT product is a general-purpose investment, and the additionally lower prices further contribute to the diffusion of IT investment throughout the US economy. Globalization of IT increases its power to accelerate change in the US economy.

Forces of globalization are important factors underpinning IT hardware prices, where production and demand have been most globalized. But so far there has been less fragmentation and globalization of production of IT services and software. The globalization forces that affect these prices appear more muted. Going forward, some factors suggest a pattern for IT software and services globalization similar to that for IT hardware, but other factors suggest less of a role for globalization of IT services and software to accelerate change in the US economy.

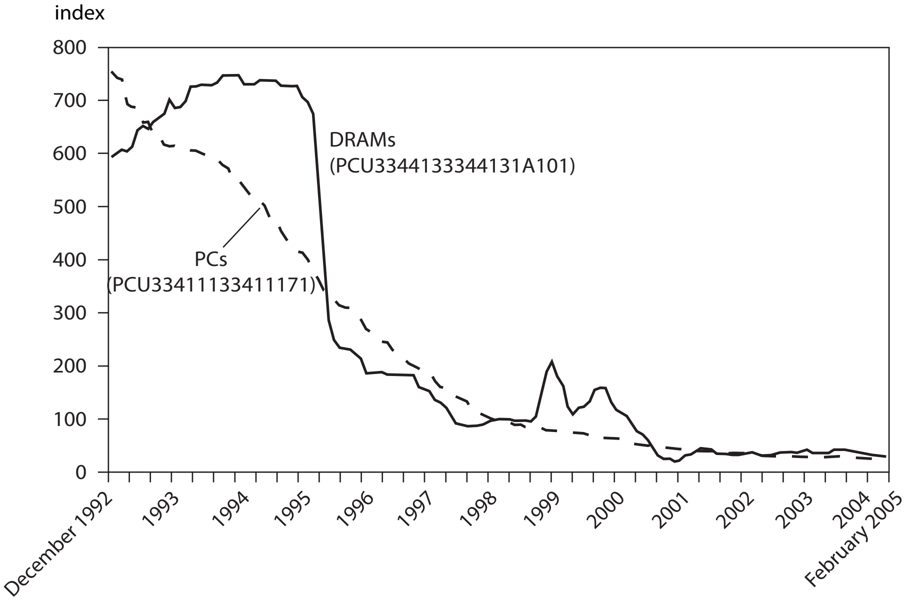
IT Hardware Prices

This section pulls together the observations on costs in the integrated global network and on new producers and exporters in the global marketplace in order to analyze price trends for two specific categories of IT hardware. In principle, given the lower wage costs inferred from the integrated global production network for IT hardware, globalization of production by US firms should result in lower prices for these IT products. Moreover, increased investment in IT productive capacity around the world, as well as a more diverse set of global exporters, should raise competitive pressures, putting additional downward pressure on prices. Can these effects be quantified?

Research that conclusively links the globalization of IT hardware production to lower prices is elusive, primarily because of difficulties in obtaining adequate and appropriate data. There are problems of matching data on firm operations to data on the prices of products. There is limited information on the geographic location of facilities. And data are neither available for a sufficiently long time frame nor of sufficiently recent vintage for detailed and in-depth analysis across many segments of the IT industry. However, there are two categories of IT hardware for which there is sufficient information to do a structured analysis: dynamic random access memory chips (DRAMs), which are a type of semiconductor chip, and personal computers (PCs). These products offer a paradigm for understanding more generally the forces linking the globalization of IT production and the prices of IT products for US buyers.

Figure 3.1 shows the dramatic declines in the price indices of PCs and DRAMs. The prices of these two IT products are not independent: de-

Figure 3.1 Price indices for PCs and dynamic random access memory chips (DRAMs), December 1992–February 2005



Note: The data points are for June and December of the years indicated.

Source: Bureau of Labor Statistics, producer price index, www.bls.gov/ppi/home.htm.

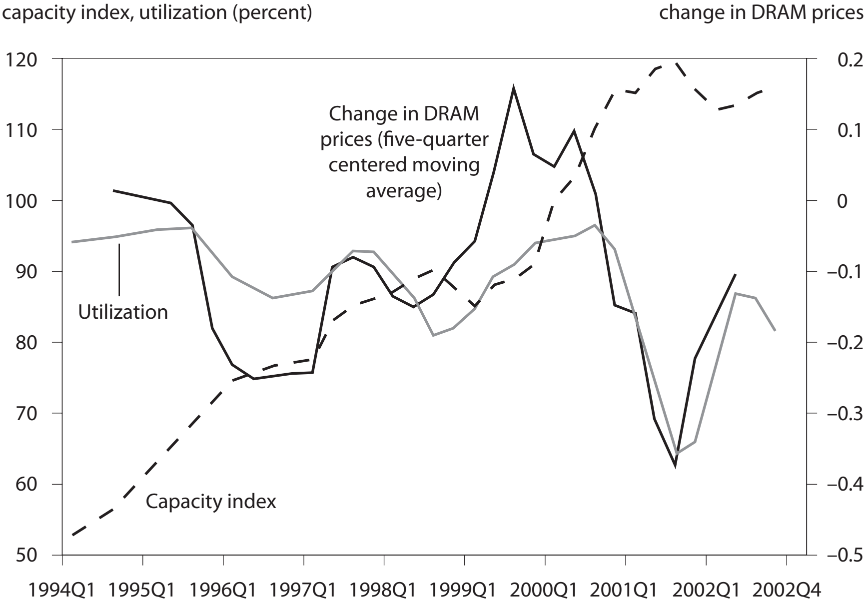
tailed research on the relationship between the prices of PCs and semiconductors finds that about 40 to 60 percent of the decline in PC prices is due to the decline in price of semiconductors (and about 30 percent of the semiconductors that go into a PC are DRAMs) (Aizcorbe, Flamm, and Khurshid 2002).

What generates the decline in the price of semiconductors (particularly DRAMs), and what additional factors affect PC prices? In particular, what might be the role for the globalization of the IT hardware industry in these price declines?

Technology is the key starting point. Technological change in the production of semiconductors reduces the price, in part by increasing the number of chips on a given-sized wafer, the size of the wafer, and the yield in production (Aizcorbe, Flamm, and Khurshid 2002).

Investment in semiconductor facilities abroad (by US firms and foreign firms, as discussed in appendix 2A in chapter 2) may play a role in technological change in semiconductor production, as these facilities compete with each other to generate the newest advancement in technologies of production and product. For example, innovation in chip speed is critically important as a driver of semiconductor prices (Aizcorbe 2002). As faster chips are introduced, the prices of older chips fall dramatically, which reduces vintage-weighted average prices of semiconductors (such

Figure 3.2 Global capacity and utilization and US prices of dynamic random access memory chips (DRAMs), 1994–2002



Sources: Semiconductor Industry Association; Bureau of Economic Analysis, producer price index, www.bea.gov/ppi/home.htm.

as the price index in figure 3.1). Research and development (R&D) is a key factor in innovations involving speed (see chapter 6).

But R&D is not the only factor behind the price declines. Competition also plays a key role. Ana Aizcorbe (2002) focuses on competition in the United States between Intel and AMD (both US companies), but to an increasing degree competition is global both in terms of ownership of the means of production and of geographic location.

Moreover, change in the price-cost margin apparently is an important determinant of semiconductor prices. Research suggests that squeezing margins between production cost and price can account for an average of about 15 percent of the decline in prices; the year-to-year range is huge—from no margin squeeze in some periods (such as the second quarter of 1995 or the third quarter of 2003), to significant margin squeezes of 20 or 30 percent in others (such as the third quarters of 1998 and 2001) (Aizcorbe 2002). Margins can narrow because of the business cycle (demand booms or falls off) or because new production facilities come on line (and supply increases). Increasingly, demand booms and supply increases have global origins—it is not just US demand or supply that matters. Data in figure 3.2 on the global integration of production, opening up of new global markets, and emerging global competitors (all evidenced in the data discussed in chapter 2) show a clear relationship between worldwide capacity and utilization and US DRAM prices.

Regression analysis of the evolution of US DRAM prices as explained by global capacity and global capacity utilization confirms that when a gap opens between capacity and production (that is, capacity utilization falls), the decline in DRAM prices accelerates.[1] Average capacity utilization from 1995 to 2002 was 90 percent, with an average deviation of 2.5 percentage points. Based on the regression analysis, a 2.5 percentage point rise in global capacity utilization (from, say, 85 to 87.5 percent) is associated with a slowing of the pace of decline in DRAM prices from 10 to 2.5 percent (quarterly rate) as producers are able to sell their product into the tighter global demand conditions at a relatively better price. Whereas the bulk of the overall trend decline in DRAM prices is almost surely on account of innovation and technological improvements in chips, the cycling between a greater and lesser pace of price decline is in no small degree due to globalization of chip supply and demand.

As noted, previous research found that the behavior of semiconductor prices explains about half of the decline in personal computer prices. This research finds that global DRAM capacity and capacity utilization play an important role in semiconductor price declines. Are there other global factors that also affect prices of PCs? Figure 3.3 shows the relationship between the net imports of computers, peripherals, and parts (not including semiconductors), which is persistently negative over the time period shown, and the change in prices of the average personal computer and laptop.

Regression analysis of these data indicates that an increase in net imports of computers, peripherals, and parts is associated with accelerating PC (and laptop) price declines. When net imports of personal computers level out (as they did, for example, in the late 1990s), PC prices stop falling so fast.[2] Net imports of PCs averaged $200 million per quarter from 1993 to 2002, with a variation of about $50 million around that average. The regression suggests that if net imports of this category decreased by $50 million (that is, the deficit in PCs and laptops narrowed), then the decline in PC prices would slow by about 10 percent during the quarter due to the decreased net supply of PCs in the US market.

