Performance of Urban Information Technology Centers:
The Boom, the Bust, and the Future*

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After being emblematic of the U.S. economic surge in the late 1990s, urban areas that specialize in information technology (IT) products have more recently been struggling with the aftermath of the IT spending bust. To what degree can they bounce back and reemerge as leaders of innovative activity and production in the IT sector? We examine the characteristics of some of the nation's leading IT centers, linking these characteristics to a discussion of economic research concerning the sources of growth in urban industrial centers. Although each of these IT centers was hit hard by the IT bust beginning in 2000, the full impact varies depending on the size, density, and composition of the local IT sector. Some IT centers are better positioned than others to resume a rapid growth path as the IT sector recovers, depending on factors such as reliance on manufacturing versus services, diversity of the product base, innovative capacity, and ability to respond to changing conditions such as the recent rise in IT imports and overseas production.

1. Introduction

Information technology (IT) producers were among the key drivers of the national economic expansion during the late 1990s and in 2000, helping to spur robust growth in output, productivity, and income. Between 1995 and 2000, IT-producing businesses accounted for nearly one-third of U.S. GDP growth and, by one estimate, nearly two-thirds of the surge in productivity growth, despite accounting for less than 9 percent of total output at the start of the period.[1] At its peak, the IT sector was growing more than four times as quickly as the overall economy. This growth was driven largely by business investment in IT products, which increased rapidly throughout the period.

While the national IT boom helped spur growth throughout the U.S. economy, certain urban areas were especially well-positioned to take advantage of the IT spending surge. These urban IT centers were at the forefront of expansion in the U.S. IT sector, posting extraordinary gains in employment and income. As in the past, Silicon Valley (the San Francisco Bay Area more generally) was among the nation's leading IT centers. However, the 1990s also marked a time when several other urban IT centers, including Portland, Seattle, Washington, D.C., and Austin came of age. All of these centers were emblematic of the IT boom, posting substantial increases in IT output and serving as home bases to researchers and companies that played an integral role in bringing innovation to the marketplace.

Just as the IT boom disproportionately benefited many regional centers of IT production, the IT bust left them struggling to regain economic stability. Battered by the

1. Data on the contributions of IT to GDP come from the Bureau of Economic Analysis (BEA) GDP releases. See Stiroh (2002) for analysis of the IT sector's contribution to productivity growth. Although the surge in productivity growth from 1995 to 2000 was dominated by IT-producing sectors, increases in productivity more generally were broad-based, with most sectors realizing productivity gains over the period.

downturn in business investment in IT equipment and software, several IT centers experienced some of the most severe net job losses in the nation. This reversal of fortune has prompted some observers to question whether cities that were at the forefront of the IT boom can return to prominence as centers of innovative activity and production. Which cities can best respond to newly emerging growth patterns in the IT sector, and what characteristics play key roles in this process?

To address these questions, we focus on the rise and fall of a sample of urban IT centers during the IT "boom and bust" cycle from 1995 through 2003. We focus on a set of ten metropolitan areas that experienced rapid growth in their own IT sectors and made a substantial contribution to national IT growth. The key characteristics that helped these areas to grow—concentrations of IT employment and wages, high levels of research and development (R&D) and patent activity, and highly skilled labor forces—appear to have survived the bust. These factors bode well for the urban IT centers to remain focal points for IT innovation and production. That said, the future is not without challenges; changes in product demand, business investment patterns, and overseas production will put pressure on IT centers to evolve, with the likelihood that some will adapt better than others.

We begin in Section 2 by discussing economic evidence regarding the development and dynamics of specialized industry clusters in cities. We then describe our sample of urban IT centers in Section 3, and in Section 4 we examine the extent to which they exhibit economic characteristics that are consistent with IT specialization and sectoral growth. These sections provide the background for the next two sections, in which we analyze the boom and bust cycle and the responsiveness of the IT centers to key growth determinants: business investment spending and the rising role of overseas production. We conclude in Section 7 with a brief comparative overview of the growth prospects for our set of major urban IT centers.

2. Urban and Industry Growth

What determines the formation of urban IT clusters and their growth? Research on these specific questions in economics and related fields is quite limited.[2] However, a substantial amount of research has been conducted that investigates the general determinants and patterns of economic growth at the urban level, and this research is relevant to the issues we address in this paper.

On the formation of specialized industry clusters, the work of Ellison and Glaeser (1997, 1999) is especially instructive. They note that Silicon Valley-style concentrations of industries can arise through two broad features of urban economies. The first is the presence of location-specific cost advantages—i.e., differences in input costs due to climate and geography, access to raw materials, and available supplies of different categories of labor. Although most inputs into the IT production process—financial capital, specialized machinery, raw materials, etc.—are unlikely to exhibit substantial price variation across geographic areas, variation in the availability and relative price of skilled labor (such as college-educated workers) may represent one important source of cost variation for IT producers.

An additional mechanism for the development of specialized IT centers is the presence of beneficial knowledge spillovers among firms within the same industry and geographic area. To the extent that these "agglomeration economies" exist and contribute to local economic specialization, they create the potential for "increasing returns" in production, or increased productivity in the locally concentrated industry as output increases. The tendency for initial industry leaders, such as Silicon Valley, to maintain or expand their innovative and productive edge over time is consistent with increasing returns in local IT centers. Moreover, this process of increasing returns through knowledge spillovers is likely to function most effectively in markets with an abundant supply of highly skilled labor, which suggests a potentially positive interaction between location-specific cost advantages and knowledge spillovers in determining IT industry growth.

Saxenian (1994) has identified some of the key features of agglomeration economies in Silicon Valley's IT sector, including knowledge transmission through employee mobility (often entrepreneurial), supportive and activist financial institutions (see Hellman and Puri (2002) for evidence on the role of venture capitalists), and the presence of knowledge centers such as research universities and institutes (see Audretsch and Feldman (1996) regarding the importance of knowledge spillovers from these sources). More general evidence, which systematically models growth performance across cities, also supports the importance of knowledge spillovers in urban IT centers. Beardsell and Henderson (1999) find strong evidence of

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2. The most well-known work is Saxenian's (1994) highly cited book comparing Silicon Valley with the Route 128 area near Boston. DeVol (1999) focuses on the contribution of the IT sector to growth in cities, while Cortright and Mayer (2001) emphasize the role of specialization for growth in urban high-tech centers. Drennan's (2002) definition of the "information" sector excludes manufacturing and includes a broad array of services not in our definition (for example, financial services, legal services, and other professional services); as such, his comprehensive analysis of the information sector and urban growth is not directly relevant to our work.

positive spillovers at the local level in an analysis restricted to the computer industry. Moreover, Audretsch and Feldman (1996) find that industries in which knowledge spillovers are more prevalent have the greatest propensity to exhibit innovative clusters at the local level.

Strictly speaking, Ellison and Glaeser's arguments regarding the sources of localized growth refer to the degree of geographic concentration of total U.S. output in a sector, hence the overall size (rather than density) of local IT sectors in our setting. However, the benefits of agglomeration economies are likely to be most pronounced when production is locally dense (constitutes a large share of output), since the benefits of knowledge spillovers may be diluted when the IT sector must compete more vigorously with other sectors for scarce knowledge resources. Thus, it is likely that specialization is important for IT sector growth, in the sense that an urban area must achieve a high density of IT activities as a share of overall economic activity in order to realize the benefits of agglomeration.[3]

Interestingly, other research finds that industrial diversity, rather than specialization, plays a key role in urban innovation and growth (Feldman and Audretsch 1999, Duranton and Puga 2001).[4] This is not necessarily inconsistent with the role of IT specialization, however, as it may also be true that diversity within the IT sector supports innovation. In particular, Duranton and Puga (2001) emphasize that innovative activities are most common and effective in diversified production environments, in which firms searching for the best products and processes benefit from a wide range of possibilities. The process of knowledge spillovers in the IT industry, achieved through employee mobility and related factors, functions as a critical delivery mechanism for realizing the benefits of diversified product environments. Duranton and Puga also note that it is common for firms to start up in diversified cities and then move to more specialized production locales; this is consistent with the tendency for IT firms to have headquarters in IT centers but to locate production facilities in lower-cost locations increasingly over time.[5] Moreover, by ensuring a wide range of production processes and of products, a diverse local IT sector may possess the advantage of enhanced flexibility in response to changing conditions in

IT markets; these may include changes in patterns of demand, changing domestic and overseas cost conditions, and other broad changes that affect the demand and supply for IT products and services.

To summarize, it appears that urban areas that have a large IT sector and that have a relatively high density of IT activities may have two key advantages over other areas in regard to IT innovation and production. First, high IT density enables a region to capitalize on local increasing returns to IT innovation and production, thereby reducing costs and enhancing productivity within its IT sector. This is especially true when highly skilled labor is in abundant supply. In addition, having a large local IT sector increases the likelihood of diversity *within* the IT sector, since growth constraints related to market size are likely to be less binding when the product array is relatively broad. In addition to providing flexibility to respond to changing IT industry demand and cost conditions, diversity within the IT sector may provide an impetus for IT innovative activities by allowing firms to access a wide range of product and process options. As such, a combination of size and density in the IT sector may be optimal and go a long way towards explaining the continuity of an industry leader such as Silicon Valley.

3. IT Centers: Definition and Sample

Before defining our sample of urban IT centers, it is important to define what is meant by "IT." Our broad definition of the IT sector is intended to capture the manufacture and service-based provision of advanced information technologies that rely on programming or other automated control mechanisms.[6] On the manufacturing side, computers and communications equipment, and their primary building blocks—semiconductors and other advanced electronic machinery—form the core of this industry. IT manufacturing also includes the production of a variety of advanced measuring and testing equipment, such as photonics and electromedical and aeronautical devices, along with consumer electronics. The services side includes firms that provide wired and wireless communication technologies, along with deliverers of Internet and other computer programming, design, and management services and research and engineering services. We use this broad definition wherever possible, although for much of what we do below, data constraints require that a narrower definition be applied (we discuss deviations where appropriate).

