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The IT Revolution across the U.S. States

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This paper presents evidence on the geographical dimension of the IT revolution in the U.S. economy. BEA and Census data show that, although neither IT diffusion nor the productivity revival was geographically narrow, the matching of the two across the U.S. states has been far from perfect. The late 1990s productivity acceleration mostly occurred in those states specialized in the production of IT goods & services as well as of non-IT durable goods. When those states are excluded from the sample, the remaining states do not exhibit any significant acceleration in productivity. In particular, the association between productivity gains and IT use is at best weak at the state level. This contrasts with previous aggregate and sector evidence where the importance of both IT production and use was stressed.

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1. Introduction

Aggregate, sector and firm-level evidence has documented the close association between the production and the use of information technologies (IT) and the U.S. productivity revival in the late 1990s. Oliner and Sichel (2000), Jorgenson and Stiroh (2000), Stiroh (2001) and Nordhaus (2002) documented the importance of *both IT production and use* using aggregate and sector data. The results in these papers have received further confirmation in recent updates by Oliner and Sichel (2002) and Jorgenson, Stiroh and Ho (2002). Many earlier firm-level studies (surveyed in Brinjolfsson and Hitt, 2000) typically found a large economic impact from *IT use*, much larger than the one implied in the aggregate. At variance with these other studies, Robert Gordon (2000, 2001) forcefully questioned the long-run nature of such productivity gains, pointing out that the U.S. productivity acceleration was narrowly concentrated in durable goods manufacturing, in particular in the computer-producing sector. Well tuned with Gordon's findings, McKinsey Global Institute (2001) also emphasized that nearly all of the productivity growth gains at the industry level was to attribute to just six industries, the implication of which would be that the massive IT investment channeled in the other sectors did produce little or no productivity gains.

This paper adds further evidence to this debate by exploiting the *geographical* dimension of the U.S. productivity revival at the state level. Two main conclusions emerge. First, accelerating productivity growth was strictly intertwined with the *production* of both IT goods and services *and* durable manufacturing goods. Second, those states with above-average IT usage have not enjoyed super-normal productivity gains in the second half of the 1990s, instead.

Our argument is developed in two main steps. First, the evidence on IT diffusion and productivity growth at the state level is separately described. In the second part of the paper, the heterogeneity in IT diffusion is related to the diverse growth performances of the U.S. states.

Taking advantage of BEA and Census data, the geographical, *i.e.* state-wide, mapping of the IT revolution is documented first. Time series state-level data on the IT content of production do not exist as such. States may be grouped, however, according to the specialization indices constructed by first classifying sectors into "IT producers", "IT users" and "non-IT intensive" from nation-wide indicators of IT intensity.[1] This sector classification, jointly with information on the structure of production at the state level, is then exploited to attach similar labels to states. Such indirect measure shows a significant presence of IT-related industries across the U.S. states. Nineteen states turn out to be specialized in IT production and ten in the use of IT, with four states (California, Massachusetts, Illinois, plus the District of Columbia) specialized in both. Altogether, based on

[1] Such indicators of IT intensity are the IT shares of output and capital. We follow the BEA classification, which in turn produces not too dissimilar results from the ones adopted by Stiroh for the United States and van Ark, Inklaar and McGuckin (2002) for 15 OECD countries.

their industry structure, thirty-one states may be labeled “IT intensive” states. We also collect and employ point-wise evidence on household computer diffusion and use at the state level from surveys conducted by the Department of Commerce. These data say that in 1994 about one fourth of the American families were endowed with a computer and in 1997 about 41% of the U.S. workforce was endowed with a personal computer at work.

The BEA also offers evidence about the productivity revival at the state level. In 1996-2000, productivity growth in the non-farm business sector rose in forty states compared to the 1987-95 average; nineteen of which grew faster than the period U.S. average of 2.3%. This productivity revival was particularly strong in the West and the North East of the country.

In the second part of the paper, we try and relate the heterogeneity in IT diffusion to the productivity performances of the various states, by employing a variety of complementary econometric specifications and tests. The basic methodology is essentially the same as in previous studies: dummy variable tests of deterministic breaks in productivity growth series.

Altogether, such tests from both indirect and direct indicators of IT diffusion produce a remarkably coherent picture of the relation between IT and growth in the U.S. states.

Reminiscent of Gordon’s results, a positive relation between IT and accelerating growth is found, but this is mostly confined to IT production. Note however that, according to our definition (borrowed from the Department of Commerce), IT production also includes the production of IT services and therefore goes beyond the narrow boundaries of the computer-producing sector. Furthermore, we also find that durable goods production has been an important complement of the IT revolution as well, both alone and, in some states, jointly with IT production. When states specialized in IT production of goods and services and non-IT durable manufacturing are excluded from the sample, the remaining states do not exhibit any significant acceleration in productivity. In particular, the association between productivity gains and IT use is at best weak. Consistent with these results, when states are split, using Census data on computer diffusion at home and at work, into those where information technologies are intensively used and those where they were not, not much of an acceleration is seen as well. This is at variance with the bulk of the previous aggregate and sector evidence.

Based on these pieces of evidence, we conclude that, although neither IT diffusion nor the productivity revival in the U.S. states was geographically narrow, the matching of the two was far from perfect.

The structure of this paper is as follows. In section 2, measurement issues and evidence on the diffusion of information technologies in the U.S. states are discussed. In section 3, the same issues are surveyed for labor productivity growth. In section 4, the much discussed hypothesis that links IT diffusion to the productivity revival of the late 1990s is documented at the state level. Section 5 concludes.

2. The diffusion of information technologies in the U.S. states

To what extent have production and use of information technologies penetrated in the U.S. state economies? To answer this question, we measure IT diffusion at the state level both indirectly and directly.