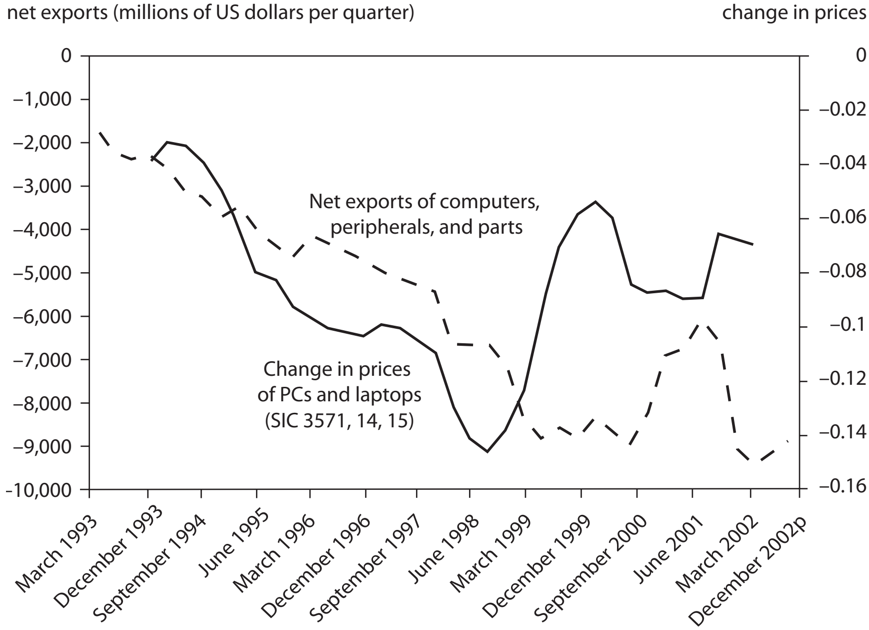
IT Software and Services Prices

If global integration and competition drive reductions in prices of IT hardware, what is happening to prices of IT software and services? For prepackaged software, the price deflators from the national accounts data on software investment reveal an 11 percent smooth decline annually in the

1. See Mann (2005) for further regression diagnostics and additional discussion.

2. See Mann (2005) for further regression diagnostics.

Figure 3.3 Personal computer prices and trade, 1993–2002



p = preliminary
SIC = Standard Industrial Classification

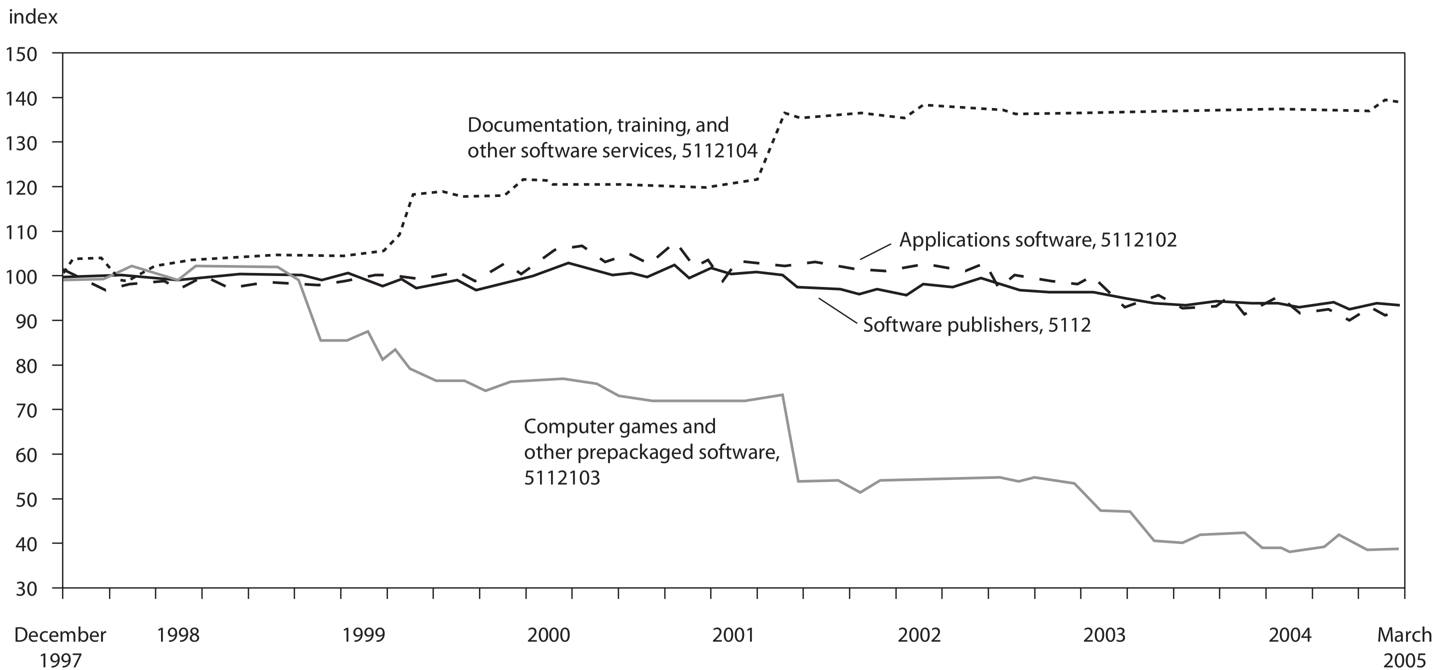
Sources: Bureau of Labor Statistics, producer price index, www.bls.gov/ppi/home.htm (accessed September 30, 2005). Bureau of Economic Analysis, international trade statistics, SIC basis, www.bea.gov.

deflator (1990 to 2004; this deflator is adjusted using hedonic methods). On the other hand, for business own-account and custom software, where labor costs play a key role in the construction of the deflator, the index is virtually unchanged from 1990 to 1998, then increases at about 3 to 5 percent per year until 2001, when that rise is abruptly halted and own-account and custom costs once again show no change until 2004.[3]

An alternative source of price indices for software is the Bureau of Labor Statistics (BLS) data based on the North American Industry Classification System (NAICS). The BLS data are designed to measure prices of types of software and services products rather than calculate deflators for types of software investment (figure 3.4). These data reveal that price declines

3. See BEA (2000) and BEA table on Software, Investment, and Prices, available at www.bea.gov/bea/dn/soft-invest.xls. See also Grimm, Moulton, and Wasshausen (2002). The price index for prepackaged software is quality-adjusted based on several familiar word processing and spreadsheet programs. Own-account software prices are based on the costs of programmers. Custom programming is an expenditure-weighted average of the two other types. See additional discussion in the next section.

Figure 3.4 Price indices for IT services and software, December 1997–March 2005



Note: Data are for March, June, September, and December of 1998–2004.

Source: Bureau of Labor Statistics, producer price index, www.bls.gov/ppi/home.htm.

for both "software publishing" (e.g., Microsoft Windows) and "application software" (e.g., customized Oracle database software) have been minimal, much less than for IT hardware. But in the more competitive and globalized market for computer games and prepackaged software, price declines are significant, although still less than for IT hardware.

Software companies in foreign countries, an increased role for offshore programming in US companies, and competition among the global software companies may all contribute to the drop in computer game and prepackaged software prices. Data on venture capital funding of software startups reveals a relatively higher share of such funding abroad for these types of software applications. In addition, international trade data show an increase in intrafirm imports of data and information services, which include software among information services (discussed in detail later). The price series and trade data are insufficiently matched to undertake an econometric assessment of the relationship between globalization and IT prices similar to that undertaken for the two types of hardware. But the lower prices of certain kinds of software suggest that the paradigm of globalization of IT hardware and lower IT hardware prices, as detailed above, may be starting to emerge for some types of software as well, particularly software that is less "tailored" or customized for specific clients.

On the other hand, for what are called "documentation and training and other software services," which surely incorporate tailored specifications for the specific needs of sectors and countries, prices continue to rise at about the rate of overall services price inflation. Recall that the IT services markets are more geographically segmented (perhaps by language, culture, business milieu, and level of sectoral development), with production and sale of the service mostly in the same market. Data already presented show that wage costs of software and IT services workers at US affiliates abroad tend to be similar to the wages at the US-located parent firm. Finally, segmented markets, ceteris paribus, have lower competition, leading to different prices for different markets.

Overall, some of the factors that have helped to make IT hardware into commodities that can be produced more cheaply abroad appear to be taking hold in some aspects of software and services, but have not extended to the full range of software products or IT services. Even in the longer term, the effect of globalization to reduce prices of all parts of the production process of services and software may be muted.

The consequence of relatively stable software prices, rising IT services prices, and rapidly declining IT hardware prices is that the share of the overall price of an IT package (which includes IT hardware, services, and software) has become increasingly weighted toward IT services and software (box 3.1). Reexamining the data on IT expenditure reveals that in 1993, for each $1 spent on IT hardware, firms globally spent $1.25 on IT services and software, whereas in 2003, for each $1 spent on IT hardware, firms spent $1.94 on IT services and software (WITSA 2002, 2004; see also

Box 3.1 Purchasing a computer: Mostly software

Since software and hardware are usually sold as a package, it is difficult for a small business shopping for a computer to figure out which products to buy and what their prices are. However, prices of computers in Dell's catalogue and of software at the retailer Best Buy (visited in July 2005 and April 2006) indicate the high and rising relative importance of embedded software in the computer package.

Suppose two small businesses priced computers in July 2005 and April 2006, respectively. How do the prices and functionality of the computer package change, and how important is the software part of the package in the overall price?

In July 2005, a Dell Dimension 9100 Desk Top at Dell.com cost $1,417 with free shipping. It included a range of hardware and preselected software:

- *Hardware (nonexhaustive list):* Intel® Pentium® 4 processor at 3GHz, 1GB dual channel DDR2 SDRAM at 533MHz, 40GB serial ATA hard drive (7200RPM), 32x CD-RW/DVD-ROM combo drive, and a standard 17-inch CFT monitor.
- *Preselected software:* Windows XP Professional and Microsoft Office Professional.

Given the retail value of the software at Bestbuy.com—Windows XP Professional cost $299 and Microsoft Office Professional cost $499—the above price suggests that more than half of the value of the computer package was embedded software.

Suppose the small business wanted a cheaper package and selected different software options. If it selected Windows XP Home Edition and WordPerfect Office 12 for its Dell machine, rather than the preselected software, the overall price fell to $968, and the share of the package represented by embedded software fell to 30 percent.