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3. Ciccone and Hall (1996) provide persuasive evidence that the density of overall economic activity in local economies, rather than their size, is a key determinant of economic growth.

4. The importance of industrial diversity for urban growth is an idea often traced back to Jacobs (1969).

5. For example, the growth of IT production and employment in Oregon and other relatively low-cost states over the past decade has occurred in part because existing companies such as Intel have relocated production facilities from high-cost areas such as Silicon Valley (while maintaining research and management facilities in their origin cities).

6. The broad definition that we use is generally identical to the definition used by the American Electronics Association (see AEA 2003). It includes North American Industrial Classification System (NAICS) industry codes 33400, 333200, 333300, 511200, 511700, 518000, 541500, 541700, and 611400 (see also footnote 9).

Notably excluded from this definition are the biotechnology and pharmaceuticals industries ("biotech"). These sectors share some of the key characteristics of our IT industries, most notably a knowledge-intensive production process, as reflected in an advanced skill base and extensive R&D outlays and patenting activity. However, these industries tend to play a much smaller role than IT industries in local economies, and the demand and innovation cycles in these industries are independent of those in IT; for example, the biotech and pharmaceutical industries did not share in the recent boom-and-bust cycle experienced by our more narrowly defined providers of IT goods and services. These features of biotech support its exclusion from an analysis of the shifting fortunes of IT centers.

With a definition of IT-producing industries in hand, we selected a sample of metropolitan areas where these industries play an important role. Our definition of IT centers relies on the concept of "metropolitan statistical areas" (MSAs), as defined by the U.S. Office of Management and Budget and as used by federal statistical agencies. In general, MSAs consist of a core area containing a substantial population nucleus, together with adjacent communities that have a high degree of socio-economic integration with that core. To identify our IT centers, we applied the broadest available MSA definition, which in most cases corresponds to combined MSAs that form a "consolidated" MSA, or CMSA. Each of these areas is tied together internally by economic factors, such as commuting patterns and business ties, that form a shared economic base.[7]

We chose our exact set of cities by considering the importance of the IT sector in the local economy and the contribution of the local IT sector to total national IT activity. Starting with a sample of sixteen MSAs known to have large IT sectors or high IT shares of local activity (American Electronics Association 2000), we measured the importance of IT to the local economy by the share of IT industries in total nonfarm wage and salary payments (payrolls) in 2000 and payroll growth between 1995 and 2000. Similarly, we measured the contribution of local IT sectors to national IT activity by the share of local IT sec-

tors in national IT payrolls.[8] Attaching equal weight to these factors, we then ranked cities based on the combined magnitude of these three factors.

The resulting list of ten urban IT centers (in alphabetical order) is Atlanta, Austin, Boston, Dallas, Denver, Los Angeles, Portland, the San Francisco Bay Area, Seattle, and Washington, D.C. Table 1 lists the principal IT product specializations of each. In general, these are large MSAs as measured by population. Except for the Los Angeles area and Portland, each boasts personal income per capita above the U.S. metro average, with the San Francisco Bay Area achieving a level that is about 50 percent above the U.S. metro average. (See the Appendix for a table listing population and per capita income for the ten IT centers in our sample.)

The factors contributing to our ranking are listed in Table 2 (from this point on, we use shortened names for the broad MSAs listed in Table 1). As in the nation as a whole, IT-producing industries made a disproportionate contribution to overall economic growth in our IT centers. This can be seen by comparing the IT share of payrolls in 1995 (Table 2, column 1) to the IT contribution to total payroll growth (column 3). For the ten IT centers on which we focus, the IT growth contribution is larger than the IT growth share (and indeed, except for Los Angeles, is larger than the IT growth contribution for the nation as a whole). The contribution of IT to overall payroll growth was especially large in the San Francisco Bay Area, accounting for over one-third of the total. The IT contribution to the growth in payrolls also was quite large in Portland, Seattle, and Washington, D.C., ranging from twice to more than two and a half times as large as the initial IT share. On average, the contributions of IT-producing sectors to payroll growth were about one and a half to two times as large as their share of total payrolls in 1995, with West Coast IT centers exhibiting especially large absolute contributions. The sole exception is Los Angeles, which exhibits an IT contribution to local growth somewhat below that for the U.S. as a whole. However, that MSA's inclusion in our

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7. For example, as indicated later in this section, rather than focusing narrowly on "Silicon Valley," which corresponds roughly to the San Jose MSA in California, we include the San Francisco and Oakland MSAs in our definition of the San Francisco Bay Area IT center. Although the San Jose MSA traditionally exhibits the highest IT density of any MSA nationwide, San Francisco and Oakland also are relatively dense centers of IT activity, and the connections between IT and related firms throughout the region are strong (similar to the "Route 128" region in and around Boston).

8. Tabulations of IT sector shares of total nonagricultural employment and wage payments are the most readily available and commonly cited measures of IT production activity and shares. These data are from the U.S. Bureau of Labor Statistics' (BLS) Covered Employment and Wages (CEW) program (now called the Quarterly Census of Employment and Wages), which provides data on all establishments covered by state and federal unemployment insurance provisions. The available degree of industry detail therefore is quite large, enabling implementation of a relatively precise definition of the IT sector. Excluded establishments constitute a very small share of urban employment in general. Although it would be preferable to use output measures, to make these tabulations comparable to the national figures cited in the introduction, the requisite data on output by state and industry are not available.

TABLE 1
URBAN IT CENTERS AND PRINCIPAL PRODUCT SPECIALIZATIONS

Region	Product Specializations
Atlanta, GA (MSA)	Databases, Telecommunications
Austin-San Marcos, TX (MSA)	Semiconductors, Computers, SME
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH (NECMA)	Computers, Medical Devices, Software
Dallas-Fort Worth, TX (CMSA)	Communications Equipment, Semiconductors, Telecommunications
Denver-Boulder-Greeley, CO (CMSA)	Data Storage, Communications Equipment, Telecommunications, Software
Los Angeles-Riverside-Orange County, CA (CMSA)	Household Audio and Video Equipment, Search and Navigation Equipment
Portland-Salem, OR-WA (CMSA)	Semiconductors, Display Technology, SME, Wafers
San Francisco-Oakland-San Jose, CA (CMSA)	Semiconductors, Computers, Software, Communications Equipment, SME, Data Storage
Seattle-Tacoma-Bremerton, WA (CMSA)	Software
Washington-Baltimore, DC-MD-VA-WV (CMSA)	Databases, Internet Service, Telecommunications

Notes: SME refers to Semiconductor Manufacturing Equipment. MSAs are Metropolitan Statistical Areas; CMSAs are Consolidated Metropolitan Statistical Areas; and NECMA is New England County Metropolitan Area.
Sources: Center on Urban and Metropolitan Policy (The Brookings Institution) and authors' tabulations of U.S. BLS data.

sample is largely determined by its overall size and resulting large contribution to total national IT payrolls (column 4).

These numbers imply an additional interesting feature of the distribution of IT production activities. In particular, the relatively large contribution of IT payrolls to total payroll growth in these IT centers is consistent with increased concentration of national IT payrolls in these urban areas. Additional calculations (not shown) confirm that this is indeed the case: with the exceptions of Boston and Los Angeles, the share of national IT payrolls increased for our IT centers between 1995 and 2000. In 2000, our ten urban IT centers accounted for 44 percent of national IT payrolls.

For comparative purposes, Table 2 also lists figures for four MSAs not included in our primary sample (we also examined data for Rochester and Phoenix, which were ranked below all other cities in our list). The New York and Chicago metro areas both made a large contribution to total national IT payrolls (column 4), but the relatively small

TABLE 2
IT PAYROLL DEVELOPMENTS IN THE BOOM

Region	IT share of MSA total payrolls (%)		IT share of MSA total payroll growth (%)	Local IT share of U.S. IT payrolls (%)
	1995 (1)	2000 (2)	1995–2000 (3)	2000 (4)
Sample MSAs				
Atlanta	10.1	13.4	16.3	2.5
Austin	15.8	16.9	21.2	1.1
Boston	12.2	12.6	16.2	4.4
Dallas	10.1	16.2	20.5	3.9
Denver	12.7	16.0	21.5	2.3
Los Angeles	7.9	9.4	12.2	5.0
Portland	9.4	14.3	23.5	1.4
S.F. Bay Area	21.4	30.0	37.2	15.1
Seattle	9.6	18.3	25.5	3.4
Washington, D.C.	10.5	12.2	21.0	5.0
Excluded MSAs				
Chicago	6.8	8.5	11.7	3.3
Minneapolis	10.6	10.8	14.5	1.8
New York	6.2	6.1	5.9	5.5
Raleigh	16.9	12.8	14.2	0.8
United States	7.5	8.9	14.8	—

Source: Authors' tabulations using data from the U.S. BLS.

contribution of IT to overall activity in these areas led to their exclusion from our primary sample. The remaining two MSAs, Minneapolis and Raleigh, lacked in both these measures, neither making a large contribution to national IT payrolls nor seeing a large contribution by IT to local growth. Moreover, each of these excluded cities saw a decline in its share of national IT payrolls between 1995 and 2000.

4. Profiles of Urban IT Centers

We now examine the extent to which the urban IT centers in our sample conform to the characterizations of specialized urban industrial centers described in Section 2. We begin by considering the intensity of IT production and innovative activity and the availability of skilled labor in each of these centers. We then describe the level of diversification within IT centers.