Indirect information blends data about IT investment and capital stock of each industry at the nation level with data on the industry structure of each state. We borrow the industry classification of the non-farm business sector by IT intensity provided by the Department of Commerce (2002), to be detailed below. Then, industries identified respectively as IT-producers and IT-users are grouped together, with the remaining non-IT industries partitioned into durable and non-durable goods manufacturing, non-IT services, and construction. Since the various states present varying industry structures, they can in turn be grouped depending on whether IT industries are more localized in the state economy than in the nation as a whole.

The results of this indirect industry-based classification are then contrasted with those arising from a direct one, which draws on Census data on household computer diffusion at home and individual computer use at work.

The two indicators seemingly capture different aspects of IT diffusion, for the state classification originating from them is rather dissimilar. It is therefore useful to consider both, although we tend to attach a greater emphasis on the results obtained from the industry-based classification for more akin to previous studies and more immediately amenable to economic interpretation.

2.1 Measurement

The extent of penetration of information technologies in the U.S. economy can be gauged using indirect and direct measures. In sub-section 2.1.1 and 2.1.2 indirect measures based on sector data are described. Direct measures of computer use are described in sub-section 2.1.3.

2.1.1 Identifying "IT-intensive" industries

Identifying which industries are strictly related to IT is essential to the purpose of determining whether an industry mix favorable to IT might be able to influence productivity patterns positively. The relation to IT can be examined both in terms of IT production and usage. As mentioned above, the current debate on the impact of IT at the aggregate level revolves around the prominence of IT production or usage in triggering productivity gains.

To address this crucial issue, we first split the sixty-three U.S. industries provided by the BEA into two groups, depending on their being IT producer or user. We rely upon the definition of IT-producing, IT-using and non-IT intensive industries provided by the Economics and Statistics Administration of the U.S. Department of Commerce in its 2001 Report (US Department of Commerce (2002)). [2]

According to the definition of the Department of Commerce, an industry is *IT-producing* if it "supports IT-enabled business practices and processes across the economy, as well as the Internet and e-commerce". At the two-digit SIC level [3] (the level at which GSP estimates are produced), the following industries are included among the IT-producers:

- Industrial machinery and equipment (inclusive of computer and related hardware manufacturing);
- Electronic and other electric equipment (inclusive of semiconductor manufacturing and related products);
- Telecommunications (inclusive of phone, satellite and multimedia services);
- Business services (inclusive of software development, data processing services and computer rental and leasing)

An industry is *IT-using* if it features either a high IT capital stock over total installed capital stock or a high level of IT investment per employee. Within the list of 63 industries that makes up the U.S. non-farm business sector, the Department of Commerce lists the top fifteen industries in terms of IT capital and investment to compile the list of 'IT users'. Here is the list of IT-using industries, obtained from the union of the two sets (and aggregating F.I.R.E. industries in the same aggregate):

- Electronic and other electric equipment (inclusive of semiconductor manufacturing and related products)
- Telecommunications (inclusive of phone, satellite and multimedia services)
- Business services (inclusive of software development, data processing services and computer rental and leasing)
- Instruments and related equipment
- Chemicals and allied products,

[2] The Department of Commerce definition has then been employed by Beemiller and Downey (2001) and Nordhaus (2002).

[3] At the two-digit SIC level IT-intensity within industries may vary because some component industries at the three- or four-digit level are included, that are not IT-intensive. However, for data constraints, the IT-intensity criterion has been applied at the two-digit level.

- Petroleum and coal products,
- Pipelines except natural gas,
- Wholesale trade,
- F.I.R.E., (depository and non-depository institutions, insurance carriers, security and commodity brokers; holding and other investment offices)
- Health services,
- Legal services,
- Motion pictures,
- Other services

Note that three of the four IT-producing industries also belong to the group of the IT-using industries. In the next section, we separately evaluate the productivity contribution of ‘pure’ IT users from the contribution of those sectors which are simultaneously users and producers.

It should also be kept in mind that the distinction between IT-producers and IT-users as well as the distinction between IT and non-IT industries at the state level has been derived using detailed data by industry on *nation-wide* information about IT production, investment and capital stock. An industry recognized to be an IT producer or user at the national level remains such at the state level too. This amounts to assuming that the various industries tend to adopt the same technology and the same factor intensity across states.

2.1.2 Relating the industry composition of output to the penetration of IT in the U.S states

The degree of localization/specialization of a particular economic activity or geographical unit may be measured in terms of employment or production. Our classification is mainly based on production data. Below, we also briefly report how results would change had we replaced production by employment as a classification criterion.

We look for a summary statistics of industrial classification conveying two pieces of information. First, we want to know how important a specific industry is in a particular state. This is easily computed as the ratio between the output of industry *k* in state *i* and total output in state *i*. Second, since we want to know whether this state-specific ratio is higher or smaller than its nation-wide counterpart, we normalize the ratio computed at the first step by the same ratio evaluated at the national level. Hence, to evaluate the importance of the various sectors at the state level, the following specialization index is calculated for each state *k* and industry *i*:

$$SI_i^k = \frac{y_i^k / y^k}{y_i / y} = \frac{y_i^k / \sum_i y_i^k}{\sum_k y_i^k / \sum_i \sum_k y_i^k} \qquad (1)$$

where y_i^k denotes the value added (GSP) of industry *i* in state *k*. The specialization index SI_i^k thus equals one if the production share of industry *i* in state *k* is equal to the share of industry *i* in national production. The index is smaller (respectively, bigger) than one when the production share of industry *i* in state *s* is below (respectively, above) the nation-wide average. *SI* is computed for the two groups of IT-intensive industries and also for specific sub-aggregates of the heterogeneous non-IT group residual (mining, non-IT durable manufacturing, non-IT non-durable manufacturing, non-IT services and construction), for all U.S. states (including the Department of Columbia) over the first half of the 1990s.