Now suppose a similar small business priced computers in April 2006. At Dell.com, a Dell Dimension E310-P4 Desk Top cost $1,093 with free shipping. It included a range of hardware and preselected software:

- *Hardware (nonexhaustive list)*: Intel® Pentium® 4 processor at 3.0GHz, 1GB dual channel DDR2 SDRAM at 533MHz, 80GB serial ATA hard drive (7200RPM),[1] 48x CD-RW/DVD-ROM combo drive,[2] and a standard 17-inch CFT monitor.
- *Preselected software:* Windows XP Professional and Microsoft Office Professional.

Given the retail value of the software at Bestbuy.com—Windows XP Professional cost $299 and Microsoft Office Professional cost $499—the above price

(box continues next page)

Box 3.1 Purchasing a computer: Mostly software *(continued)*

suggests that almost three-quarters of the value of the computer package was embedded software.

Again, suppose the small business wanted a cheaper package. If it selected Windows XP Home Edition and WordPerfect Office 12 for its Dell machine, the share of the package represented by embedded software fell to about 40 percent.

No doubt software costs of Dell are much lower than those of a software retailer, but embedded software costs are a large and increasing share of the total costs incurred by businesses and consumers when buying a computer.

Over the nine-month period of this example, the overall package price fell by more than did the value of the embedded software. Even over this short period, the relative share of software costs in the computer package rose even when cheaper software was selected for the machine, mostly on account of the falling cost of the hardware component.

Unlike hardware, where globalized production and competition are fierce, software is an area of IT where these forces are just beginning to be felt. Going forward these factors likely will push down further the price of the total IT package, thus putting these productivity-enhancing IT packages within reach of a wider range of businesses throughout the US economy.

1. Note that the 80GB hard drive available in April 2006 has twice the capacity of the hard drive available in July 2005.

2. Note that the 48x CD-RW/DVD-ROM combo drive available in April 2006 is 50 percent faster than that available in July 2005.

figure 2.1 in chapter 2). This skew was even greater for US buyers, who spent almost $3 on IT services and software for every $1 on IT hardware in 2003. Faster globalization has reduced the relative importance of IT hardware and increased the relative importance of IT services and software in the expenditure package. It should come as no surprise that users want lower prices for IT services and software, and that US IT firms are trying to meet that demand by fragmenting the production process and moving some activities to lower-cost locations abroad in order to reduce the price of providing the tailored software and services.

Macroeconomic Overview of IT Investment in the US Economy

How have the IT price declines—due to both technological innovation and globalization—been reflected in investment patterns in the United

States? Prices are not the only factor that drives investment demand—so does GDP growth. It is difficult to parse out the relative roles for prices and GDP.

IT Waves in US National Income and Product Accounts Data

IT hardware and communications have been considered investment all along. But software was reclassified from spending to investment as part of the benchmark revision of the national income and product accounts in 1999. Waves of investment spending on IT and communications can be seen in the National Income and Product Accounts (NIPA) data that correspond to the changing emphasis on hardware and software/services already noted in the international marketplace, in the corporate data, and in the data on US multinationals (figure 3.5).[4]

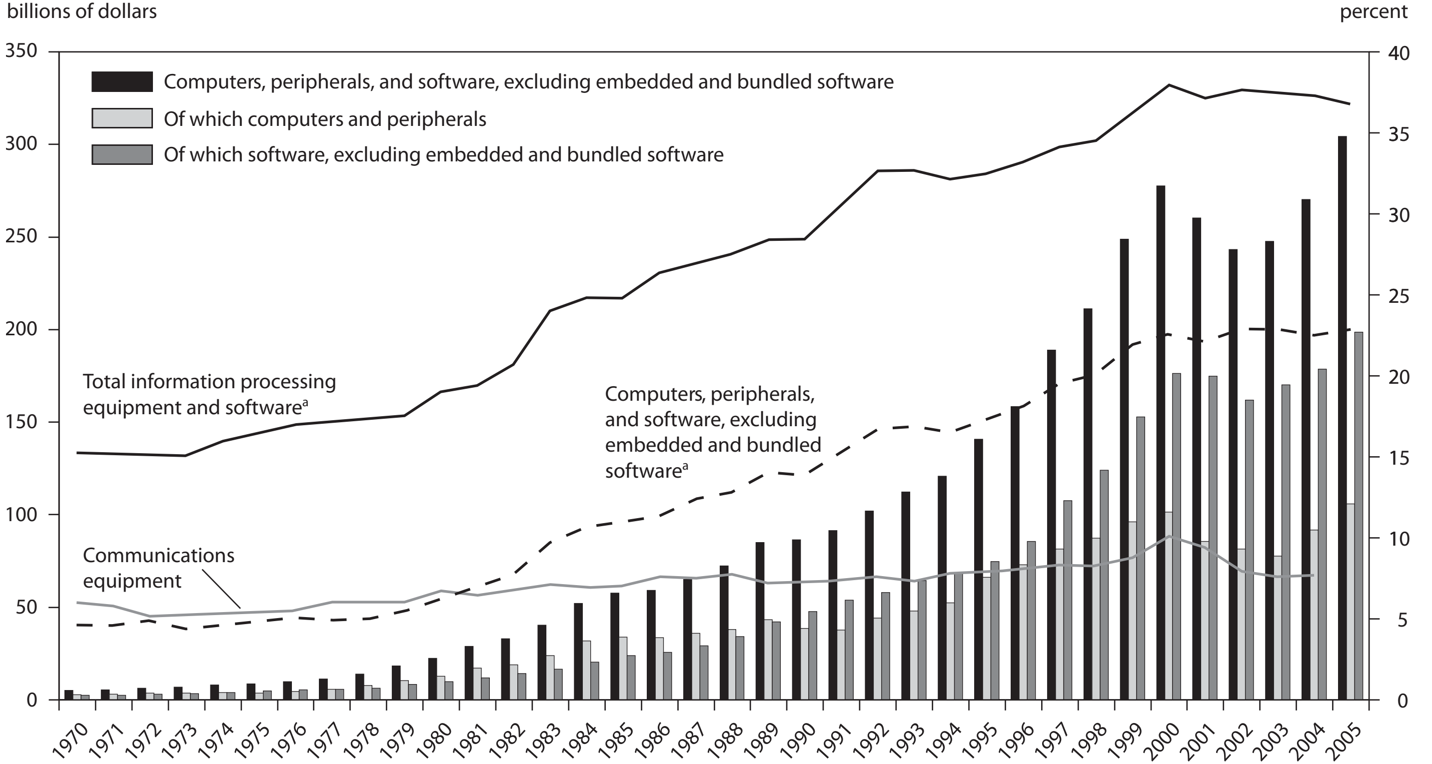
Patterns of importance of IT and communications in the United States can be seen by disaggregating the sector into its main components of communications, IT hardware, and software, and then considering both nominal investment patterns and contribution to real investment growth. Nominal investment in computers and peripherals increased in the 1980s both in absolute terms and as a share of domestic nonresidential investment. Communications equipment is becoming less important in investment. Following the recession pause of 1991–92, investment in equipment and software resumed, but with software investment increasingly being the driving force for growth. In terms of real investment, the contribution of the two components of information equipment and software to real private investment follows a similar pattern, with a hardware wave in the 1980s and then a second wave of both hardware and software in the 1990s, and with the contribution of software investment to real investment becoming more important as the 1990s progressed. Finally, taking these investment patterns and cumulating them to reflect asset stocks yields the same observations, with the software share of total private assets exceeding the hardware share from the late 1990s onward. All told, the NIPA data tell the same story for the United States as do the data based on global expenditure and on multinational production and sales.

Focus on Software

The increasing importance of software investment, combined with the nascent globalization of production and international trade in software,

4. Revisions of the historical NIPA data were based on detailed analysis of expenditure and involved construction of new price indices. The consequence of the reclassification to investment affected GDP growth and emphasized the important role for IT investment in the US economy.

Figure 3.5 IT and communications investment, 1970–2005



a. Share of total nonresidential investment.

Source: Bureau of Economic Analysis, National Income and Product Accounts (NIPA), tables 5.3.5 and 5.5.5, www.bea.gov/bea/dn/nipaweb (accessed April 3, 2006).

make it worthwhile to look more closely at this category of investment. Software investment is classified in three categories: prepackaged, custom, and own-account software. "Prepackaged" software does not imply that it comes in a box—Internet downloadable software, for example, is considered part of this classification—but rather that this software has general applicability without requiring modification. Custom software is tailored to the specifications of a business by third-party consulting firms or individuals. The customization process and expenditures counted as investment in the data may include analysis, design, and new programming, and may also include software that has been customized from preexisting or standardized modules. Finally, investment in own-account software consists of expenditures including wages, salaries, and related compensation (including indirect costs such as depreciation on the computer equipment) for an enterprise's employees whose job it is to analyze, design, and produce new or significantly enhanced software for the enterprise's own use. Thus, outsourcing of own-account software to third-party consultancies would change the classification of software investment from "own-account" to "custom" software. Offshore outsourcing of this activity would imply a reduction in own-account software investment and a rise in imports in the trade classification of unaffiliated "computer and information services."[5]

Between 1997 and 2003, nominal investment in the three categories of software rose from $128 billion to $191 billion, with the bulk of this investment (about 80 percent) undertaken by business (the remainder is investment by government and by individuals for personal consumption). Investment in own-account software doubled ($42 billion to $80 billion), while investment in prepackaged software rose less quickly (from $40 billion to $55 billion). The middle category—third-party customized software—rose dramatically through 2001 (from $47 billion to $72 billion) and then dropped off in 2003 to $57 billion. Is the drop in customized software related to the technology boom generally, to Y2K specifically, or to offshoring of software services?[6] "Software repair" to avoid Y2K glitches in existing software is explicitly excluded from the software investment data. But new spending for an upgrade or new software would be included as investment, so the Y2K phenomenon would accentuate the technology

5. If the new software activity remained "own-account" software but the programmers were located in India, then this offshored but not outsourced activity would appear as an import of affiliated computer and information services, to the extent that such transactions are captured in the data surveys.