4.1. Concentration

As noted above (footnote 8), IT shares of employment and payrolls are the most commonly used measure of local IT concentration. We provide these figures for the year 2000,

which corresponds to the peak of the IT boom.[9] Figure 1 (panel A) shows the IT shares of employment and wages in our IT centers. The IT shares in our centers are on average about one and a half times as large as the overall U.S. value (an all-metro value is not readily available in these data). The typical IT payroll share is about twice as large as the IT employment share, indicating that jobs in the IT sector pay about twice as much as the average wage in the non-farm sector as a whole. The difference is largest for Seattle, with an IT wage share more than three times greater than the IT employment share, implying that IT jobs are compensated especially well there. The San Francisco Bay Area is a notable outlier with respect to the concentration of IT employment and wages in the area, with nearly 15 percent of regional employment and 33 percent of regional wages and salaries coming from the IT sector.[10]

Except for Los Angeles, all of the urban IT centers in our sample are more focused on IT industries than the nation. However, there is considerable diversity in the concentration on IT manufacturing or IT services, with most urban IT centers specializing in one or the other (Figure 1, panels B and C). For the U.S. as a whole, the IT services share of employment and wages is about 65 percent larger than the IT manufacturing share. The IT sectors in the Los Angeles area and the San Francisco Bay Area are notable for their relatively even distribution between IT manufacturing and IT services, which implies a greater focus on IT manufacturing than the nation as a whole. Austin and Portland also have a relative specialization in IT manufacturing; Atlanta, Denver, Seattle, and Washington, D.C., specialize in IT services; and Boston and Dallas have an IT manufacturing/services balance similar to that for the nation as a whole.
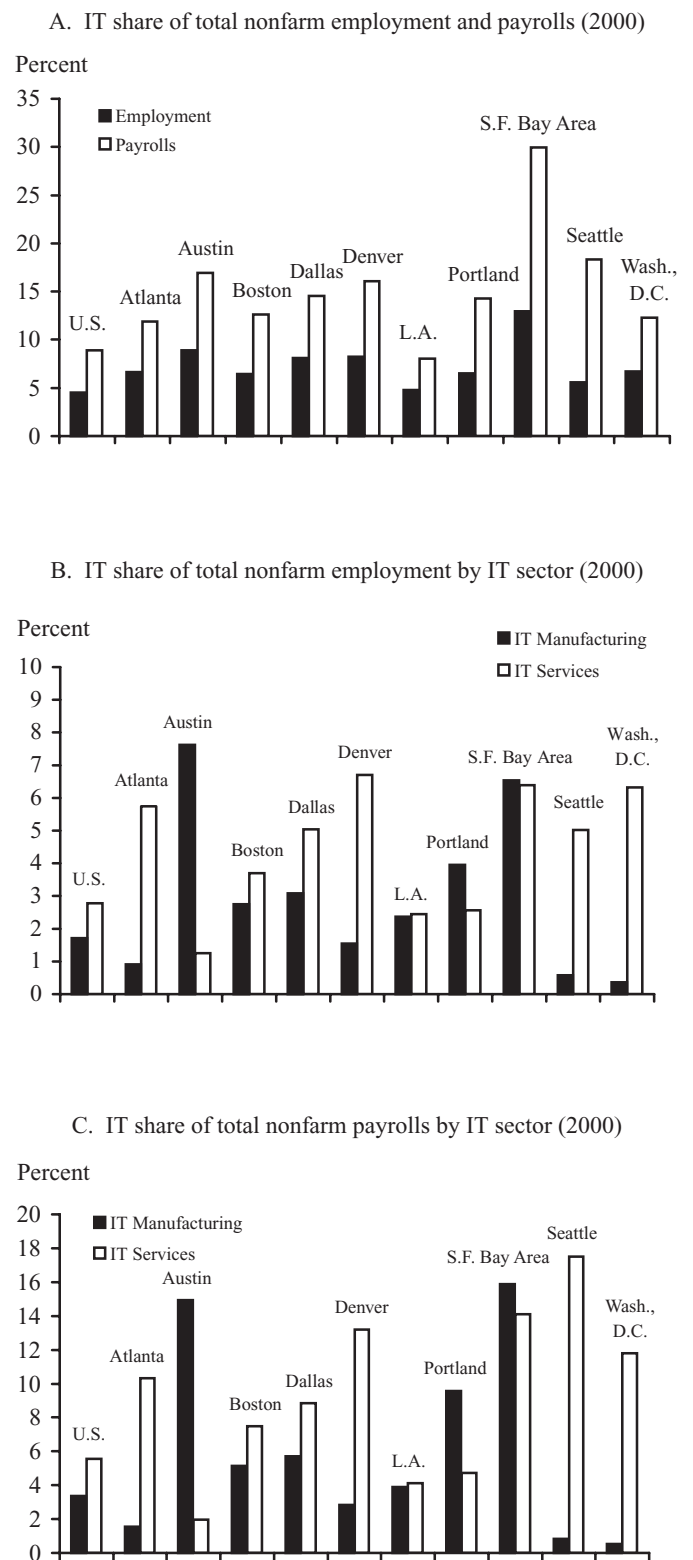
Among the key features of IT centers is their focus on innovation. One measure of innovative activity is spending on research and development. Data on R&D spending by firms with publicly traded stock are available from Compustat. Since Compustat does not provide data for individual establishments, values for R&D spending are based on the location of a firm's headquarters.[11] Figure 2,

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9. Through the year 2000, these data are provided under the Standard Industrial Classification (SIC) system. Beginning with data for the year 2001, NAICS has been used. Although data through 2002 have been released, the NAICS-based data are plagued by a high incidence of nondisclosed information for IT industry segments at the MSA level, and according to the BLS the 2002 data are based on incomplete information and are highly preliminary.

10. The IT shares for the San Jose MSA, which contains Silicon Valley, were especially large (28.5 percent of employment and 53.8 percent of payroll), although they have fallen since 2000.
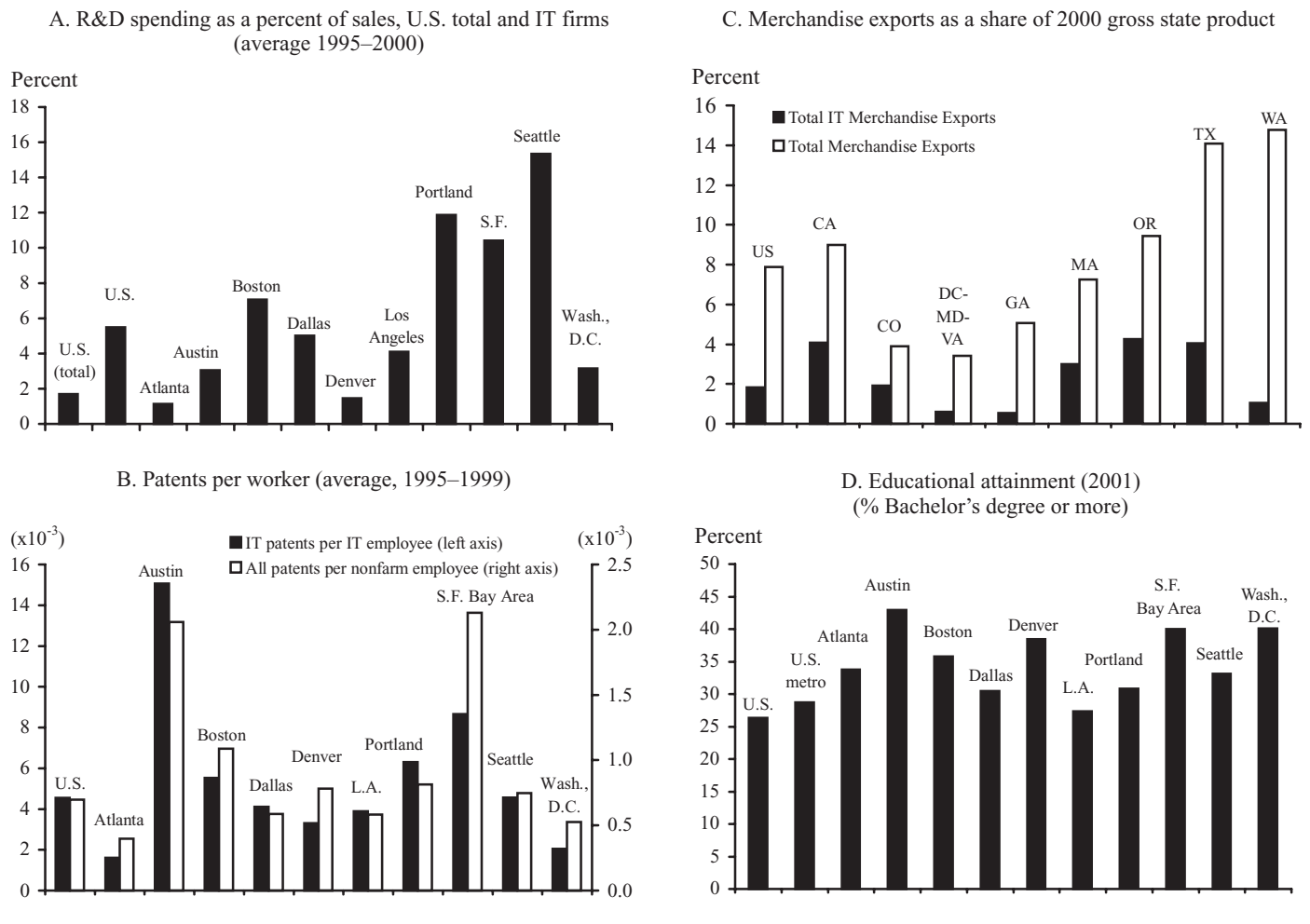
11. The number of IT firms with information on R&D spending ranges from an average of about 10 to 15 firms per year in Austin up to about 300 firms per year in the San Francisco Bay Area.