In principle, *SI* may have been computed for any of the years for which BEA data are available (thus 1987-2000, or 1977-2000, depending on the specific output variable). We picked the first half of the 1990s as our benchmark classification period, for we deemed it the most appropriate time framework for our purposes, *i.e.* evaluating the role of IT in propelling the acceleration of productivity growth around the mid 1990s.

Some industries have indeed begun investing in IT assets since the late 1970s, as testified by the high capital stock in IT goods in place in the following years. Yet the extraordinary boom of IT investment in the US occurred in the early 1990s, soon after the short 1990-91 recession. Hence, using information about the 1970s or the 1980s would imply underestimating the role of IT in those states which turned their production towards information technologies in the years immediately before the occurrence of the beginning of the boom. At the same time, we also left out the values of *SI* for the years after 1995, so as to lessen the risk of picking the result of accelerating productivity, rather than its cause (or at least one of its covariates). Note that the risk of reverse causation is not eliminated, for it may well be the case that IT investment surged just in those sectors where productivity increases were anticipated. Our period choice is eventually aimed at striking a balance between the conflicting goals of having latecomers in and avoiding the pitfall of reverse causation.

In the end, we use the empirical distribution of the indices to single out relatively homogenous groups of states, on the basis of the diffusion and importance of IT use and production within them as well as within other sectors of activity. This allows us to classify states in IT-producers, IT-users and “IT-unaffected” states, in turn distinguished in durable and non-durable goods producers, construction and non-IT private services.

2.1.3 Computer diffusion at the state level

Direct information about IT diffusion is from the *Current Population Survey (CPS) Supplements*, released by the Census Bureau at the Department of Commerce. The CPS is conducted by the Census over a sample of some 50.000 households. Sampled survey responses are multiplied by weights so that the tabulated counts or averages reflect the national, state or county totals. The weights are a function of the probability of selection and reflect any needed sub-sampling, non-response adjustment, and post-stratified ratio adjustment to population control totals.[4]

Information on computer diffusion and use at home and at work for many localities, including the 51 U.S. states, are available for specific reference years. Data on household computer diffusion at home are there for 1994, 1997, 1998, 2000, 2001, while data on individual computer use at work are only available for 1997 and 2001.

The available information on computer diffusion and use is not the same for all years. In order to precisely assess the impact of computer use on productivity, one would like all data to also convey specific information on the effective time spent by users on the PC. Unfortunately, effective time spent on personal computers has never been included in the survey questions. Still, 2000 and 2001 data are indeed more detailed than previous ones. In the August 2000 and September 2001 surveys, respondents were asked to report in more detail on different activity areas like word processing, spreadsheets and databases, calendar and scheduling, graphics and design, programming. Even the 1994 and 1997-98 surveys convey information on a number of tasks related to computer and internet use, though.

To measure computer diffusion at home, we picked the ratio between the number of respondents answering YES to the question “Does anybody in this household own a personal computer?” and the total number of households in each state in the 1994 sample. To measure computer diffusion and use at work, we picked the ratio between the number of respondents answering YES to the question “Does anyone in this household directly use a computer at work?” and total state employment in 1997. These are the only available measures of overall IT usage available at www.bls.census.gov/cps/computer/computer.htm . This is valuable information on the degree of IT diffusion in the U.S. states, for collected independently of the distinction between IT-intensive and non-IT intensive industries engineered above.

Here as above, as we are meant to explore the link between IT diffusion and accelerating productivity growth in the second half of the 1990s, we chose not to exploit the most recent and detailed data. By using an IT intensity classification relative to 1999 or 2000, we might not capture the association between IT intensity and labor productivity, but rather the effect of rapid productivity increases, caused, say, by favorable cyclical circumstances, on the adoption of information technologies. With this caveat in mind, we employed those data closest to the breakpoint year for productivity growth (1995). Hence data on computer use at home refer to 1994 and data on computer use at work refer to 1997. Although less detailed and not directly linked to

[4] For a technical overview see *Current Population Survey, Technical Paper 63RV, Design and Methodology*, BLS and Census Bureau, March 2002.

production, the number of households provided with a PC in 1994 has the clear advantage of being defined before 1995, while 1997 computer use at work may convey more precise information as to the productive use of computer, but is unfortunately observed too recently to be regarded as a safely exogenous classification criterion.

Having said so, raw data on the presence of computer devices home or at work may detect important symptoms of an underlying process of IT diffusion. Furthermore, using different classifications for the same years may be a good robustness check for our results as to the impact of IT use on productivity.

2.2 The evidence

2.2.1 Indirect indicators

Following the methodology described in subsection 2.1.1 and 2.1.2, states have been sorted on the basis of their SI values. As made clear above, the resulting breakdown does not reflect which industries hold the largest shares of state production. The answer to this question would be the same for nearly all states. Practically everywhere the industries with the largest shares of non-farm business sector GSP are private non-IT services. Similarly, this index is not aimed at providing an exhaustive description of state economies and industrial structures. Rather, we simply wanted to identify in which states the localization of any industry (notably, IT industries) is significantly higher than the national "norm" of the industry.

Table 1 reports the values of SI compiled for all states and industries and averaged over 1991-95. Thirty U.S. states are singled out as, one way or another, *IT-intensive* in **Table 2**. Sixteen of them are IT producers, ten are IT users and four are both IT producers and users. Overall, they make about 50% of total output and 47% of total employment in the United States in 2000. This may be enough to conclude that information technologies are widespread in the United States, but we want to dig deeper.

There is one major piece of evidence in **Table 1**: the localization of IT production is more concentrated than the diffusion of IT use. This reflects in a higher value of the aggregate standard deviation of the SI index for IT production (0.27) than for IT use (0.15). This aggregate difference stems from within-region rather than cross-region variability, though. Since there is at least an IT producer in each region, differences across states are more pronounced within the eight broad BEA regions (New England, Mid East, Great Lakes, Plains, South East, South West, Rocky Mountain and Far West) than across regions.