6. Y2K is the colloquial term used to address the software issue whereby old software was designed to recognize only the last two digits of the year-date (such as 75 for 1975). There was a real concern that many computer systems that depended on such two-digit dates would fail when the calendar changed from 1999 to 2000. Hence there was substantial upgrading of computer systems to correct this internal glitch. Other businesses saw this as the opportunity to buy new computers and software products.

cycle in the data. Whether the dropoff in the data also suggests offshoring of this customizing activity will be addressed in the sections that follow.

There is a fourth category of software—so-called embedded or bundled software—that is not included in the software investment category, but rather is included in the investment category for computers and peripherals. This software comes preinstalled with the hardware (such as when a personal computer comes with preinstalled Microsoft Windows or even when the software is embedded into the semiconductor chip). The line between hardware, embedded software, and prepackaged software is becoming blurred, further challenging our analysis of the effects of globalization and technological change.

Diffusion of IT Throughout the Economy

Another approach to examining IT trends in the US economy is through input-output tables such as those presented in tables 3.1a and 3.1b. First consider the share of IT hardware and services in total intermediates used in the economy for 1998 and 2004. The share of IT hardware in total intermediates fell from 3.4 to 2.4 percent over that period, but the share of IT services in total intermediates rose from 1.5 to 2 percent. The drop in hardware is consistent with the lower prices, and the two trends together are consistent with the movement away from hardware as well as the growing importance of services in terms of making IT useful to firms as they do business.

Looking at the two-digit sectoral breakdown reveals some changes in the rankings of sectors in their intensity of IT use as an intermediate. For IT hardware, the stability in the rankings is almost complete, in that none of the sectors move more than one place in the rankings. On the other hand, for IT services intensity, there are more changes in rankings. Most notable is the fall in the relative intensity of "health care and social assistance," even though in terms of absolute use of IT services as an intermediate this sector actually increased its use. Other relative decliners include transportation, warehousing and storage, and utilities, all of which actually saw declines in their absolute share of IT services intensity in intermediates used.

These diffusions in terms of IT hardware and services use as an intermediate to production provide important insights into why some sectors lead and some lag in US productivity growth, a topic to which we now turn.

IT Diffusion and US Productivity Growth

US macroeconomic performance in the 1990s was extraordinary (and following the 2001 recession, equally robust). In terms of the standard mea-

Table 3.1a IT hardware intensity, 1998 and 2004 (percent share of total intermediate goods used)

NAICS category	Sector	1998 Rank	1998 Intensity	2004 Rank	2004 Intensity	Change in rank, 1998–2004
31–33	Manufacturing	1	6.634	1	4.744	→
51	Information	2	5.227	2	4.411	→
42	Wholesale trade	3	3.978	3	3.201	→
81	Other services, except government	6	2.926	4	2.999	↑
T001	**Total intermediate use**	5	3.396	5	2.440	→
54	Professional scientific and technical services	4	3.605	6	2.160	↓
56	Administrative support and waste management and remediation services	7	1.743	7	1.590	→
62	Health care and social assistance	9	1.093	8	0.973	↑
44	Retail trade	8	1.097	9	0.890	↓
61	Educational services	11	0.964	10	0.863	↑
23	Construction	10	0.986	11	0.852	↓
55	Management of companies and enterprises	12	0.728	12	0.527	→
48	Transportation	14	0.371	13	0.350	↑
52	Finance and insurance	13	0.461	14	0.324	↓
53	Real estate and rental and leasing	15	0.328	15	0.263	→
21	Mining	18	0.151	16	0.193	↑
71	Arts, entertainment, and recreation	16	0.210	17	0.139	↓
22	Utilities	17	0.198	18	0.106	↓
72	Accommodation and food services	20	0.085	19	0.064	↑
49	Warehousing and storage	19	0.097	20	0.055	↓

sures, productivity growth accelerated to rates not seen since the 1960s; GDP growth was sustained at more than 4 percent; inflation was the lowest in a generation; and the unemployment rate fell below where it had been for decades. Research on the underpinnings of this positive economic performance focused on the rising importance of IT, initially in terms of IT production in the US economy and then in terms of investment in and use of IT throughout non-IT sectors of the economy. Now, researchers are examining the role for global engagement and productivity growth through the channels of reductions in the cost of IT, more fragmented production facilitated by globally networked communications, and global competition that enhances forces that promote more effective use of IT by business and in the workplace.

Table 3.1b IT services intensity, 1998 and 2004 (percent share of total intermediate goods used)

NAICS category	Sector	1998 Rank	1998 Intensity	2004 Rank	2004 Intensity	Change in rank, 1998–2004
55	Management of companies and enterprises	1	7.46	1	7.5	→
54	Professional scientific and technical services	2	3.42	2	3.6	→
56	Administrative support and waste management and remediation services	4	2.75	3	3.0	↑
51	Information	5	2.35	4	2.7	↑
48	Transportation	3	2.94	5	2.2	↓
42	Wholesale trade	6	2.21	6	2.2	→
44	Retail trade	7	1.82	7	2.1	→
T001	**Total intermediate use**	8	1.54	8	2.0	→
52	Finance and insurance	9	1.49	9	1.9	→
61	Educational services	11	1.32	10	1.6	↑
21	Mining	15	0.94	11	1.5	↑
81	Other services, except government	12	1.28	12	1.5	→
62	Health care and social assistance	10	1.44	13	1.5	↓
71	Arts, entertainment, and recreation	14	1.13	14	1.3	→
49	Warehousing and storage	13	1.19	15	1.2	↓
72	Accommodation and food services	16	0.78	16	1.0	→
31–33	Manufacturing	19	0.72	17	0.9	↑
53	Real estate and rental and leasing	17	0.77	18	0.8	↓
23	Construction	20	0.39	19	0.4	↑
22	Utilities	18	0.73	20	0.3	↓

Source: Bureau of Economic Analysis, Input/Output Tables, www.bea.gov.

Role of IT in Transforming US Workplaces and Businesses

The most important ingredient to the positive economic outcomes of the 1990s was the sustained increase in productivity growth. Research on US data as well as detailed analysis of data from other economies concludes that investment in and increased use of IT yielded faster GDP growth and higher productivity growth. For the United States, one-quarter to one-

7. See Dedrick, Gurbaxani, and Kraemer (2002, table 2); Oliner and Sichel (2000, 2002); Jorgenson, Ho, and Stiroh (2002).

third of the increase in real GDP growth from 3 to 4 percent (1973–94 versus 1995–2000) came from investing in and using IT.[7] Industry sectors that used IT intensively grew 75 percent faster than other sectors throughout the 1990s (ESA 2002, figure 4.1). Intensive use of IT accounted for 60 to 70 percent of the doubling of labor productivity growth after 1995.[8]

Researchers have investigated four linkages between IT and productivity growth: (1) IT capital deepening and increasing efficiency within the business enterprise; (2) the role of network effects and transactional spillovers between enterprises that both use IT, which raises the productivity of both enterprises; (3) the positive association between increased productivity and changing workplace practices within the firm; and (4) international engagement in IT and productivity growth.

The overwhelming finding is that production and investment in IT capital are not the most important source of economic gain. It is the effective use of IT, a step beyond IT investment, and the transformation of business activities and of the relationships between businesses with networked IT, that most augment productivity growth. To emphasize this key point, it is instructive to put forth a brief historical review of the research on IT, communications networks, and productivity growth.

The earliest research on the relationship between IT and faster US GDP and productivity growth focused only on investment and the use of IT by businesses in the IT-producing sector. This early work suggested that it was extraordinarily high productivity in the IT-producing sector that accelerated US productivity growth. However, as time went on and expansion of the IT-producing sector waned, research turned to the relationship between IT investment and productivity growth throughout an economy rather than the IT sector alone. Using detailed data for the United States and Europe, as well as more aggregated data for a broader set of economies, this research made it clear that investment in and effective use of IT by businesses throughout the economy are what increased productivity and GDP growth.[9] These observations came from comparing productivity and growth for industry sectors (both goods and services) that were more versus less intensive in investment in various kinds of IT capital. IT producers are IT-intensive in terms of purchasing and using IT, but they are neither the whole story nor even the major part of it when it comes to macroeconomic performance.

Making the distinction between fast growth and high productivity in IT-producing firms versus IT-using firms is important for the source and sustainability of robust GDP and productivity growth. First, of course, broad-

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8. Sixty percent is from van Ark, Inklaar, and McGuckin (2003, appendix table C) and 70 percent from ESA (2002, 36).

9. See van Ark, Inklaar, and McGuckin (2003); Stiroh (2001, 2002); Baily and Kirkegaard (2004); OECD (2003); Wilson (2004); Mun and Nadiri (2002); Atrostic and Nguyen (2005).

based high productivity growth is the foundation for faster GDP growth without generating inflation. If productivity growth is confined to IT producers, then sustaining rising productivity growth overall will require an increasingly large share of IT production in an economy. Moreover, if high productivity comes mostly from producing IT, then an economy without an IT production sector would appear to be doomed to low productivity and slow GDP growth. If, instead, what matters is using IT, then a country can get productivity benefits by importing and using IT products.[10]

One way to measure changes beyond labor productivity that signal the effective use of IT and the transformation of business activities and relationships is with total factor productivity (TFP) growth. TFP measures the additional output obtained by a reorientation of the means of production using the same inputs—in other words, the transformation of business activities, which would include new products, processes, business and customer relationships, and workplace practices. Much of the second wave of research on the role of IT in the economy has focused on how IT changes the internal activities of the firm and the relationships between firms.

This complementarity between IT investment and workers is the second strand for the research on how effective use of IT affects productivity growth. Researchers have focused on the relationship between labor productivity and changing workplace practices in the presence of IT capital.[11] Innovation in four areas where employees interact with the business activities of the firm are considered: (1) the employees' voice, where nonmanagerial staff contribute directly to innovations in business process; (2) work design, where managerial staff can reallocate labor and capital resources to respond more effectively to changing business demands; (3) workforce training, which complements the increased flexibility of labor in the business process; and (4) incentive-based compensation systems, which give nonmanagerial staff an incentive to maximize the financial potential of the business.