FIGURE 1

MEASURES OF IT CONCENTRATION: EMPLOYMENT AND PAYROLL

A. IT share of total nonfarm employment and payrolls (2000)

B. IT share of total nonfarm employment by IT sector (2000)

C. IT share of total nonfarm payrolls by IT sector (2000)

Source: Authors' tabulations using data from the U.S. BLS.

FIGURE 2
OTHER MEASURES OF IT CONCENTRATION

A. R&D spending as a percent of sales, U.S. total and IT firms
(average 1995–2000)

C. Merchandise exports as a share of 2000 gross state product

B. Patents per worker (average, 1995–1999)

D. Educational attainment (2001)
(% Bachelor's degree or more)

Note: United States figures calculated from 1997–1999 data (panel A).
Sources: Authors' tabulations of data from Compustat (panel A), the U.S. Patent and Trademark Office and BLS (panel B), Global Trade Information Services (panel C), and the U.S. BLS (panel D).

panel A displays the ratio of R&D spending to sales, averaged over the years 1995–2000, for IT firms in the U.S., for firms across all industries in the U.S., and for IT firms headquartered in our sample of urban IT centers. As the figure shows, the R&D/sales ratio is higher among IT firms than among firms in all industries (first two bars). IT firms located in Portland, the San Francisco Bay Area, and Seattle reported R&D spending in the neighborhood of 12 percent of sales, a ratio approximately three times as large as for IT firms in the nation as a whole. IT firms headquartered in Boston also exhibit R&D/sales ratios higher than the national average for IT firms. The R&D tabulations suggest that these four metro areas devote substantial resources to innovative activity. By contrast, Atlanta, Austin, Dallas, Denver, Los Angeles, and Washington, D.C., all recorded lower R&D/sales ratios in IT than the nation.

The intent of private sector R&D spending is to innovate. The most commonly used measure of innovative outcomes is patents, for which we have data at the MSA level.[12] In Figure 2, panel B, we list tabulations of patents per employee, for all nonfarm industries and IT industries separately. Measured relative to employment, our IT centers are evenly split, with half exhibiting higher rates of IT patenting activity than the U.S. as a whole, and half exhibiting lower rates. Consistent with their relatively high R&D spending in IT, Portland and especially the San Francisco Bay Area exhibit very high rates of IT patents

12. These data are from the United States Patent and Trademark Office. Wilson (2003) documents the positive relationship between R&D and patents at the state level. However, patents also may be used as a strategic device for protecting other patents (see Bessen and Hunt (2003) for evidence regarding software patents).

per IT worker. Despite its relatively low private sector R&D spending, Austin is a notable outlier in regard to patents, with a rate of IT patents per IT worker over three times that in the nation as a whole and nearly double that for the next ranked MSA (the San Francisco Bay Area).[13] The Boston area also exhibits a relatively high rate of IT patenting relative to R&D spending. By contrast, Atlanta, Dallas, Denver, Los Angeles, Seattle, and Washington, D.C., all exhibit IT patenting rates equal to or less than that for the nation as a whole.

An additional feature of these IT centers is their reliance on exports. The U.S. is one of the world leaders in the export of technology products, and these IT centers play an integral role. Although detailed export data are not available at the MSA level, data for the states corresponding to our IT centers are available and provide adequate information on the export of IT merchandise.[14] To assess the role of merchandise exports in general, and IT merchandise exports in particular, for these states, we tabulated the shares of merchandise exports and IT merchandise exports in total state output (gross state product, or GSP) in the year 2000 (Figure 2, panel C). The share of all exports in state GSP varies substantially across these states, with some exhibiting values above the U.S. average and some below. However, most of these states exhibit IT export shares that are well above the national average, especially California, Oregon, and Texas.

Another important potential source of local cost advantages for IT production is the skill level of the workforce. As Figure 2, panel D shows, advanced educational attainment, measured by the percentage of individuals with a bachelor's degree or more, generally is higher in our urban IT centers than in the nation or in metropolitan areas nationwide. In Austin, the San Francisco Bay Area, and Washington, D.C., 40 percent or more of individuals have at least a bachelor's degree, compared to less than 30 percent in metropolitan areas nationwide. Only the Los Angeles area exhibits a lower share of college graduates than the U.S. metro average.

Finally, it also is important to acknowledge variation in the financial environment. In particular, given the rapidity and risk associated with change in the IT sector, venture capitalists, who focus on the financing of start-ups, have an important role to play in the growth of IT centers (see Hellman and Puri 2002 for evidence regarding their role). Although a breakdown of venture capital (VC) spending is not available at the MSA level, regional figures are available. In general, these data show that through 2000, venture capital spending (all industries) was heavily dominated by the San Francisco Bay Area, which is well known for its extensive array of VC firms. Data for 2001 and 2002 show a sharp drop in overall VC spending, but the San Francisco Bay Area still received about one-third of the total. Overall, these data suggest that, while VC spending has played an important role in the development of IT, a disproportionate share of the VC activity has been in the San Francisco Bay Area.

4.2. Diversification

As discussed in Section 2, the economic literature on the formation and growth of industy clusters suggests that diversification may be an important attribute of urban IT centers. The degree of specialization within the IT sector varies across our IT centers. We already have noted substantial differences across our IT centers in regard to the respective shares of IT manufacturing and IT services (see Figure 1). More precise measurement of the degree of specialization/ diversity in the IT sector can be obtained through the use of the inverse Herfindahl index: higher values of the index indicate a greater degree of diversity, as measured by the dispersion of an indicator (employment, patents, etc.) across subsectors within IT.[15] In Table 3, we list inverse Herfindahl indexes tabulated based on the distribution of IT employment, IT payrolls, and IT patents. Los Angeles and Dallas exhibit the highest degree of IT sector diversity, as measured by the distribution of employment, wages, and patents across IT subsectors. In fact, IT sector diversity in the Los Angeles area is even higher than that for the nation as a whole. In regard to employment and payrolls, the San Francisco Bay Area and Portland each exhibits relatively high degrees of IT diversity. Seattle, Washington, D.C., and Boston exhibit relatively low diversity, while Atlanta, Austin, and Denver fall in the middle of the distribution. A generally similar pattern is evident in regard to the diversity of IT patents. However, Boston shows a relatively high de-

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13. Several of these urban IT centers also have a substantial concentration of IT R&D and patenting activity emanating from universities and government-funded research centers. The San Francisco Bay Area stands out in this regard, with two major research universities (University of California, Berkeley, and Stanford University) and several major government-funded research centers that engage in substantial IT-related research.

14. Available information suggests that our urban IT centers account for the majority of IT exports for their states. Data on services exports are not available at the state level.

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15. In our setting, the Herfindahl Index (H) is defined as $\sum_i s_i^2$, where s_i equals the share of IT subsector i in total IT employment (or payrolls, patents, etc.). When measured in inverse form H^{-1}, the value of this statistic increases as the number of subsectors increases and the distribution of employment approaches complete uniformity across subsectors (complete uniformity means that s_i equals $1/n$ for every subsector, where n equals the number of subsectors).

Region	Employment		Wages		Patents	
	H^{-1}	Relative rank	H^{-1}	Relative rank	H^{-1}	Relative rank
Atlanta	3.0	(6)	2.8	(6)	4.7	(8)
Austin	3.5	(5)	3.1	(5)	4.0	(10)
Boston	2.8	(8)	2.5	(8)	6.5	(3)
Dallas	4.3	(2)	4.1	(2)	7.0	(2)
Denver	2.8	(7)	2.8	(7)	6.3	(5)
Los Angeles	6.0	(1)	5.7	(1)	7.9	(1)
Portland	3.9	(3)	3.3	(4)	5.3	(6)
S.F. Bay Area	3.7	(4)	3.6	(3)	6.4	(4)
Seattle	2.2	(9)	1.4	(10)	4.7	(9)
Washington, D.C.	1.8	(10)	1.7	(9)	5.3	(7)
United States	4.8	—	4.3	—	7.2	—

Source: Authors' tabulations using data from the U.S. BLS and U.S. Patent and Trademark Office.

gree of IT diversity in patents relative to employment and wages, while IT patent diversity in Austin is comparatively low.[16]

It is likely that areas with high IT sector diversity are well positioned to respond to emerging IT product demand trends. Of course, diversity is not the only determinant of success in IT: Seattle's economy has surged largely based on the success of Microsoft, which is contained within the narrow software segment of the IT industry. But IT centers such as Los Angeles, Dallas, the San Francisco Bay Area, and perhaps Portland are likely to benefit from the diversity in their IT industrial base, which allows them to respond flexibly to changes in IT production and demand conditions.

In the next sections we consider how the concentration of IT production and the diversification among IT industries contributed to the run-up and subsequent downturn in employment in our sample of urban IT centers.

5. IT Boom and Bust

5.1. National IT Employment

Before considering the impact of the national IT boom and bust on urban IT centers, it is useful to review the basic trends in U.S. IT employment associated with the run-up and subsequent downturn in IT investment. Between 1995 and 2000, business investment in IT goods and services increased at an average annual rate of 20 percent per year, fueling rapid growth in output, employment, and earnings among IT companies.[17] Although most IT sectors expanded rapidly during this period, growth in some sectors was especially brisk. Figure 3 (panels A and B) show the expansion of national IT manufacturing and services employment by detailed sector.[18] The first thing to note is that employment in IT services expanded much more rapidly than employment in IT manufacturing. IT services employment in the U.S. grew at an average annual rate of 8.5 percent from 1995 through 2000, while IT manufacturing employment expanded by 1.7 percent at an average annual rate. Nearly every subsector of IT services exhibited more rapid employment growth than IT manufacturing, with scientific research and development services being the sole exception.