As also visually emphasized in **Chart 1**, the values of SI are on average bigger than one in New England, Great Lakes and the South West states for IT production and in the Mid East and New

England states for IT use. SI indices usually present comparative lower levels in the South East and Rocky Mountains states, although with notable exceptions (Colorado and Idaho, Georgia and Virginia for IT production; Florida for IT use).

The specialization index for IT production takes an average value of 0.92 with a median of 0.95 (the state of New York), with its highest value recorded for New Mexico (1.71) and its lowest value for Wyoming (0.31). Wyoming ranks last as to IT usage as well. The state where IT use is relatively more pronounced is instead Delaware (SI_{ITuse}=1.42).

Within the IT producers, the telecommunications industry plays a particularly important role in Colorado and Georgia, while "Electronic and other electric equipment" is important in Vermont, Arizona, Oregon and New Mexico. Idaho, Indiana, Iowa, Minnesota, New Hampshire, Ohio and Wisconsin present a strong localization of "Industrial machinery". In the remaining states of this group, "Business services" represents the bulk of IT production.

IT-using industries tend to mainly concentrate along the Atlantic Coast. "F.I.R.E." plays a primary role in Delaware, New York, Connecticut and Maryland; "Wholesale trade" in New Jersey and Florida; "Chemicals" and "Petroleum and coal products" in Delaware and New Jersey. Understandably, in D.C., legal services represent 14% of GSP, against a national average of 1%.

The third group, finally, includes those states that show a localization of both types of IT-industries. California, Massachusetts, Illinois and the Department of Columbia are the four states specialized in both IT production and use. The nation's prevailing rule is therefore not to be specialized in both, although this does not imply a negative correlation between IT production and IT use either. The correlation between the two indices is in fact very close to zero (ρ=0.04) and the rank correlation coefficient is also not much higher (0.13).

What if the SI indices are recomputed using employment rather than GSP data? The classification does not change much. In a few cases, however, employment data fails to register a significant presence of IT producing and using industries, whereas GSP does. In particular, New Mexico, Vermont and, to a lesser extent, Oregon are IT producing states when using GSP and are not so when employment is used instead. At the same time, however, other statistical sources (see below) confirm the importance of IT-producing industries in these states. One reason why employment data might fail to capture some aspects of the IT phenomenon (otherwise confirmed by other statistical sources as well)[5] may depend on the fact that the development of IT industries does not always give rise to consistent creation of jobs, at least not as much as it does affect type and organization of production. As a result, leading IT industries may well end up covering a considerable part of production without increasing the IT employment share by the same proportion.

[5] The main of these sources is the Census of Manufacturers for 1992 and 1997.

So far, only a small portion of the available information on the state industrial composition has been used. In fact, most, if not all, states are not exclusively specialized in one single industry, but often show a notable presence of other industries too. It might be the case that those states that we have labeled IT-intensive are instead specialized in some other sectors, which happens to be highly correlated with either IT production or use. The pattern of pair-wise correlation between the SI indices in **Table 3** shows that this is not the case. Correlation is usually rather low (and usually not statistically different from zero), in particular for the SI indices of IT production and use.

The *SI* index for IT-producing industries is negatively correlated with mining, non-IT services and construction and mildly positively correlated with non-IT durable and nondurable manufacturing.

The group of IT producers includes two durable goods manufacturing industries: electronic and other electric equipment and industrial machinery. All the remaining manufacturing durable producers are instead included in the index for non-IT durable goods manufacturing. **Chart 2** shows that the overlaps in the specialization in the production of non-IT durable goods and IT production are not many (light-blue colored and printed in light grey in the chart). As expected, they are mainly confined to North-Eastern states.

2.2.2 Direct indicators

As mentioned above, states have been ranked by computer diffusion and use at home in 1994 as well as at work in 1997. A problem here is that we do not know for sure whether these figures always reflect a productive use of IT. In a few cases, other forces such as low population density or long distance from national markets provide strong incentives to take advantage of IT devices mainly for communication purposes, but this may not materialize in higher productivity at work.

Table 4 presents data for both at-home and at-work indicators. The number of personal computers per family and at the workplace is reported in column (1) and (3). The same figures are divided by the respective nation-wide averages and intensity indices computed in column (2) and (4), where, by construction, these indices are equal to one for the U.S. economy. **Chart 3** presents the classification of the U.S. states when sorted on the basis of household computer diffusion at home in 1994.

On average, in 1994 about one fourth of the American families were endowed with a computer and in 1997 about 41% of the U.S. workforce was endowed with a personal computer at work.

Even a quick look at **Table 4** is enough to gauge that the two indicators are very imperfect substitutes to each other and to the indirect indicators constructed above.

For instance, the IT intensity index for household computer diffusion is much more diversified across states than the other index showing intensity of PC individual use at work. The 10^{th} : 90^{th}

percentile ratio of the index values is in fact about 1.8 for the household index (1.36 for Colorado and 0.75 for Tennessee) and only 1.3 for the individual index (1.11 for New Jersey and 0.87 for South Dakota).

The IT intensity indices in **Table 4** also lend themselves to be contrasted to the SI for IT production and use computed in the previous sections. The correlation between these two sets of indicators is rather low, and ranges between 0.05 and 0.33. Even the correlation between the two direct indicators themselves is not very high. It looks as though these direct indicators are not capturing the same phenomena captured by the other, indirect, indicators. There is a simple explanation for some of these discrepancies, however. At the top of the household use ranking, one finds a few Western states, such as Alaska, Utah, Wyoming and Kansas, which are clearly not specialized in IT production and use. Geographical and dwelling characteristics of those states are hence likely determinants of their inhabitants' decision to endow themselves with access to PCs (to bridge natural isolation). Yet this does not go necessarily hand in hand with a productive use of computers at work or with agglomeration of IT activities within the borders of these states.