Controlling for IT investment (which takes account of the capital deepening component of labor productivity growth), researchers find, both within specific industries and across industries, that application of innovative workplace practices raises productivity further. Perhaps even more important for the understanding of the relationship between IT capital and productivity growth in an enterprise, the researchers find that diffusing computers to the nonmanagerial workers increases productivity, whereas IT capital investment has no effect on overall productivity when computers are diffused only to the managers.

10. See Bayoumi and Haacker (2002) regarding this point in the context of developing countries.

11. Black and Lynch (2001, 2003, 2004, and forthcoming); Boning, Ichniowski, and Shaw (2001); Bresnahan, Brynjolffsson, and Hitt (2002); and Ichniowski, Shaw, and Prennushi (1997).

IT and Inflation

Thus far, the gain from lower prices of IT products has been couched in terms of accelerated productivity growth. However, another macroeconomic benefit of lower IT prices is lower inflation.

First, falling prices for computer items reduces measured inflation simply because the falling prices for IT capital are included in the basket of purchases. In parallel to the research on productivity growth, which focused on the IT-producing sector, the price-dampening effect of IT initially was thought to derive mostly from this rapid decline in the quality-adjusted price for computer equipment as it showed up in the producer price index for the US economy. On this basis, some analysts (particularly in Europe) thought that their measured inflation was higher (and therefore their output and productivity growth were lower) simply because they did not quality-adjust their IT producer prices. An examination of this question, however, revealed that quality adjustment had little to do with the inflation (or by extension productivity or growth) dynamics in Europe compared with the United States.[12]

Further analysis finds that, just as for productivity growth, it is the dynamics of the response of prices and costs outside the IT-producing sector that matter most for the overall inflation dynamic. The reduction of inflation on account of IT is more significant for those sectors that have integrated IT into their businesses.[13] The detailed analysis presented here based on US data reveals the systematically lower price inflation of sectors that are IT-intensive. Effective use of IT appears to lower output price inflation. IT intensity could lower price inflation because, within a sector, the more competitive firms integrate IT into their business operations, reduce their prices, and drive less IT-intensive competitors out of business (McKinsey Global Institute 2001, Baily and Kirkegaard 2004). Across sectors, firms with high IT intensity can lower their costs more and reduce prices, which feeds into lower overall price inflation. Translated to the macro level, core inflation might have been 1 percentage point per year higher during the 1990s (3 percent versus 2 percent) had there not been increased use of IT (ESA 2002, 39).

12. Triplett (2004); Ahmad et al. (2003); Schreyer (2001); Deutsche Bundesbank (2001); Gust and Marquez (2000); and Landefeld and Grimm (2000). The two main reasons for the limited impact of disparate utilization of hedonic deflators for IT goods across countries is that many of these products are used as intermediate goods, as well as imported from abroad so the "failure" to quality adjust "nets" out.

13. See intermediate costs analysis in Mun and Nadiri (2002).

Globalization, Technology, and Labor Productivity

The forces of global competition and engagement work in conjunction with other factors to affect productivity, including IT intensity, research and development spending, resource reallocation, and trade patterns. There is a long and rich history of research on this broad topic, sometimes specifically addressing IT, sometimes not. Much of the most recent work focuses on the interactions among the various factors, particularly the way global integration and international competition work to strengthen the effect of the other factors.[14] It is worthwhile to briefly summarize key research that links globalization, technology, and productivity growth.

Although the direction of causality is not well specified, the robust research finding is that firms that produce for export markets and face import competition are more productive.[15] What is the additional relevance of technology to the trade-productivity link? The link between productivity and trade is found to be particularly strong both for technologically sophisticated products as well as for firms that use IT (Baygan and Mann 1999; Haskel, Pereira, and Slaughter 2002; Lewis and Richardson 2001). That is, trade in technologically sophisticated products is associated with higher productivity, as compared with overall trade or trade in lower-technology products. But it is also the case that the industries that have invested heavily in IT have a greater propensity to export. This suggests that IT both demands and enhances international competitiveness.

For the United States, there are several transmission channels for these effects. First, research shows that the least productive firms go bankrupt, low productivity firms (likely those least intensive in the use of IT) serve only the domestic market, and the most productive firms export and serve the domestic market (Helpman, Melitz, and Yeaple 2003). Second, multinationals are more robust than domestic-only companies and are more technology-intensive. US-headed multinationals use 31 percent more advanced manufacturing technologies in US plants, yielding 11 percent more labor productivity and a 7 to 15 percent wage premium to blue- and white-collar workers, respectively. Foreign-headed multinational firms in the United States use 27 percent more advanced manufacturing technologies, and have 13 to 19 percent higher wages compared to domestic-only plants (Lewis and Richardson 2001). Thus, global engagement goes hand-in-hand with the use of advanced manufacturing technologies, with benefits accruing to both workers and firms—or at least to those that successfully adjust (an issue we will turn to again in subsequent chapters).

14. There are too many works to cite. A short review is found in Navaretti and Tarr (2000). OECD (2003) offers a much longer assessment, along with some original work.

15. See Baily and Gersback (1995); Jensen and Musick (1996); Bernard and Jensen (1997); and Mann (1998). See also the more recent set of papers using plant-level micro data by Bernard, Jensen, and Schott (2002, 2003, and 2005).

Third, import competition can lead to changes in the goods produced and more capital-intensive production technology, both of which promote greater productivity. Competition from imports from low-wage countries, such as China, pushes output and employment toward capital-intensive plants (including those intensive in IT capital), and changes the product mix toward capital- and skill-intensive production methods, both of which tend to increase productivity (Bernard, Jensen, and Schott 2003).

In sum, to an increasing extent the detailed research finds important channels linking global engagement, IT, plant-level productivity, and worker skill intensity. Box 3.2 shows the price reductions and product enhancements that can be facilitated by globalized production for a specific individual product, in this case cell phones.

Evidence and Implications of Uneven Sectoral Diffusion of IT Investment

Whereas the macroeconomic gains from intensive use of IT are clear, large segments of the US economy have not yet integrated IT fully into their business operations. Figure 3.6 shows the relationship between IT intensity and contributions to aggregate productivity growth in the United States by sector, along with the size of the sectors in terms of GDP.[16] The upward slope of the regression line mirrors the relationship as derived from the macroeconomic time series data, as discussed earlier. Considering the economic behavior of different sectors of the economy gives insights as to the source of overall macroeconomic performance, but also presents puzzles about why certain sectors have lagged in their investment and use of IT. Understanding better why some sectors have led in the investment and use of IT while other sectors have lagged may point to the future role for deeper globalization of IT, particularly IT software and services, with implications going forward for the US economy.

A first observation is that many of the larger sectors (in terms of GDP) leading the way in terms of contributions to productivity growth and IT-intensity are services activities, including wholesale trade, securities and commodity brokers, depository institutions, and communications. Retailing is the only notable example of a large services sector that did not use IT particularly intensively across the board but experienced above-average productivity growth.[17] Among manufacturing sectors, electronics

16. Analysis by the Economics and Statistics Administration (2002) for the *Digital Economy 2002* report for the US Department of Commerce developed sector-level measures of IT investment, productivity contributions to US growth, inflation, and other important indicators.

17. Although the sector as a whole does not appear to use IT particularly intensively, research shows that much of the productivity gain in retailing comes from more productive establishments replacing less productive ones, and that an important factor underpinning the more productive establishments was IT. See Foster, Haltiwanger, and Krizan (2002).

Box 3.2 Cheaper cell phones for the world through global production

Cell phones today have become the top-selling consumer electronics good in the entire developed world. Of course, the cell phone is actually a bundle of phone and telecommunications carrier (and perhaps other functions as well). Since cell phone prices for wealthy consumers remain heavily subsidized by telecommunications carriers, the average wholesale value of a cell phone was not insubstantial $174 in 2004. And the price is expected to decline only by about 1.5 percent annually until 2009 as phones become packed with more and more new features such as digital cameras, FM/AM radios, and Internet capabilities.[1]

The persistently high wholesale price of cell phones has remained a significant obstacle to large-scale adoption of mobile telephony in developing countries, despite rapidly improving wireless infrastructure and more competitive telecommunications charges. In 2005, while 80 percent of the world's population lived in areas with wireless coverage, only about 25 percent used mobile telephony services.[2]

The spread of wireless services in developing countries represents a huge business opportunity for wireless services providers that face increasingly mature and saturated markets in industrial economies. And a widening body of economic research indicates that rising mobile phone penetration is highly beneficial for economic growth. Leonard Waverman, Meloria Meschi, and Melvyn Fuss (2005) find that a developing country with an average of 10 more mobile phones per 100 inhabitants between 1996 and 2003 would have enjoyed per capita GDP growth that was 0.59 percent higher than an otherwise identical country.

As a result, the GSM Association, Motorola, and a large number of wireless services providers in developing countries launched the "Emerging Market Handset Initiative" in early 2005.[3] The goal was to produce a "no-frills cell phone" by the second quarter of 2005 at a price point below $40 (exfactory) to allow wireless services providers in developing countries to offer consumers phones within their purchasing capacity on a commercially viable basis (i.e., without the mas-

(box continues next page)

is a leader in terms of IT investment and above average contribution to productivity growth (which was why this sector was the focus for the first stage of research on IT and productivity growth), but it is a relatively small sector (in terms of GDP). There are other high-productivity manufacturing sectors, but summed up, "above-average manufacturing" accounts for only about 10 percent of GDP. Instead, the leading services activities account for 31 percent of GDP. In sum, the rapid acceleration of US productivity growth comes more from productivity-enhancing IT use in the services arena rather than from manufacturing.[18]

18. Research already cited from Mun and Nadiri (2002) confirms this finding. In addition, researchers from Europe (including van Ark, Inklaar, and McGuckin 2003) have noted that

Box 3.2 *(continued)*

sive handset subsidies offered to developed-world consumers).[4] In June 2005, Philips Electronics announced a supplementary initiative aimed at a $20 handset (exfactory) with the goal of reaching $15 by 2008.[5]

The operational opportunities for both Motorola and Philips for offering mobile phones within the much lower price range of developing-country consumers comes from both companies' extensive use of low-cost production facilities in developing Asia, in particular. Motorola, for instance, produces all its handsets at facilities located in China, Singapore, Brazil, Malaysia, and South Korea, and relies on electronics manufacturing suppliers (EMS) in Asia for approximately a third of the company's handset production.[6] For its part, Philips Electronics specifically located its low-cost cell phone initiative at its production facility in Shanghai.