Within the services sector, employment growth was most rapid among software publishers, Internet service providers, and computer systems design firms, with average annual growth rates of 11 to 15 percent. Employment growth in telecommunications and business and technical support was less extraordinary, but very robust. Within IT manufacturing, employment growth for makers of semiconductors and electronic components and makers of magnetic media expanded job counts most quickly, by just over 4 percent per year on average. Employment growth among makers of computers and communications equipment was much less rapid, averaging 0.6 percent and 2 percent per year, respectively. Unlike the IT services sector, two subsectors of IT manufacturing—audio and video equipment and electronic instrument manufacturing—shed jobs during the expansion.[19]
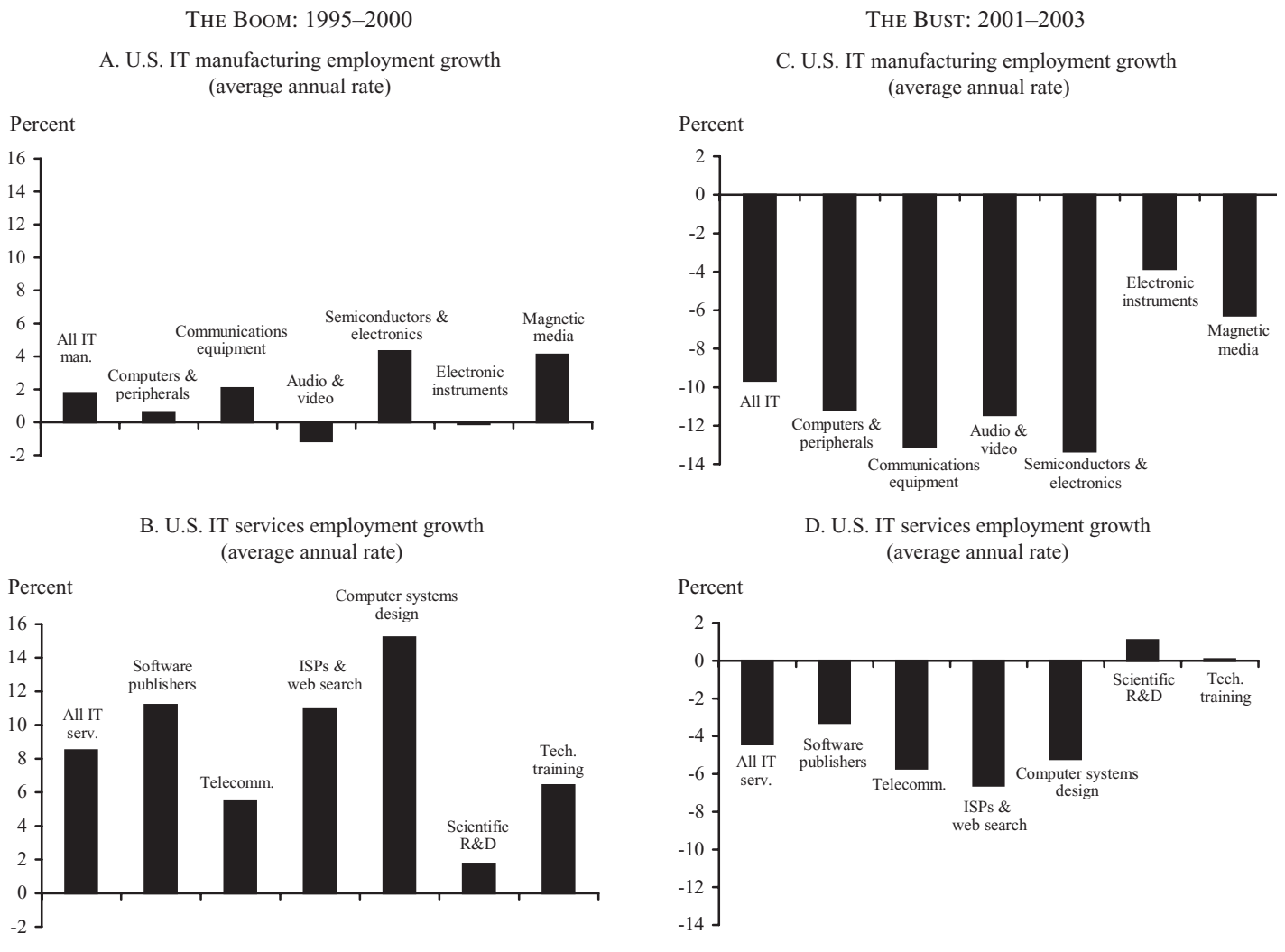
Following more than five years of double-digit growth, business investment in IT products and software slowed in 2000, damped by uncertainty in the national economy, the

16. The employment and payroll calculations rely on SIC data at the four-digit level, from the BLS CEW program. Although these calculations are affected by nondisclosure restrictions for industry categories with a small number of establishments, it is likely that nondisclosed categories are small and therefore have only a limited influence on the diversity calculation. Nondisclosure is not an issue for the patents data. The patents calculation relies on a breakdown of IT patents into eleven subcategories obtained from the NBER Patents Citation Data File (see Hall, Jaffe, and Tratjenberg (2001)).

17. Consumer demand for IT products also grew rapidly during the period, continuing a trend that began at the end of the early 1990s recession.

18. The panels display IT manufacturing and IT services as previously defined, with a breakdown into their primary subsectors (based on the 2002 NAICS).

19. These are areas of manufacturing that reportedly have faced the most intense import competition.

THE BOOM: 1995–2000

A. U.S. IT manufacturing employment growth
(average annual rate)

THE BUST: 2001–2003

C. U.S. IT manufacturing employment growth
(average annual rate)

B. U.S. IT services employment growth
(average annual rate)

D. U.S. IT services employment growth
(average annual rate)

Note: November 2003 is the last month of data used for all categories.

Source: Authors' tabulations using data from the U.S. BLS.

dot-com and telecommunications crash, and overinvestment by businesses in IT goods.[20] The abrupt slowdown in business investment in IT had a pronounced impact on overall demand for IT products, reducing orders, shipments, output, and employment at most IT firms. However, just as there was heterogeneity in the expansion, the IT bust also was felt to varying degrees across more detailed IT sectors (Figure 3, panels C and D). Job losses in IT manufacturing were especially pronounced, with employment falling by nearly 10 percent per year on average during the period from January 2001 through November 2003. Makers of semiconductors and other electronic compo-

nents, as well as communications equipment manufacturers, shed jobs even faster, with reductions of more than 13 percent per year. Makers of electronic instruments and magnetic media were least negatively affected by the drop in business investment; those sectors lost jobs at rates of 3.9 and 6.2 percent, respectively.

IT service providers fared slightly better, cutting jobs at about half the pace of IT manufacturers; employment in IT services contracted by 4.4 percent per year on average from 2001 through November 2003. Consistent with the dot-com crash, Internet service providers and web search and portal firms experienced the most rapid declines, shedding jobs at an average annual rate of 6.6 percent. Telecommunications providers and computer systems and design firms also reduced employment, cutting jobs by 5.7

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20. See Doms (this issue) for a more detailed treatment of the determinants of the IT investment bust.
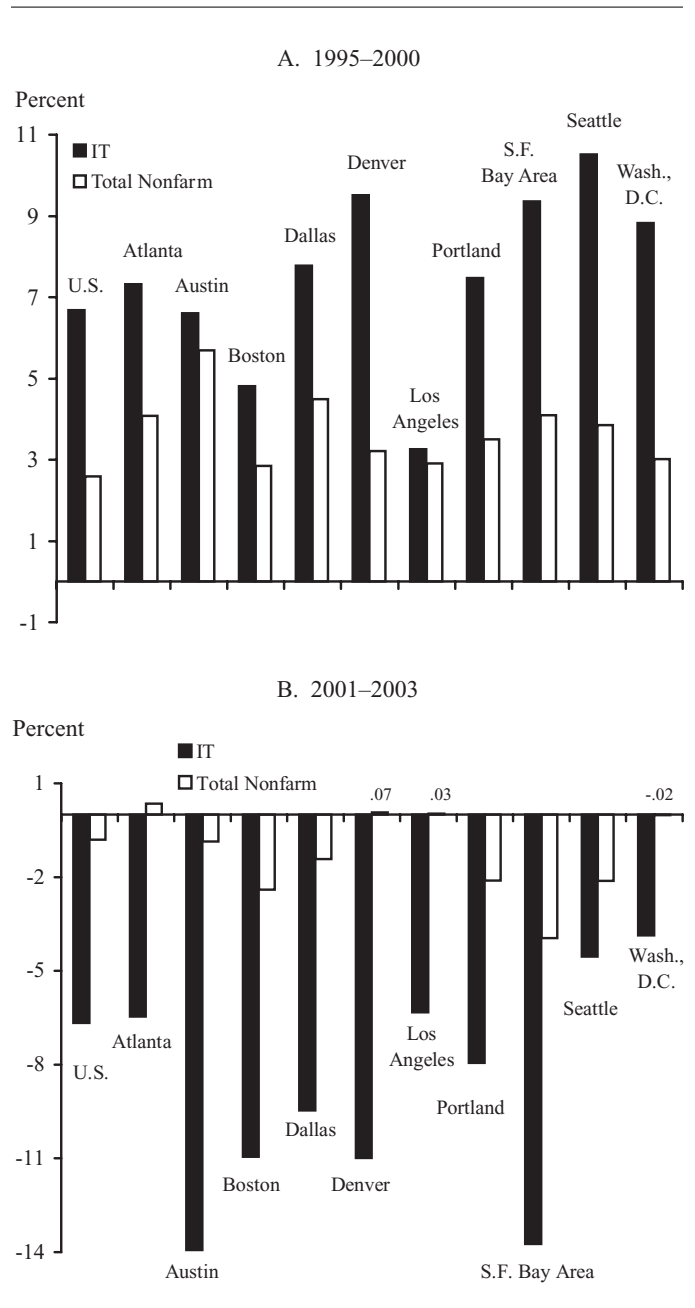
and 5.2 percent per year, respectively. Software publishers, scientific research and development firms, and business and technical support companies were the least affected by the downturn, with the latter two subsectors adding jobs during the period.