3. Labor productivity growth in the U.S. states

3.1 Measurement

Computing labor productivity requires state-level data on real output and on some measure of the labor input. Our output measure is the Gross State Product (GSP) by industry, which obtains as the sum of the value added originating in all industries in each state. The industry aggregate we refer to in computing state labor productivity is the non-farm business sector, which implies the exclusion of agriculture, government and government enterprises.

The Bureau of Economic Analysis (BEA) at the Department of Commerce provides estimates of the GSP in current and chained 1996 dollars for all the U.S. states and the District of Columbia. [6] The estimates of real GSP are obtained deflating current price GSP by national price deflators for sixty-three detailed industries. Hence, the estimates of real GSP reflect the distinctive features of each state's industry mix, but fail to capture geographic differences in the prices of goods and services produced and sold locally. Data are currently available from 1977 to 2000 for GSP in current and fixed-weight constant dollars, and only from 1987 to 2000 for chained-dollar GSP. Our basic specification employs 1987-2000 data for the non-farm business sector. In the robustness checks

[6] For detailed information on data construction and sources see Beemiller and Woodruff (2000) and Friedenberg and Beemiller (1997).

section, we also check that our results still hold with 1977-2000 data referring to the business sector as a whole, however.

The productive input of labor is measured in terms of total employment. Total employment by place of work refers to full and part-time employment of wage and salary earners as well as self-employed persons. This variable is available at the BEA website as well. The number of average hours worked is instead not available at the state level. In the extensions section, though, we employ a sector-based national measure of average hours worked weekly by the employees to partially control for labor utilization.

Our indicator of labor productivity is thus an imperfect one for well known and less well known reasons.

Starting with the well known ones, GSP is a value added measure, produced from the income side of the accounts as the sum of employees' compensation, indirect taxes and property-type income. This is a reasonable approximation for the numerator of a productivity index if the value added produced by primary inputs, such as capital and labor, is separable from intermediates - a possibly overly restrictive assumption.[7] Yet using an output measure would greatly complicate or make the task of aggregating across states outright infeasible, in the absence of detailed information on input-output flows between the U.S. states.

Moreover, business-cycle influences are not filtered out from our productivity indicator. Estimating cyclical adjustment for each individual state would introduce considerable noise into the analysis, however, given that all data are deflated by national price indices. Even a full fledged attempt to net out business-cycle influences with our information set would anyway leave the problem of distinguishing between residual price-change elements and pure quantity-change components unsolved.

These are all well-known (and hard-to-tackle) problems. Our productivity indicator presents other measurement problems, though. They are specific to a state-level framework of analysis and therefore their relevance is somehow less appreciated, but by no means less important.

The problem is as follows. GSP by industry is the state counterpart of the nation's GDP by industry, with one important difference. At the nation's level, GDP and GDI (Gross Domestic Income) originate from different sources. GDP measures output as the sum of the expenditure components, the second one as the sum of costs incurred and incomes earned in the production process. Just because they stem from largely independent data sources, these two measures that conceptually should be equal, differ in practice by the statistical discrepancy. This discrepancy is often small, however, for aggregating over states cancels most of the interstate income flows within the U.S.

[7] Basu and Fernald (1995, 1997) have shown that the use of value added data leads to biased estimates and incorrect inferences as to production parameters.

economy. This is to say that the difference between income and production data is, to a large extent, minor at the national level.

It may not be so at the state level, though, whenever the distinction between legal ownership and the localization of production is important. The production of goods located in Ohio, for example, might be imputed to New York, because the ownership of those incomes may pertain to a holding located in the state of New York. Two separate problems seem to arise. There may be a difference between the place of residence and the place of work for proprietors' income. It is also not obvious how to allocate across states the 'corporate profits' items within the bigger 'other capital charges' item.[8]

The BEA presents a distinction between place of residence and place of work for some components of personal income. An adjustment coefficient to allocate the labor earnings of interstate commuters and the wages and salaries of border workers is made available at the state, but not at the industry, level. Although partial, this adjustment coefficient may help identify which states could be physiologically exposed to divergence between place of residence and place of work also for components other than labor earnings (namely: proprietors' income). **Figure 1** depicts the ratio of the residence adjustment to total earnings by place of work over the sample 1958-2000 (see also Bernat and Recipe (2000)).

The impact of this adjustment is practically immaterial for the bulk of the U.S. states. The adjustment ratio lines for most states lie very close to the zero line and have therefore been omitted from the graph. Connecticut, Delaware, Rhode Island, New Jersey and D.C. are more prone to this commuting problem due to their small size. Furthermore, states with substantial portions of their economies concentrated in large metropolitan areas that extend across state boundaries are also more subject to interstate commuting (Virginia and, once again, D.C.). The District of Columbia stands out in the lower part of the graph. People working in D.C. often commute in and out of the district borders on a daily basis. This reflects in a highly negative value of the adjustment ratio. Finally, Alaska shows a relevant adjustment share because the number of immigrant workers there is high compared to its sparse population.

The second problem concerns the distribution of corporate profits and other aggregates of property-type income among states. In fact, except for banking and some other regulated industries, state-level data on corporate profits and other property-type items are generally not available. As to the distribution of corporate profits across states, although the magnitude of the deviation from true location is not known, it is subject to various counterbalancing forces that might actually reduce its

[8] The accounting treatments and definitions of these various items are given and shortly discussed in the Appendix.

significance for a large number of states. This issue may be particularly relevant for states with above-average localization of administrative offices of multi-state companies (notably New York).

To gain a clearer insight into the problem, we have attributed the amount of national profits to the states proportionally to their labor share and checked whether the ratio of the attributed profits to state property-type income deviates substantially from the value obtained for the whole economy. We could not find any significant deviation, except for Alaska (which shows a share below the national average by 0.11 percentage points) and Wyoming (0.07 points below the average). Yet, importantly, none of the ex-ante most likely candidates (New York, California) shows substantial deviations from zero.