The mobile telephony sector illustrates the powerful trend, noted elsewhere in this book, of how technology companies today utilize global low-cost supply not only to offer products at declining prices to consumers in the developed world, but also to offer technology products at affordable prices to consumers in developing countries, thus facilitating the closing of the digital divide.

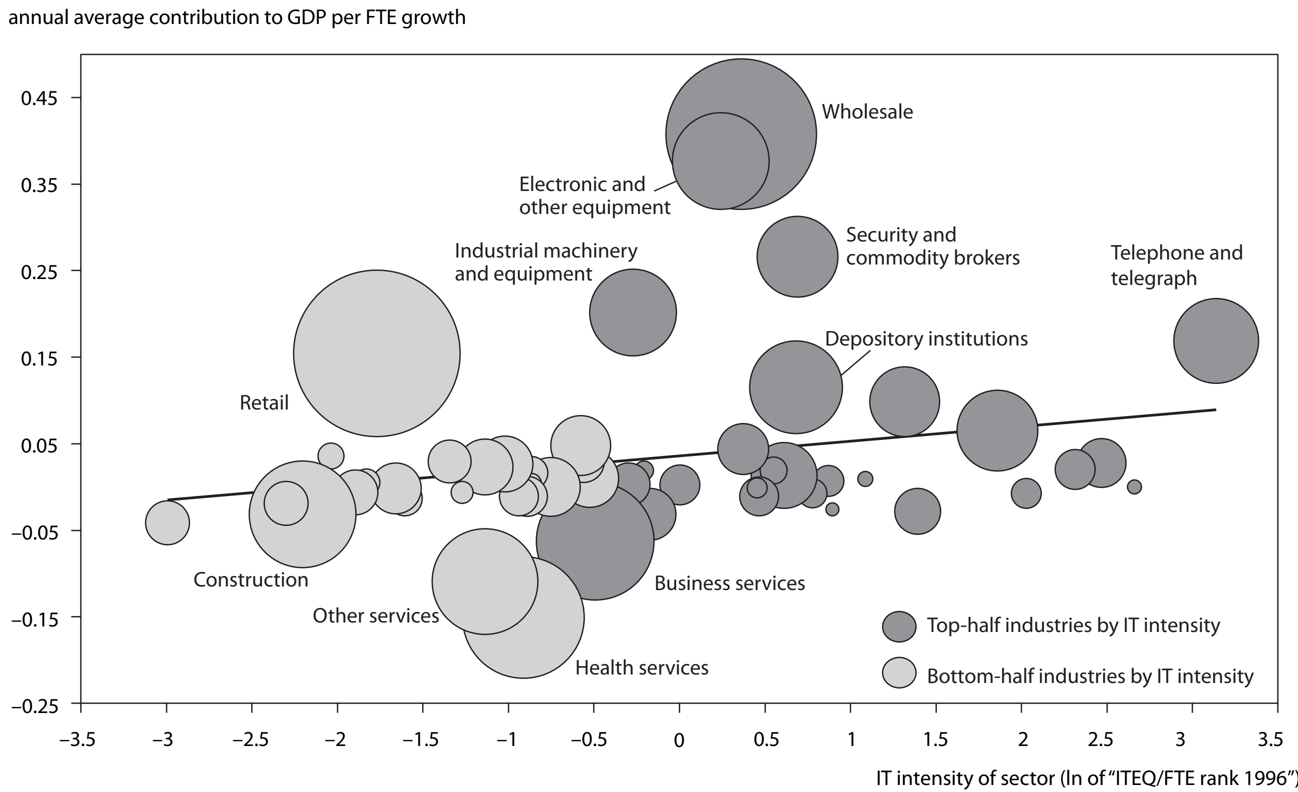
1. Gartner, "Forecast: Mobile Terminals, Worldwide, 2000–2009," July 18, 2005, available at www.gartner.com.
2. GSM Association press release, "GSM Association Announces New Phase for Emerging Markets Initiative," July 4, 2005.
3. Developing countries are defined here as those with GNP below the average of the World Bank's GNP/Capita Index and with a mobile penetration of less than 60 percent.
4. Motorola press release, "Motorola Chosen by GSM Association to Connect the Unconnected," February 14, 2005.
5. Philips Electronics press release, "Philips Launches Global Initiative to Develop Solutions for Ultra Low-cost Mobile Phones," June 29, 2005.
6. Motorola 10-K filing, 2005, available at the SEC EDGAR database at www.sec.gov/edgar (accessed on September 30, 2005).

Three sectors stand out for being large in GDP terms, low in IT intensity, and below average in terms of productivity. All are in services: health, construction, and the highly heterogeneous group of "other services," which among other activities includes engineering, accounting, research, and management services.

Exactly why some sectors have led in the use of IT and others have lagged remains a fertile area for research. There are several nonexclusive hypotheses, including those related to the information content of the activities of the sector; the degree to which firms in the sector were already

the disparity in productivity performance between Europe and the United States is due more to productivity performance in services than in manufacturing.

Figure 3.6 IT intensity and contribution to GDP per FTE growth, 1989–2000



ITEQ/FTE = information technology equipment/full-time equivalent (worker)

Note: Size of bubbles indicates share of GDP by individual sector.

Source: Bureau of Economic Analysis, *Digital Economy,* 2002, table A4.4.

organized in or around networks; the population of small and medium-sized enterprises in the sector; the extent of sector-specific regulation; and exposure to international market forces (the last hypothesis will be discussed in chapter 4).

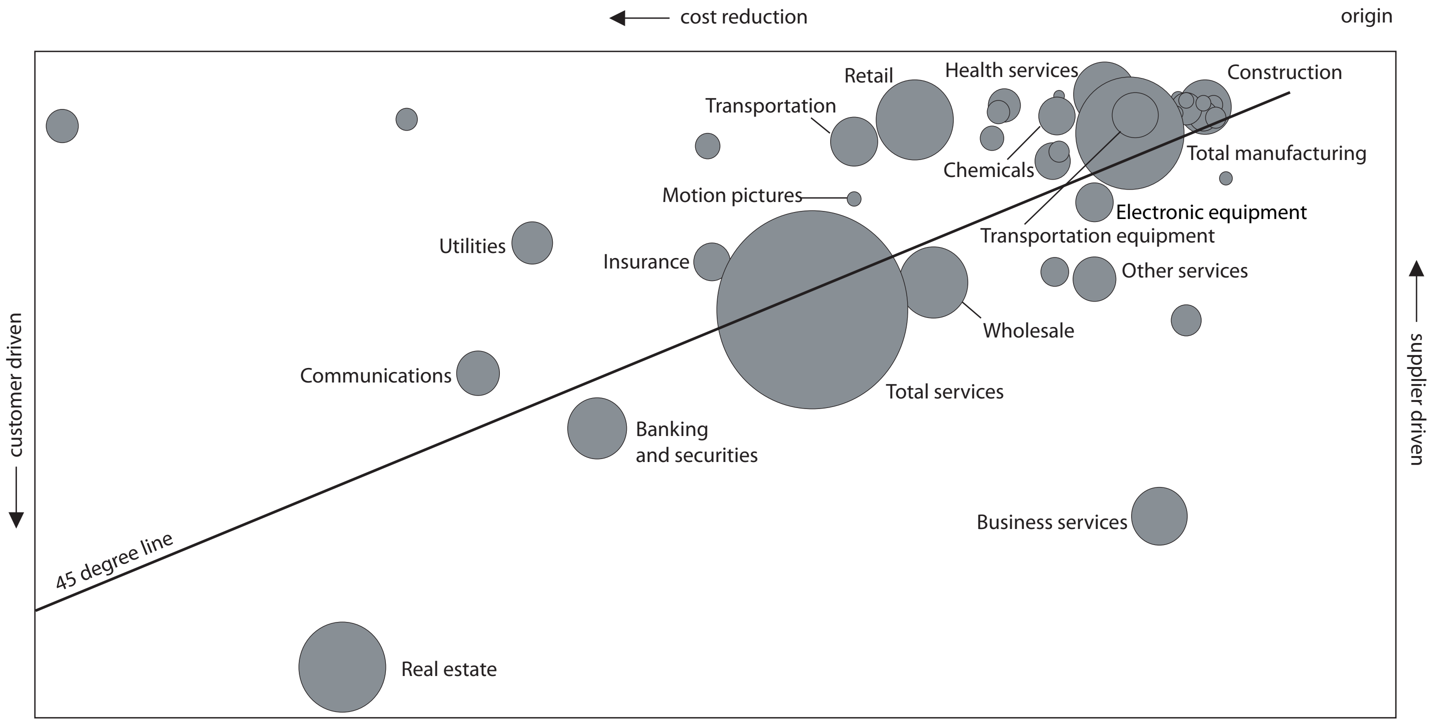
With regard to the nature of the sector's activities, research begun by Frank Levy and Richard Murnane (1992) and then continued with a coauthor (Autor, Levy, and Murnane 2002) finds that industries intensive in business processes and jobs characterized by routines and explicit rules have invested the most in IT, thus changing the mix of tasks between those done by people and those done by technology. IT-intensive industries then increase their demand for labor with skills such as judgment, problem solving, and communications, and reduce their demand for workers who performed the routine tasks that follow explicit rules. In fact, Daniel Wilson (2004) suggests that these routine tasks increasingly can be done by IT itself using various software programs.

With regard to the second hypothesis on the role of pre-Internet networks, it may be that the sectors that have been the leaders in IT intensity and contribution to GDP growth already exchanged information over telecommunications networks before the advent of the public Internet and IT made this interchange even more integral to the activity of the sectors. For example, in the financial system, interbank payment systems and automated teller machine networks networked financial institutions well before the advent of Internet technology.[19] Similarly, telecommunications firms were well positioned with networks in place to add new services based on IT investments. Finally, lower-cost supply-chain logistics and improved management of supply-chain information have been at the heart of just-in-time inventory management systems and rapid package delivery systems that contribute to improvements in productivity in some manufacturing sectors and wholesale trade (Gereffi 2001, Bair and Gereffi 2001, McKinsey Global Institute 2002).