The pervasiveness and magnitude of the job changes in the national IT sector portend similar patterns for each of our urban IT centers. That said, the heterogeneity of the gains and losses within the IT sector, and the different specializations evident in our urban IT centers, suggest that the impact of the boom and bust may vary substantially across our sample.

5.2. IT Employment in Urban IT Centers

Figure 4 displays the annual rate of employment growth for our MSAs and the nation, listed separately for the IT sector and for total nonfarm jobs. The top panel lists growth rates during the IT boom, from 1995–2000, and the bottom panel lists growth rates from the beginning of the recession in 2001 through 2003.[21] As in the nation, IT employment growth was quite rapid in our sample of urban IT centers. With the exception of Boston and Los Angeles, IT employment growth in our urban centers was at or above the national pace. For urban centers with large concentrations of IT services, including Denver, the San Francisco Bay Area, Seattle, and Washington, D.C., growth was especially rapid, averaging over 9 percent per year during the boom.[22] In keeping with the slower growth of IT manufacturing employment nationally, urban IT centers dominated by manufacturing (Austin and Portland) saw IT employment expansion at a rate nearer the U.S. average. The relatively slow growth in IT employment in Boston and Los Angeles (compared to the U.S.) likely owes to product specializations in those areas (see Table 1). Boston specializes in computers, medical devices, and software production; nationally, employment in the computer industry grew slowly during the expansion (0.6 percent per year), while electronic instrument manufacturing, which includes medical devices, fell (see Figure 3, panel A). Similarly, Los

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21. These calculations are based on monthly employment data from the BLS Current Employment Statistics (CES) program. The degree of industry detail available in these data is somewhat limited, so our definition of IT services in these data are less precise than it is in our analyses based on other data (we have nearly complete data for IT manufacturing). This is especially true in the smaller MSAs; for example, using these data, the IT services sector in Austin is limited to telecommunications services. We assume that these restricted definitions produce series that are representative of patterns in IT service industries more generally.

22. See Figure 1, panel B, for a breakdown of IT manufacturing and IT services employment shares in our urban IT centers.

FIGURE 4
EMPLOYMENT GROWTH (AVERAGE ANNUAL RATE)

A. 1995–2000

B. 2001–2003

Source: Authors' tabulations using data from the U.S. BLS.

Angeles specializes in household audio and video equipment manufacturing, which shed jobs during the boom.

Relatively rapid growth in IT employment was matched by relatively rapid growth in total nonagricultural employment in our urban IT centers. Indeed, all of the urban IT centers experienced more rapid growth in total employment from 1995 through 2000 than did the nation. Although no clear causal relationship between IT employment growth and total employment growth can be drawn

from the figure, the correlation suggests that rapid increases in IT employment spilled over to other sectors of the economy. Given the relatively high wages paid to workers in the IT sector, the spillovers to employment may have been large.

Just as the run-up in IT investment disproportionately benefited many urban IT centers, its collapse moved several into recession. In the extreme, Austin and the San Francisco Bay Area shed IT jobs at a nearly 15 percent annual pace from January 2001 through November 2003 (Figure 4, panel B). Both areas, especially Austin, were highly exposed to the IT manufacturing downturn. The San Francisco Bay Area also was quite exposed to the dot-com collapse and the loss of Internet service and web portal jobs (see Figure 3, panel D). The downturn in telecommunications had a negative effect on Dallas and Denver, homes to makers of telecommunications equipment and providers of telecommunications services. Both areas shed jobs rapidly from 2001 through 2003, reducing IT employment at annual rates of 9.5 and 11 percent, respectively. The Portland area, which specializes in semiconductor manufacturing, suffered a substantial hit due to the pronounced downturn in that sector. In areas more focused on IT services other than communications or Internet support—Atlanta, Seattle, and Washington, D.C.—IT job losses were less severe, occurring at or below the national pace.

As was true in the run-up, the downturn in IT employment in our urban centers is reflected in the total employment growth numbers. However, unlike the run-up, when the IT boom helped propel growth in total employment in our urban centers above the national average, the downturn had a more mixed effect. To be sure, several of the IT centers experienced contractions in total employment in excess of the national average: these include Boston, Dallas, Portland, the San Francisco Bay Area, and Seattle. But Atlanta, Denver, Los Angeles, and Washington, D.C., fared relatively well compared to the U.S., with total employment remaining essentially flat during the period. This suggests the presence of positive factors that offset the loss of IT jobs, such as population growth or stimulative effects from sources such as the federal government.

As already discussed, IT jobs tend to be high-wage, and as such gains or losses of IT jobs are likely to have large impacts on total personal income, even if the impact on total employment is offset by other factors. Figure 5 shows changes in income per capita, which reflect growth in living standards. With the exceptions of Los Angeles and Portland, each of the IT centers saw more rapid growth in income per capita during the 1995–2000 period than did the nation as a whole. Subsequently, all of the IT centers except Los Angeles and Washington, D.C., saw slower in-
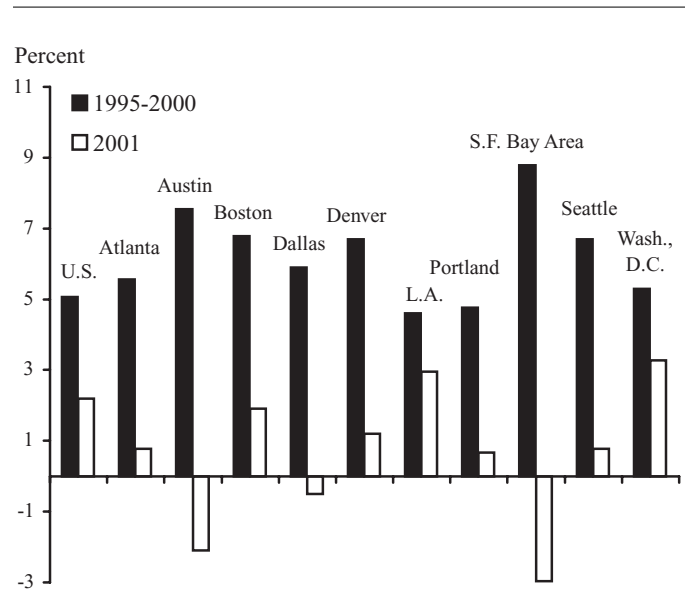
Source: Authors' tabulations using data from the U.S. BEA; data available only through 2001.

come growth than the nation in 2001. The San Francisco Bay Area is an extreme case on both counts, having seen extremely rapid income growth during the boom followed by a 3 percent drop in 2001. Austin also saw an especially sharp turnaround in income growth. Of interest is the fact that in most of our IT centers, personal income growth slowed but remained positive. This was true even for centers that saw contraction in total employment as well as IT employment.

These results bring out two key points. First, the detailed composition of the IT sector played an important role in determining the patterns of growth and decline in urban IT centers during the boom and bust. Second, while developments in IT affect our IT centers, both positively and negatively, they are not the only factors contributing to the economic vitality of the regions, with several urban IT centers benefiting from factors that offset the IT bust during the past few years.

6. Empirical Determinants of Urban IT Growth

6.1. Business Investment Spending on IT

Thus far, we have examined the characteristics of our urban IT centers and assessed their links to the boom-and-bust dynamics of the 1995–2003 period. These unidimensional comparisons point to considerable heterogeneity among urban IT centers in terms of performance during the national IT run-up and the subsequent downturn. We now

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BOX 1
MODELS OF BUSINESS INVESTMENT IN IT AND REGIONAL IT EMPLOYMENT GROWTH

We estimate multivariate descriptive relationships between regional IT employment growth and growth in national business investment in IT, controlling for growth in other national variables.

Our basic specification takes the following form:

$$IT\,Employ_t = \alpha + \beta IT\,Invest_t + \gamma X_t + \varepsilon_t,$$

where $IT\,Employ_t$ and $IT\,Invest_t$ are the quarterly annualized growth rates of IT employment and national business investment in IT, X_t is a vector of national control variables, α, β, and γ are coefficients to be estimated, and ε_t is a normally distributed error term. The control variables include quarterly annualized growth in total U.S. nonagricultural employment, real U.S. GDP, and personal consumption expenditures on computers, as well as a time trend. The models are estimated separately for the U.S. and each of our ten regional IT centers. Standard errors in all regressions are corrected for heteroskedasticity and autocorrelation.

The IT business investment series and the personal consumption expenditures on computers series come from the Bureau of Economic Analysis (BEA). We use series expressed in real dollars.

Employment data are from the BLS CES employment file. IT employment is defined as specified in Section 3.

The investment series can be decomposed into investment in computers and peripherals, other IT equipment, and software. We use these decompositions to estimate the following specification:

$$IT\,Employ_t = \alpha + \beta_1 IT\,Invcomp_t + \beta_2 IT\,Invother_t$$
$$+\beta_3 IT\,Invsoft_t + \gamma X_t + \varepsilon_t.$$

We also include a measure of the IT import share in some regressions. That ratio is computed as nominal imports of IT goods divided by nominal sales of IT goods. Data for the calculation come from the BEA.

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turn to an investigation of the factors that are important to explaining these differences and link the results to the growth potential going forward. We first consider the linkages between national business investment in IT and growth in urban IT centers. Since the run-up in business investment in IT defined the IT boom and the contraction in these investments was a major factor in the IT bust, it is a potentially important factor in explaining the diversity of outcomes among urban IT centers.