Taken together, the previous considerations drive us to think that the first-order effect of these biases, if any, is small. Moreover, it should also be kept in mind that the bulk of our analysis concerns the growth rates of labor productivity or their period changes from the first to the second half of the 1990s. Thus any state-specific bias would wash out as long as time-invariant.

GSP levels are only used to classify states on the basis of their sector composition of production. We made an attempt to control for possible biases by comparing index values based on GSP to alternative values based on data based on employment by place of work. The fraction of employment exposed to distorting effects is about 16%, whereas for GSP it amounts to about 40%.[9] The computation of a measure of specialization based on employment rather than on GSP data, does usually lead to very similar results, however. Just in a few cases, employment data fail to register a significant presence of IT producing and using industries, while GSP does. This is the case in Oregon, New Mexico, and Vermont. However, data for 1992 and 1997 from the Census of Manufacturers confirms the importance of IT-producing industries for these states. The reason why employment data might fail to capture some aspects of the IT phenomenon in Oregon and New Mexico may depend on the fact that the development of IT industries has not always been relevant in terms of number of employees; rather, it has been concentrating on type and organization of production processes, leading IT industries to cover a considerable part of production without increasing the employment share by the same proportion. Data on employment in Vermont, instead, are not released since that would disclose the operations of individual establishments or companies. Extrapolations from previous data, however, confirm the relevance of IT-producing industries for Vermont too.

Overall, we conclude that these biases likely imply small consequences for our labor productivity indicator. In any case, in the robustness checks section, we present some sensitivity analysis to

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[9] The portion of the data on employment that could present the same problem as GSP refers to employment for the *nonfarm sole proprietorships* and for the *nonfarm partnership* portion whose tax-filing address is not the business address of the partnership but the residence of one of the partners.

understand whether the regression results discussed below are driven by such outliers as D.C. or Alaska, or other influential observations.

3.2 The evidence

Previous work on the effects of information technology on productivity growth (Gordon (2000), Jorgenson and Stiroh (2000), Oliner and Sichel (2000)) has taken the fourth last quarter of 1995 as a breakthrough for productivity growth in the 1990s. Formal testing procedures, appropriate to search for the existence of unknown break points, such as those reported in Stiroh (2001), have confirmed that 1995 was not a bad choice. We take 1995 as a break point as well.

In **Table 5**, productivity growth data over 1987-2000, split in 1995, are shown. The years before 1995 represent the final part of the productivity slowdown years. Here the geographical dimension of that period matters. Strikingly, at least with the hindsight given by the recent performance of the U.S. economy, the maximum growth rates of labor productivity over the pre-1995 period were in the neighborhood of 2% and this was just in three states. New Hampshire (2.3%), New Jersey (2.3%) and Connecticut (2.25%) were the fastest growers, with another five (New Mexico, Massachusetts, Rhode Island, Delaware, and South Carolina) clustering around 1.8% per year. In parallel, ten states showed negative or zero yearly productivity growth throughout the whole period. In other words, the pace of growth was disappointing in the United States at large, and in fact (relatively) fast productivity growth at some 2% per year was by and large restricted to New England states.

Things changed radically in the second part of the 1990s. Whereas productivity growth did not reach 2.5% per year in any of the U.S. states in 1987-95, sixteen states experienced productivity growth rates beyond 2.5% per year, and twenty-four went beyond 2% per year, in 1996-2000. As a result, fast productivity growth was no longer a business of the few, and instead extended to most regions in the country, in particular in the Western states. To name some of the most significant turnaround episodes, productivity growth in the states of Washington and California boomed to about 3.5% per year - more than 2.5 percentage points higher than in the previous period.

Chart 4 provides a visual representation of the acceleration in the growth rates in average labor productivity in the U.S. states in 1996-2000, with respect to 1987-95. Nineteen states, dark-grey colored in the picture, enjoyed accelerating growth in excess of 1.36 percentage points (the U.S. average acceleration). Twenty-one states – in light grey in the picture - exhibit a ‘moderately positive’ (between zero and 1.36 p.p.) productivity growth variation, with the remaining eleven showing a deceleration in productivity growth. Although definitely more broad-based than in the past, the productivity revival has mostly benefited the states in the West and the North East of the country.

A quick glance at **Table 5**, where productivity growth rates before and after 1995 as well as the implied growth acceleration are reported, is enough to infer that the presence of IT production was tightly associated to positive changes in productivity growth. Seven of the ten states experiencing the biggest jump in productivity growth in 1996-2000 were IT producers in the previous five years. This is *prima facie* evidence that the values of SI for IT production may be good predictors for the productivity growth jumps in the next five years. The correlation is instead much less apparent for IT-using states and states specialized in durable goods production. This is further explored in the next section.

4. IT and productivity growth in the U.S. states

In this section we exploit states productivity growth data in panel formats. The purpose here is to evaluate whether firm conclusions can be drawn as to the association between IT production and use and labor productivity growth in the U.S. states.

4.1 Evidence with industry-based state groups

The main issue here is which groups of states to single out in order to test whether there was a group-wise effect on productivity growth after 1995. Although we are primarily interested in IT-producing and IT-using states, inspection of **Charts 1-4** mildly suggests that there may be a positive link between non-IT durable good production and productivity growth.

Hence we start investigating the presence of deterministic trend breaks in the series of productivity growth for three groups of states characterized by IT production, IT use and non-IT durable good production. These are classified as discussed in previous sections by looking at the values of the relevant SI index over 1991-95. Initially, we do not force groups to be non-overlapping and test for group-specific post 1995 acceleration separately.