Research using this same sectoral decomposition finds that the productivity-enhancing effect of IT capital investment is greater among industries with strong transactional linkages (Mun and Nadiri 2002). A related finding is that IT networks appear to be an independent factor in raising the productivity growth of plants. Figure 3.7 shows the reduction in average variable cost in the sector associated with investment in IT by both customers (forward linkages) and suppliers (backward linkages). These IT spillovers show how reductions in costs come from the importance of transactional linkages to other firms' IT. Cost reductions induced by networked IT free up financial resources to be devoted to other activities or investments. Sectors below the 45 degree line are those where IT use by the customer (or forward-linking sectors) are more important in

19. This is consistent with the research cited from Atrostic and Nguyen (2005). See also Morisi (1996).

Figure 3.7 Reduction in own costs from IT usage by suppliers and customers



Note: Size of bubbles indicates industry share of GDP.

Source: Mun and Nadiri (2002, table 4).

reducing the sector's own costs. Sectors above the line are those where the IT use by the suppliers (or backward-linking sectors) has the greater impact on the sector's own costs.

Considering the main segments of the economy—manufacturing versus services—this research shows that the benefits of IT spillovers to reduce costs are greater for services sectors (the cost reduction from transactional linkages is greater) than for manufacturing sectors (the services bubble lies to the left of the manufacturing bubble in the figure). In part, these greater spillover benefits come from the greater overall investment in IT by the relatively larger services sector. But it is also the case that services firms have a more diversified set of forward linkages (customers) throughout the economy—in terms of the figure, more of the individual services sectors lie below the 45 degree line. The more diversified the transactional linkage and the more the transaction-linked sector uses IT, the greater the spillover benefits of one's own IT investment to reduce costs.

Just as in the case of overall macroeconomic performance, the diversity in the importance and direction of transactional linkages across sectors in the US economy reveals the source of economic gain from IT investments. Banking, business, and wholesale services have strong forward linkages (i.e., below the 45 degree line) and show significantly reduced costs from these transactional linkages (i.e., well to the left in the figure). Health services, retail, and construction are sectors where, in general, there is little cost reduction coming from IT in transactional linkages (i.e., these bubbles are close to the origin of the figure). This pattern of diversified forward linkages and greater spillover gains is suggestive of the role that competition and tailored customer demands can play in driving IT investment and spillover gains. A key strategy for tailoring IT is through software and services—but these are the relatively more expensive parts of the IT package. Globalization to reduce the costs of IT software and services, just as it has reduced the cost of IT hardware, could play a role in further customization, greater investment, and increased spillover gains for these lagging sectors.

Corroborative research, undertaken using detailed plant-level data, finds an independent role for IT networks (Atrostic and Nguyen 2005). IT networks enhance the productivity of a plant beyond the gain from internal IT investment by the plant. The network impact is stronger in raising the productivity of newer plants. Not only are the newer plants more likely to have made IT investments, but the share of those investments in IT services and software—the necessary tools to link IT hardware together—is likely to be higher, at least judging from the NIPA investments waves presented earlier. Finally, the newer and more networked plants are also likely to have a higher share of skilled workers.[20]

20. Specifically, there is a higher share of nonproduction workers, who are often used as a proxy for skilled workers.

Table 3.2 Capital expenditure per employee, by industry sector and size of company, 1998

Sector/size of company	Computers and peripherals (US dollars)	Total equipment (US dollars)	Share of total employment (percent)
Durable manufacturing			
SME: 0–499 employees	942	4,562	38.5
Large: 500+ employees	1,463	20,291	61.5
Construction			
SME: 0–499 employees	112	3,250	89.6
Large: 500+ employees	493	3,731	10.4
Health			
SME: 0–499 employees	231	1,284	43.1
Large: 500+ employees	476	2,760	56.9

SME = small or medium-sized enterprise

Source: Buckley and Montes (2002, table 3).

Why do some sectors seem to lag consistently in IT adoption, cost reductions, spillovers, and productivity growth too? Sectors with a higher population of small and medium-sized businesses appear to lag. The data suggest that these sectors generally have invested less per employee in productivity-enhancing IT. The construction and health services sectors have particularly high populations of small and medium-sized enterprises. Controlling for the same sector, the IT investment per employee has been significantly less than at their large-firm counterparts, and their investment in IT has been drastically less when compared with firms engaged in durable-goods manufacturing (table 3.2).

Culture and regulatory constraints may affect the uptake of IT by the lagging sectors. For example, in health services, privacy and regulatory issues are quite important for software and services design and implementation. Moreover, there are no IT hardware, software, and services packages that are common to the disparate entities that are part of the sector (doctors' offices, pharmacies, hospitals, etc.). Professional licensure, particularly when it varies from state to state, may be important for construction and for engineering services as well. Such fragmentation could increase the costs of producing IT applications appropriate for these sectors and thus reduce IT investment and use by firms in these sectors. Finally, legacy issues of existing training, information management systems, and technology equipment complicate integration and the type of business transformation and networks that are the hallmark of productivity growth in the leading sectors.

In sum, the growing body of research on different aspects of the relationship between IT capital and productivity growth reflects the complementary relationships between IT investments within the plant (hardware, software, and services), communications investments to network the plants, and IT use by increasingly skilled workers. To the extent that globalization of IT reduces the price of investments, and aids or hinders the uptake of IT (including the training needed by workers to use it effectively), productivity growth likely is enhanced or dampened. Going forward, as the software and services component of the IT package increasingly becomes a key part of that package within and between firms (as evidenced by the spending data discussed earlier), there will be a greater and greater premium on reducing the price of these components. As it has for IT hardware, globalization can play a role.

The uneven productivity growth across sectors of the United States raises questions for further research: Why do some sectors lag? Do they face more challenges to using communications networks? Is there greater sensitivity to the cost of IT services and software? Does customization of these parts of the IT package cost more?

Global sourcing of components of software and IT services offer the potential to reduce the module prices on which customized software and tailored services can be built. Econometric estimates show that the demand for software and services is even more responsive to price reduction than is the case for IT hardware. Therefore, as prices fall, demand for services and software is likely to rise more than one-for-one, helping to diffuse IT into the lagging sectors, deepening the use of IT in the leading sectors, and raising productivity growth throughout the US economy (see, for example, Deloitte Research 2003 for finance). Extending the beneficial forces of globalization to the components and activities that matter the most for the lagging sectors of the US economy portend a second wave of productivity growth.

The US Experience Compared with Other Countries

Looking at the US experience by itself is instructive, but there is even more to learn about the role that IT can play in transforming an economy by comparing the US experience with that of other countries. In particular, this cross-country comparison can give some insights into the consequences of the changing share of the United States in global IT production and expenditure. Cross-country analysis will also highlight the role for transformation and networks in the presence of IT as being of particular importance to reap the full benefit of it. Finally, the role for complementary services infrastructure and services (including communications) is highlighted on account of the key role that such infrastructure plays in the development of IT services and software as well as cross-border trade in services more generally.

Production versus Use of IT

Rapid innovation and falling prices for IT products reduce the entry cost to effective use of IT and the benefits that accrue to its use. But many countries still impose tariffs on imported technology capital, sometimes thinking that this will promote development of a domestic industry. Moreover, a number of countries—including Malaysia, the Philippines, Singapore, and Ireland—have expended significant sums of money via direct and indirect subsidies to become globally important producers and exporters of IT products. Are there lessons to be learned from these strategies and their impact on the countries that employ them?

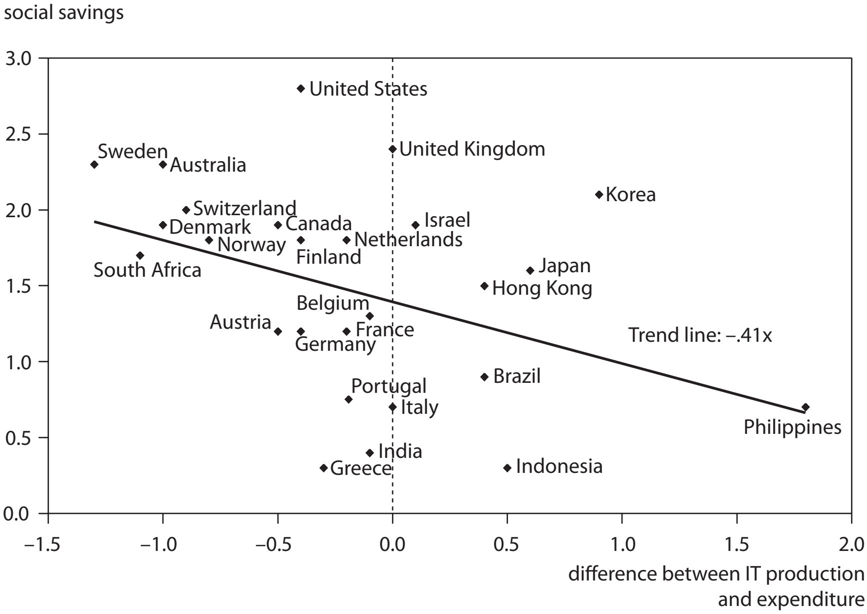
While production and export of IT products obviously should not directly harm an economy,[21] declining prices for IT products mean that the terms of trade (export prices compared to prices of imported products) are moving against these producers. Thus, the gains to the domestic economy that do come from producing IT hardware for export are partly offset by the opportunity cost of not using those increasingly cheaper and more powerful IT products throughout the domestic economy.

One way to document the relative importance to economic well-being of being an IT producer as opposed to IT buyer (or somewhat in between, which is the case for most economies) is to net out the benefits to an economy of being one or the other. "Social savings" is a methodological concept used to assess the benefits of technological change. As prices of a new technology fall, the gains to national income of an economy can be calculated as the difference between what the economy pays for the new technology when it buys and uses it in the domestic economy compared to what it receives when it produces and sells the new product. If spending exceeds production, the economy is a net importer of IT; if production exceeds spending, it is a net exporter. Social savings can be mapped into the more familiar growth accounting framework emphasized in the research discussed earlier on the United States in the 1990s. Broadly speaking, the social savings measure equates to the measure of total factor productivity growth.[22] Figure 3.8 shows scatter plots of Tamim Bayoumi and Markus Haacker's calculations of social savings against net expenditure on IT (net expenditure is the difference between IT as a share of production and as a share of expenditure, averaged for 1996–2000).