Before considering a multivariate model of the relationship between national business investment in IT and IT employment in our urban IT centers, it is useful to pin down their association using simple causality tests. We use the Granger causality test (Granger 1969) to quantify the extent to which information about business investment patterns strengthens predictions of IT employment in our urban centers, and vice versa. Specifically, for each urban IT center we test whether annualized quarterly growth of business investment in IT equipment and software Granger-causes annualized quarterly growth in IT employment, and vice versa.[23] We perform the analysis using one to four lags of both variables in the test.

The results confirm the importance of national IT investment in predicting urban IT employment, with increases (decreases) in IT investment leading increases (decreases)

in IT employment. Growth in IT investment Granger-causes IT employment growth in each of our urban IT centers.[24] Importantly, there is little evidence that the relationship works the other way, i.e., changes in urban IT employment do not tend to lead changes in national IT investment. IT employment growth Granger-causes growth in IT business investment in just one urban center—the San Francisco Bay Area.[25]

To analyze these relationships more completely we estimate multivariate models of urban IT employment growth and growth in U.S. investment in IT equipment and software for each of our urban IT centers. Our basic specification estimates the relationship between quarterly annualized growth in IT employment and quarterly annualized growth in business investment in IT equipment and software, controlling for national employment growth in all sectors, real U.S. GDP growth, real consumer expenditures in computers, and a time trend. We augment this basic specification by decomposing total IT investment into investment in computers, investment in other IT equipment, and investment in software. The period covered is 1990 to 2003 (September). Box 1 provides details of these regressions.

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23. Contrary to its name, tests for Granger causality do not tell us whether one variable is causally related to another variable. In our context, the test simply indicates whether changes in national business investment in IT help predict changes in IT employment in our urban IT centers and vice versa.

24. This statement holds at the 5 percent level of statistical significance.

25. This is true at a significance level of 10 percent but not at 5 percent.

FIGURE 6

IT EMPLOYMENT AND IT INVESTMENT
RESPONSE OF URBAN CENTERS RELATIVE TO U.S. TOTAL
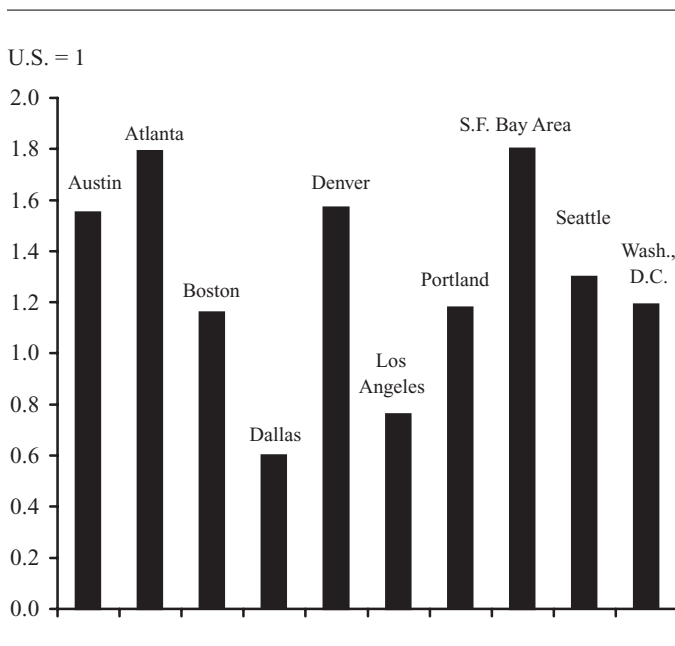
Note: All estimated coefficients are significantly different from zero and the U.S. baseline coefficient.
Source: Authors' tabulations using data from the U.S. BEA and BLS. See Box 1 for details.

TABLE 4

IMPORTANCE OF IT INVESTMENT
TO REGIONAL IT EMPLOYMENT GROWTH, BY TYPE

Region	Computer investment		Other IT equipment investment		Software investment	
	Signif.	Relative to U.S.	Signif.	Relative to U.S.	Signif.	Relative to U.S.
Atlanta			x	>	x	>
Austin	x	>	x	>	x	>
Boston			x	<	x	>
Dallas						
Denver			x	>		
Los Angeles					x	>
Portland			x	>		
S.F. Bay Area			x	>	x	>
Seattle			x	>	x	>
Washington, D.C.			x	>	x	>

Note: x indicates that the coefficient is significantly different from zero and significantly different from the U.S. baseline coefficient.
Source: Authors' tabulations using data from the U.S. BEA and BLS. See Box 1 for details.

The results indicate that growth in business investment in IT equipment and software has a statistically significant effect on IT employment growth in the U.S. and in each of our ten urban IT centers. For the U.S. as a whole, a doubling of the annual rate of growth of IT investment—for example, from 5 to 10 percent—produces about a 30 percent increase in the rate of growth of IT employment. Based on the mean relationship between IT employment and IT investment spending in the U.S. from 1990 through 2003, an increase in the rate of growth of IT investment from 5 to 10 percent would increase the rate of IT employment growth about a quarter of a percentage point, from 0.66 to 0.93 percent (27 basis points).[26]

In general, compared to the nation as a whole, the response of IT employment to national IT investment spending is even larger in our urban IT centers, with the notable exceptions of Dallas and Los Angeles (Figure 6).[27] IT employment growth in the San Francisco Bay Area and in Austin are especially responsive to changes in national IT investment spending, with coefficients 1.8

times as large as the U.S. This means that a doubling of IT investment nationally would produce about a 50 basis point increase in IT employment growth in Austin and the San Francisco Bay Area. The relative importance of IT investment is more muted in the other IT centers but remains higher than for the U.S. as a whole. IT employment in Dallas and Los Angeles is less responsive to changes in business investment in IT than the nation. While this is not entirely predictable, it is consistent with their relative dependence on demand for consumer IT products as compared to business IT products (not shown). For example, IT employment in Dallas and Los Angeles is more than twice as responsive to changes in personal consumption expenditures on computers than is the nation. The next most responsive urban center is Austin, with a value about 1.2 times that of the U.S.

Given the differences in product specialization across IT centers, it is instructive to decompose IT investment into its component parts—computer investment, investment in other IT equipment, and software investment. Table 4 lists the results of these analyses, which rely on the same regression framework as above. All reported results are statistically different from zero and statistically different from the relevant U.S. coefficient. The impact of business investment in computers on IT employment is statistically significant in Austin but not in other MSAs. Investment in other IT equipment is the most influential category, statistically significant in every IT center except Dallas and Los Angeles and, in general, more important in urban IT centers than it is for the nation as a whole. Growth in software

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26. The average annual rate of U.S. IT employment growth over the period was 1.2 percent.

27. Note that the coefficients on IT investment in our urban IT centers are all significantly different from zero and significantly different from the U.S. coefficient.

investment has a significant impact on IT employment growth in Atlanta, Austin, Boston, Los Angeles, the San Francisco Bay Area, Seattle, and Washington D.C., and the magnitude of these effects is larger than in the nation as a whole.

The results of these regressions support the notion that, in general, the IT sector in urban IT centers is more responsive to national changes in IT investment than is the IT sector for the nation as a whole, even when controlling for other factors. Austin and San Francisco stand out as areas especially responsive to changes in IT investment growth, while Dallas and Los Angeles are notable exceptions.[28]

6.2. Overseas Production

The analysis of the preceding subsection indicates that, as the economy recovers and IT investment growth accelerates, IT employment and output growth in our set of IT centers should rebound. However, the impact of rising IT investment is likely to vary across urban IT centers. Moreover, there is no guarantee that the past relationship between IT investment and IT employment will continue into the future, given factors that could weaken or alter this relationship.

One such factor—indeed, one of the key emerging trends evident in the U.S. IT sector—has been an increasing reliance on overseas production facilities. The shift has mainly been toward East Asia, especially China, in the form of increased foreign investments by U.S. IT companies and increased reliance on production outsourcing to foreign IT companies. This shift was especially pronounced in 2002, as the locus of demand growth for IT products shifted towards East Asia and U.S. IT firms facing prolonged weakness in overall product demand were forced to focus increasingly on low-cost production opportunities; the result was a sharp increase that year in the U.S. merchandise trade deficit for IT products (U.S. Department of Commerce 2003, Valletta 2003).

Although this overseas shift poses a challenge to domestic IT producers who cannot respond effectively to the changing locus of production, it likely is a positive development for the U.S. economy more generally. The successful reliance on lower-cost production techniques reduces prices for IT products sold in the U.S. Moreover, some U.S. IT firms are able to capitalize on these trends, increasing their overseas exports, reducing costs, and improving their own production processes, leading to improvements in their bottom lines.

It is likely that our IT centers have varying degrees of exposure to this overseas shift, depending on their degree of access to East Asian and other overseas markets (for example, due to the product mix of their IT production base, geographic location, cultural ties, etc.). Continuing with the analysis reported in the preceding subsection, we investigate the relative responsiveness of urban IT employment growth to changing patterns of IT trade. To measure the IT trade balance, we use a variant of a common measure of import competition known as the "import penetration ratio." In particular, we measure the U.S. net trade balance in IT products as the ratio of nominal IT imports of manufactured goods to nominal U.S. sales (domestic and export) of IT manufactured goods. This ratio fluctuates with the business cycle and trends in the value of the dollar, but it reflects more generally the U.S.'s relative reliance on imports in the domestic IT sector. The value of this variable increases with IT imports and decreases with IT exports and domestic sales, and, as such, reflects changes in the full range of domestic and overseas production and sales conditions (outsourcing, increased foreign direct investment by U.S. IT firms, declining domestic demand for IT products, etc.). To gauge the responsiveness of IT employment in our IT centers to the IT trade balance, we include this variable in a regression with our control variables (specified in Box 1) and our measure of growth in total IT investment. As in the previous regressions, the results are reported relative to a baseline U.S. regression coefficient.