Our basic specification follows Stiroh's (2001) and is written as follows:

$$G_{k,t} = \alpha + \beta D + \gamma C + \delta D \cdot C + \varepsilon_{k,t} \qquad (2)$$

D = 1 if t > 1995, D = 0 otherwise

C = 1 if state k $\in$ g, C = 0 otherwise

Equation (2) is appropriate to test for a deterministic change in the mean growth rate of labor productivity across states. $G_{k,t}$ is the growth rate of GSP per employed in state *k* at time *t*. A state *k* belongs to state group *g* when the value of its SI index is bigger than one for the appropriate industry group, irrespective of the values taken by the SI index of that state for other industries. Here, α is the mean growth rate for states not included in the state group g in the pre-1995 period, $\alpha+\gamma$ is the mean growth rate for group g prior to 1995, β is the acceleration for states not included in g, $\beta+\delta$ is the acceleration for group g and δ is the differential acceleration of group g relative to all other states. Standard errors are corrected for heteroskedasticity.

Table 6, 7, and **8** has the same format. Column [1] in each Table presents the estimated values of α, β, γ, and δ in a baseline regression. Column [2] through [4] present additional estimates of the same parameters when: *(i)* Alaska, Hawaii, and D.C. are dropped; *(ii)* state fixed effects, instead of a constant plus group dummies, are included. There may be good reasons to leave Alaska, Hawaii and D.C. out of the sample, and indeed Barro and Sala-i-Martin did so. Hawaii is quite far away from the other fifty states. GSP data for Alaska and D.C. are instead potentially biased by interstate commuting, as emphasized above. We want to make sure that our results are not mainly driven by these potential outliers. Fixed effects, instead, account for the presence of possibly different productivity growth rates across states. The estimation method in all regressions is weighted least squares (WLS), with endogenously determined weights based on the size of the OLS error terms.

Table 6, 7, and **8** contains a number of important results. Before 1995, the states involved in IT production and IT use enjoyed already a better productivity performance (by about half a percentage point) than the rest of the economy, while the states producing non-IT durables did not. After 1995, though, the productivity performances of IT producers and IT users significantly diverged. While the productivity growth jumped upwards in the U.S. economy as a whole, IT producing states did better than the national average by a full percentage point.

The results in **Table 8** also indicate that IT-using states have grown faster than the U.S. average over the whole period, while the same does not apply to states with above-average localization of durable goods production. IT-using states as well as non-IT durable good producers did no better than before 1995, instead. The estimated δ - our measure of accelerating growth after 1995 – turns out not statistically different from zero for both categories of states. Dropping Barro and Sala-i-Martin outliers (Alaska, Hawaii and Washington, D.C.) as well as replacing group-specific dummies by state-fixed effects, make no difference: results only slightly change across columns.

This is clearly not enough, however, to conclude that both IT users and non-IT durables have not contributed to the productivity growth acceleration in the second half of the 1990s. Take the results in **Table 6** once again. IT-producing states have indeed worked out wonders; at the same time, though, the rest of the economy still shows an economy-wide productivity growth acceleration of about 0.7 percentage points in 1996-2000 compared to previous years. One is thus left wondering what is behind this acceleration.

It may in particular be the case that either IT use or non-IT durable good production has, jointly with IT production, eased the way to the occurrence of productivity gains in the U.S. states. To capture these effects, we allow for some interaction effects between these three groups of industries and reclassify states accordingly. We do not try all of the possible interactions, but just those involving the three industries that our presumptions and visual inspection suggest as the most plausible candidate to make sense of the 0.7 productivity growth acceleration outside the IT-producing states.

Then, we supplement our former results by running regressions where the states are grouped into seven mutually exclusive groups so as to infer whether each group, taken in isolation or joint with others, enjoyed higher productivity growth in 1996-2000. This is different from **Table 6-8**, where overlaps were allowed.

In the end, the seven groups are as follows:

(1) IT-producing states (SI_{ITprod}>1; SI_{ITuse}<1; SI_{dg}<1; 10 states in this group);

(2) IT-using states (SI_{ITprod}<1; SI_{ITuse}>1; SI_{dg}<1; 7 states);

(3) States specialized in non-IT durable good production (SI_{ITprod}<1; SI_{ITuse}<1; SI_{dg}>1; 14 states);

(4) States specialized in IT production and use, but not in non-IT durables (SI_{ITprod}>1; SI_{ITuse}>1; SI_{dg}<1; 4 states);

(5) States specialized in IT production and non-IT durables, but not using IT (SI_{ITprod}>1; SI_{ITuse}<1; SI_{dg}>1; 6 states);

(6) States specialized in IT use and non-IT durables, but not in IT production (SI_{ITprod}<1; SI_{ITuse}>1; SI_{dg}>1; 3 states);

(7) All other states (7 states).

A modified expression of the previous test for deterministic trend breaks is now:

$$G_{k,t} = \beta D + \sum_{1}^{7}\left(\gamma_g C_g + \beta_g D \cdot C_g\right) + e_{k,t} \qquad (3)$$

$$D = 1 \text{ if } t > 1995 \text{ , } D = 0 \text{ otherwise}$$
$$C_g = 1 \text{ if state } k \in g, \; C_g = 0 \text{ otherwise}$$

where g represents the groups mentioned above, γ_g is the mean growth rate for group g prior to 1995, β_g is the productivity acceleration for states belonging to g. In this way, we have split both the constant and the post-1995 dummy into group constants and group post-1995 dummies. All estimates are weighted least squares, with endogenous weights. Standard errors are corrected for heteroskedasticity. **Table 9** reports the results of the WLS estimation of equation (3) under various specifications.

The flexible specification in (3) allows us to compare the magnitude of the acceleration across groups of states. In addition, the adopted specification has the advantage that the results coincide with the “true” accelerations within each group. Given that no group has been left out, the coefficients on the dummies no longer give the estimated acceleration with respect to the other states, but simply reflect the productivity acceleration with respect to the previous growth rate within each group.