21. Assuming that the targeting of certain sectors does not lead to corruption or other inefficient activities.

22. See Crafts (2004) for an instructive comparison of the social savings approach to measuring the gains from IT as compared to the growth accounting methodology.

Figure 3.8 Social savings and the difference between IT production and expenditure (percent of GDP)



Note: Excluded countries include Singapore, Malaysia, Ireland, Taiwan, and Thailand.

Source: Bayoumi and Haacker (2002).

The figure reveals several points.[23] First, all countries to the right of the zero y-axis are net exporters with the share of IT in production (where falling prices reduce the net gain to social savings and national income) greater than the share of IT in domestic expenditure (where falling prices increases the net gain to social savings and national income). Those to the left of the zero y-axis are net spenders and net importers of IT. Now consider the trend line, which reveals the negative relationship between social savings and the net of IT production and expenditure; when the net gain to social savings and net income is greater, the greater is the gap between expenditure and production. This does not imply that a country needs to be a net importer to gain from IT. The trend line cuts the zero y-axis at a positive net export of 1.4 percent, and many net exporters enjoy

23. Five economies with intense concentration in production (Singapore, Malaysia, Ireland, Taiwan, and Thailand) are not included in the figure. For Ireland, Malaysia, and Singapore, net social savings is above 1.5 percent, whereas for Taiwan and Thailand, it is less than 1 percent. However, these economies are such outliers in net production (located at far right of the y-axis) that they mask the relationship relevant for economies with more average characteristics.

positive net income gains from using IT. However, they may well generate even greater gains if they were to use more of their home-produced IT internally.

The trend line shows the "average" social savings for this set of countries; those above the line generate more than average social savings from the IT they do buy, whereas those below the trend line do worse than average. The US experience is notable for being well above average in deriving gains from IT. The experience of several industrial countries (the United States, Australia, and European countries) will be discussed in more depth in the next section, but a preliminary assessment of their experiences can be seen here. The United States, Australia, Canada, United Kingdom, and the Nordic countries stand out as countries that are net purchasers of IT and have used it more effectively than the average country to generate net income and social savings (they are above the trend line and to the left of the zero y-axis). On the other hand, the larger countries of continental Europe represent countries that are net importers of IT, but have not used it as effectively to economic gain (they are below the regression line), suggesting a TFP lower than the average for this set of countries. With respect to net exporters, some are above average in using IT (Japan and Korea) and others below average (Brazil and Indonesia). The social savings concept is a useful strategy for comparing the experiences of the United States against many other countries along the dimensions of production and expenditure.

Contrasting the Experiences of the Industrial Countries

The productivity experience of the United States has not been widely shared. What can be learned from the experiences of other countries about the source of productivity benefits and the relative role for IT, the transformation of activities, or other factors? Research on industrial countries suggests that differences in outcomes are related to differences in patterns of investment and responsiveness of domestic markets to economic signals, as well as to patterns of international trade.

For many European economies, domestic production of technology capital is relatively small. But, unlike the United States (or Australia, as shown in box 3.3), investment in IT has been slower and imports have been unremarkable.[24] On balance, the lower share of technology capital in the capital investment of firms in many other industrial economies to date is an important reason for their relatively lackluster productivity performance from the latter half of the 1990s to 2002. It is difficult to start on the path of transformation if there is not a lot of IT to precipitate the change (Scarpetta et al. 2000, Elmeskov and Scarpetta 2000, OECD 2003).

24. OECD (2002b); tables 2.1 and 2.2a in chapter 2.

Box 3.3 The productivity experience of Australia

Australia offers an important example of how the benefits of IT can diffuse throughout an economy that does not have a significant base in IT production. In Australia, the share of IT production in GDP in 2000 was 0.2 percent, whereas it was 1.8 percent in the United States, 5.3 percent in Finland, and 39.2 percent in Singapore. So Australia is not a big producer of IT.

The acceleration in labor productivity growth in Australia was greater even than that experienced in the United States. Labor productivity can increase for several reasons, including increases in the amount of capital that is used, increases in skill levels of workers, and transformation of the activities in the workplace. The contribution of direct investment in IT capital (so-called capital deepening) to acceleration in labor productivity growth was about the same in the United States and Australia during the period examined (line 3). On the other hand, the role of the transformation of activities (total factor productivity, or TFP, growth) in the acceleration in labor productivity was even greater in Australia than it was in the United States (line 5).

TFP measures how an economy uses its existing resources (capital, labor, land, and so on) to produce more output. An increase in TFP reflects the outcome of doing things differently in an economy in order to get more output out of the same or fewer inputs. TFP proxies for the importance of transformation in raising labor productivity. For Australia, the gains from buying IT abroad and effectively using it in the transformation of business activities have also supported the creation of a domestic IT services sector, thus further expanding the gains from IT.

IT and productivity growth: Contributions to labor productivity accelerations in the 1990s (percent)

	United States[a]	Australia[b]
1. Labor productivity growth	0.5	1.0
2. Capital deepening	0.2	–0.1
3. IT/communications capital	0.3	0.4
a. Hardware	0.3	0.4
b. Software	0.1	0.0
4. Other capital	–0.2	–0.5
5. Total factor productivity contribution	0.3	1.1

a. Growth in 1992–2000 less growth in 1986–92.

b. Growth in 1993–94 to 1999–2000 less growth in 1988–89 to 1993–94.

Note: Percent per year and percentage point contributions by IT to labor productivity acceleration in the 1990s cycle.

Source: Parham (2002, table 1 on p. 9); and author's calculations on IT production as a share of economy-wide production.

Table 3.3 Average annual growth of GDP per hour worked in ICT-producing, ICT-using, and non-ICT industries in the European Union and United States, 1979–95 and 1995–2002 (percent)

	1979–95		1995–2002	
	EU-15	United States	EU-15	United States
Total economy[a]	2.3	1.2	1.8	2.5
ICT-producing industries	6.8	7.2	8.6	9.3
ICT-producing manufacturing[b]	11.6	15.1	16.2	23.5
ICT-producing services	4.4	2.4	5.9	2.7
ICT-using industries[c]	2.3	1.6	1.8	4.9
ICT-using manufacturing	2.7	0.8	2.0	2.6
ICT-using services	2.0	1.9	1.7	5.3
Of which:				
Wholesale trade	2.4	3.5	1.5	8.1
Retail trade	1.7	2.4	1.5	7.1
Financial services	1.9	1.5	2.3	5.0
ICT-intensive business services	0.8	–0.9	0.6	0.7
Non-ICT industries	1.9	0.4	1.1	0.2
Non-ICT manufacturing	3.2	2.3	2.1	1.2
Non-ICT services[a]	0.8	–0.3	0.5	0.2
Non-ICT other	3.4	1.4	2.1	0.4

ICT = information and communications technology

a. Excluding real estate.

b. Based on US hedonic price deflators for ICT production (adjusted for national inflation rates) instead of actual national accounts deflators.

c. Excluding ICT-producing.

Notes: Industry groupings into ICT-producing industries are from the OECD; distinction between ICT-using industries and less intensive ICT users is based on share of ICT capital services in total capital services from nonresidential capital; see van Ark, Inklaar, and McGuckin (2003) for exact grouping.

Source: van Ark (2005, table 4).

Detailed calculations of labor productivity for different sectors for selected economies reflect more on the differences across countries in terms of how effectively IT is used (table 3.3). The most notable difference between the United States and the European economies is in the higher level and greater acceleration of labor productivity growth in IT-using industries, particularly IT-using services.

Why have some economies not invested in and effectively used technology capital? If the environment is not supportive of upgrading business capital, changing work activities, or business entry and exit, then there is less incentive for businesses to invest in technology capital (Gust and Marquez 2000, 2002). In the case of Australia, the increased and effective use of IT was accompanied by deregulation and liberalization of the business climate (Gruen 2001). Over a broader set of countries, researchers have found that industrial economies that employ less technology capital also have an environment that is less supportive of the needed resource reallocations across firms and sectors in the economy and needed changes in organizational behavior within firms. Financial markets and perhaps accounting rules may play a role here. For example, by common measures of overall capital, the European countries have a relatively capital-intensive economic structure. So one issue may be that some of this "old" capital needs to be retired and new IT capital purchased instead. Rules and regulations may play an important role in limiting the transformation of activities in IT-using services sectors, such as retailing and securities. Resource reallocations across sectors and within firms interact with organizational change; the OECD has found a positive correlation between technology investments and adoption of new workplace practices. So if IT capital intensity is low, there is less incentive to change workplace practices, leading to a low-level productivity trap.

Does the industrial-country experience deliver lessons for the developing economies? Broad-based research on the link between IT and productivity growth that focuses only on developing economies finds mixed results in terms of the extent to which the experiences of these countries mirror the findings of the studies of industrial economies. Some researchers find little relationship between IT and productivity growth in developing economies and surmise that there is too little IT investment and that supporting communications infrastructure is poor (Pohjola 2001; Dedrick, Gurbaxani, and Kraemer 2002; Kraemer and Dedrick 2000).

In other research, when developing countries are divided into two groups based on the share of IT investment in GDP, the ones above a threshold intensity reveal the link between IT and productivity growth observed in the United States, Australia, and some other industrial economies (Lee and Wan 2001, Haacker and Morsink 2002). Thus, just as for the industrial countries, IT investment is the first step, but not enough to generate the hoped-for productivity gains. Just as for the United States, reaping the full rewards from IT requires not just IT investment but also networks and the transformation of economic activities (Moran 1999, 2001). Thus, one lesson to be discussed in more detail in chapter 4 is the need for liberalization of cross-border services, such as telecommunications, financial systems, and distribution logistics and supply chains, that help create the networked relationships and transactions linkages found to be so important for the US experience.