The results (not displayed) suggest that imports relative to sales of IT goods do influence the pace of IT employment growth, although the magnitude of the effect is quite small. For example, a doubling of the relative imports variable, which occurs periodically in the sample, reduces IT employment growth in the U.S. by about 0.05 percentage point. Relative to this baseline, Austin is the most exposed to import competition; there, a doubling of the import penetration ratio shaves about 0.1 percentage point off IT employment growth. The other IT centers that are more responsive to IT import penetration than the U.S. as a whole are Denver, Seattle, and the San Francisco Bay Area.

These effects of the IT trade balance are all small. However, because this regression analysis refers to the entire period, 1990–2003, it may understate the long-term impact of the trend towards overseas production, since this trend is a relatively recent phenomenon that may exhibit an increasing influence in the data as time passes. Some observers have expressed concern that U.S. IT pro-

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28. Available data do not enable us to examine the responsiveness of IT output growth (as opposed to employment growth). However, despite noticeable differences in productivity levels across urban IT centers, productivity growth in IT has been relatively uniform at the industry/region level. This suggests that IT output growth is likely to follow the same patterns as IT employment growth.

duction activity, and especially IT employment, is beginning a prolonged period of decline due to this production and demand shift. For example, as argued in a report commissioned by the Semiconductor Industry Association (Howell et al. 2003), China's recent success in expanding its microelectronics industry may increasingly draw capital, skilled labor, and R&D resources away from the U.S. IT sector. This in turn may serve to erode the research and production base that in the past has helped to maintain the U.S.'s competitive edge in worldwide IT markets.[29]

Although we cannot rule out the possibility that such developments will lead to a long-term decline in the U.S. IT sector, past experience and other trends suggest that it is not likely to occur. First, the competitive advantage enjoyed by the U.S. IT industry is based on the ability to identify and develop innovative products that spur worldwide growth in the IT industry. By contrast, the recent shift towards overseas production, especially to China, largely reflects normal product-cycle dynamics, in which the diffusion of technology enables less-advanced countries to manufacture products that initially were manufactured only in advanced countries. China's IT sector focuses primarily on assembly of less-advanced products at low cost, which does not threaten U.S. dominance in leading-edge technology and innovative products at this point. That dominance is likely to continue once domestic demand for IT products enjoys the expected sustained cyclical upswing. In particular, strong productivity gains in the U.S. economy over the past few years and continued R&D spending by IT companies suggest that the innovative process is alive and well in the U.S. IT industry.

In addition, during the last few years, as the U.S. IT merchandise trade balance has deteriorated, the IT services trade balance has improved markedly. Data from the U.S. Department of Commerce (2003) indicate that the U.S. trade surplus in IT services increased from $0.5 billion in 1997 to $8.4 billion in 2002 (exports of $14.3 billion, imports of $5.9 billion). Although the 2002 figure makes only a small dent in an estimated IT merchandise trade deficit of $43.3 billion that year (authors' calculations), the trend toward an increased IT services trade surplus suggests that the U.S. maintains an edge in some areas of IT service provision vis-à-vis the rest of the world. This trend runs counter to the common perception of net losses in U.S. IT services jobs to foreign locations and companies in recent

years. Although the overseas movement of some IT service jobs—such as call centers—is undeniable, the growing U.S. edge in high-value services, such as sales of software and data processing services, substantially offsets the loss of lower-value activities.

Which IT centers can best respond to these changes? The overseas shift of IT manufacturing presents opportunities as well as challenges. In particular, despite the sharp increase in U.S. IT merchandise imports from China in recent years, U.S. IT merchandise exports to China have grown rapidly as well; this has been true even during the last few years, when U.S. IT exports in general, including to the rest of East Asia, fell substantially (Figure 7).[30] But access to IT export markets varies across our set of urban IT centers. Figure 2, panel C, discussed earlier, shows that the states containing the IT centers of Austin (Texas), Boston (Massachusetts), Portland (Oregon), and the San Francisco Bay Area (California) have an especially high share of IT exports in their economic base. Each of these states also has seen increased IT exports to China between 2000 and 2003 (through the third quarter), suggesting that

FIGURE 7
UNITED STATES IT EXPORTS (GOODS)
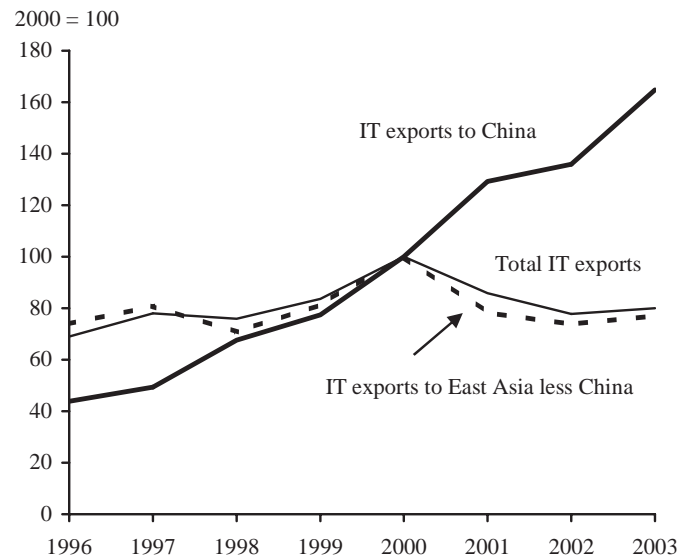
Source: Authors' tabulations using data from Global Trade Information Services.

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29. As noted in the SIA report (Howell et al. 2003), China's success has been achieved in part through preferential tax policies that favor semiconductor makers who locate facilities in China. This raises potential issues for trade negotiations, especially given China's recently acquired status as a member of the World Trade Organization.

30. The IT production process exhibits complex international linkages, with substantial cross-border flows of intermediate and final products. The content of U.S. IT exports to China and U.S. IT imports from China suggests a pattern whereby U.S.-made IT components such as microprocessors are shipped to China, assembled into final products, and then sold in the U.S. As such, expanding IT production in China represents an opportunity for some U.S. IT producers.

its respective urban IT center may have benefited from the expansion of China's IT manufacturing base (data not shown).

7. Growth Prospects

Conditions in the U.S. IT industry improved substantially in 2003 and early 2004. Production and sales moved up for a wide range of IT products; for example, according to the Semiconductor Industry Association, worldwide sales by U.S. chip makers rose 18.3 percent in 2003, with especially strong increases evident in the second half of the year. Moreover, following several years of declines, business investment spending on IT equipment and software expanded rapidly in 2003, rising 21 percent for the year, with growth accelerating as the year progressed (to 25 percent at an annual rate in the second half).

These developments bode well for the performance of the urban IT centers discussed in this paper. In particular, our statistical analyses suggest that the IT sectors of these cities in general are highly responsive to business investment spending at the national level. Moreover, despite significant deterioration in the U.S. IT trade balance in 2002, statistical analyses and additional data suggest that performance in our set of urban IT centers is relatively insensitive to these changing trade flows, with companies in many areas actually benefiting substantially (through increased export demand) from the increase in overseas IT production activity.

More generally, each of the urban IT centers that we have examined possesses features that will enable it to capitalize on the more general recovery taking hold in the IT industry. The San Francisco Bay Area, by virtue of the size, diversity, innovative performance, and unique financing of its IT sector, is well-positioned to maintain its leadership role in the IT industry, despite being among the areas hardest hit by the IT downturn. Although Boston experienced a somewhat muted IT boom compared to other IT centers, it remains a location for diverse innovative activities, making it a likely participant in any IT resurgence. Portland relies heavily on IT manufacturing and consequently was hit hard by the downturn in that sector; however, the level and diversity of innovative activity (patents) in Portland is high, which leaves it well-situated to respond to changes in production technology and product demand in the IT industry.

The future for IT in Austin and Denver may be more challenging. Both were hit hard by the IT downturn and exhibit a degree of specialization in, respectively, IT manufacturing (computers) and services (telecommunications) that may hamper somewhat their ability to capitalize on emerging trends in IT product demand. However, patent data suggest a high rate of specialized innovation in Austin, which may help keep that area at the forefront of its IT industry niche.

In the remaining urban centers, the IT downturn was less severe, making the return to stability less difficult. In the Washington, D.C., area and Seattle, continued growth in demand for IT services prevented the large declines in IT employment recorded in other urban IT centers. In Seattle, the presence of a major software industry leader, Microsoft, helps ensure its place in the recovery of IT. Atlanta, Dallas, and Los Angeles were among the most insulated from the ups and downs of the IT investment cycle, with IT employment in Dallas and Los Angeles being notably less responsive to changes in business investment in IT than the nation as a whole. The diversity of IT activity in these areas and their relatively well-educated workforces (except in Los Angeles, which is closer to the national average) make them likely locations for future IT growth, although their fortunes seem less tied to the IT cycle than our other urban IT centers.

Overall, our results suggest that the substantial IT presence built up in major urban IT centers during the 1990s survived the IT bust of 2001 and 2002. As IT investment and the IT sector more generally gain momentum, these IT centers likely will regain their prominence. However, the results also suggest that the IT centers leading the way during the last expansion may not be at the top in the next period of development. Those with highly specialized IT sectors may find themselves less able to respond to changes in product demand and development than those with a more diversified IT portfolio.

Appendix

POPULATION AND PERSONAL INCOME PER CAPITA (2000)

Region	Population (millions)	Personal income per capita ($)
Atlanta	4.15	33,507
Austin	1.26	32,185
Boston	6.07	39,125
Dallas	5.26	33,412
Denver	2.60	37,158
Los Angeles	16.44	29,488
Portland	2.27	30,619
S.F. Bay Area	7.06	47,180
Seattle	3.57	36,386
Washington, D.C.	7.64	37,684
U.S. Metro Total	226.81	31,380
United States	282.22	29,760

Source: Authors' tabulations using data from the U.S. Bureau of the Census and BEA.

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