Auxiliary regressions unambiguously indicate that the OLS residuals are positively related to the size of output (or employment). This is the reason to weigh observations with weights inversely related to the size of each state. In column [1] and [2], equation (3) is estimated with group and state dummies and group-specific acceleration coefficients, with endogenous weights based on the size of the error term. In column [3], observations are weighted by an exogenous weight such as the inverse of nominal output. In column [4], Alaska, D.C. and Hawaii are omitted to check whether results depend on few influential outliers.

Overall, the results conform to our expectations. The mutual interactions between IT production, IT use and non-IT durable production provide enough explanatory power to make the residual acceleration of productivity growth outside these three sectors and states virtually nil. **Table 9** seemingly gives a near-to-complete rendition of where accelerating U.S. productivity growth in the second half of the 1990s originated from.

As expected, the estimated acceleration for the states with above-average localization of IT production is high (+1.57 percentage points) and statistically significant. Size and significance of the coefficient stays unchanged irrespective of how the equation is specified. Productivity growth acceleration of about the same order of magnitude is there for states where specialization in IT production is associated with production of non-IT durable goods (+1.5 percentage points). A statistically significant acceleration of about one percentage point is also detected in states specialized in durable goods production only. Hence, both production of IT goods and services as well as production of durables were crucially associated to the growth acceleration.

The results in **Table 9** also indicate that the simultaneous presence of IT-producing and IT-using sectors may be associated to accelerating growth as well. Yet this result is not robust to alterations in the set of weights adopted in the regression. The acceleration is there if endogenous weights are employed, but not if output (or employment) weights are used instead.

Importantly, there is instead no evidence of growth acceleration in IT-using states when IT usage is unparalleled with IT production. The estimated β_gs for IT-using states and for states with a simultaneous presence of IT-using and durable goods producing sectors are in fact not statistically different from zero.

To sum up, our results are reminiscent of Gordon's in the emphasis put on the role of IT and durable goods production in the productivity revival of the late 1990s. At the same time, however, the productivity acceleration in the U.S. states was not narrowly geographically concentrated, for two reasons. Our list of states with some localization of IT or durable goods production (or both) includes thirty U.S. states, corresponding to a substantial part of total output and employment in the U.S. Moreover, our definition of IT producing sectors (borrowed from the Department of Commerce) also extends to some services sectors. Overall, IT and durable-goods producing industries represented respectively about 2% and 6.5% of total GDP in 1991-95.

Provided that IT production and non-IT durables only really matter, one could expect that no significant acceleration shows up outside the states with a localization of these industries. This can be tested by determining the size of the overall productivity acceleration once states specialized in IT production, durables or both are dropped out of the sample. The test is then simply:

$$G_{k,t} = \alpha + \beta D + \varepsilon_{k,t} \qquad D = 1 \text{ if } t > 1995,\ D = 0 \text{ otherwise} \tag{4}$$

where t is 1987-2000 as above; α is a constant and gives the mean of $G_{k,t}$ prior to 1995; β gives the common mean acceleration after 1995. **Table 10** shows how the estimates of β change as various categories of states are dropped of the sample.

In a first batch of estimates, whose results are reported in *Panel A* of **Table 10**, those states specialized in the production of IT goods and services only, in non-IT durables only and those producing both are sequentially dropped one at a time. As these states are left out, the estimated mean growth before 1995 remains roughly constant, while no acceleration after 1996 is observed for the remaining (twenty-one) states (see column [4], where the estimated β has become not significant). The growth acceleration falls from 0.92 to 0.77 when IT producing states are left out first, with a further reduction to 0.64 when durable goods producing states are dropped. Finally, when the states specialized in the production of both are left out as well, the point-wise estimate of the growth acceleration falls to 0.34, but this estimate is now imprecisely measured and cannot be taken to be different from zero. This is suggestive that not much room is left for IT-using states in determining the growth revival.

To double-check this result, in *Panel B* of **Table 10**, the findings from a second set of regressions are reported. Here, starting again from the full sample, IT-using states are dropped first, then the states where IT use occurs together with either IT production or non-IT durable goods production. As a result, average growth before 1995 is reduced from 0.95 to 0.80 (see column [1] and [4]), for IT-using states are traditionally fast-growing states. In parallel, though, the estimated β goes up from 0.95 to 1.05. This shows that, when IT-using states are dropped out of the sample, the average growth acceleration in the U.S. economy is even higher than otherwise.

This same pattern of results in the two panels of **Table 10** continues to hold when output weights are used instead (see Column [5] and [6]). When the Barro and Sala-i-Martin outliers (Alaska, D.C. and Hawaii) are left out, dropping IT and durable goods producers does not zero growth acceleration after 1995, instead. To eliminate the growth acceleration, states where IT use is associated to IT production have to be dropped as well. This is (weak) evidence that IT use may play a role, after all, but only jointly with IT production.

4.2 Evidence with state groups based on direct measures of computer diffusion

The previous results show that IT diffusion is related to productivity growth but its contribution varies considerably depending on whether IT production or IT use is taken into consideration. In particular, there is evidence of a positive association between production of IT goods and services and the acceleration in productivity growth, while the link is not there for IT usage.

Here we provide a further check of our main results by re-estimating equation (2) once states are classified on the basis of direct, rather than indirect, measures of computer use. As discussed in the methodological section, IT intensity may be defined in at least two ways. We use the Census Bureau data on computer use nearest to our breakpoint year 1995: computer use at home in 1994 and computer use at work in 1997. Given that none of our indicators is perfect, we use both. Each indicator is then normalized by its national average and intensity indices hovering around one constructed.

Table 11 reports the main regression results with direct indicators. While evidence of some economy-wide acceleration in the rate of growth of productivity ranging between 0.6 and a full percentage point is there, there is no consistent indication that such acceleration has been more pronounced for IT-intensive states. The acceleration coefficient is never statistically significant when output weights are employed, irrespective of which specific IT intensity indicator used in the regression. When weights are based on first-stage OLS residuals, the acceleration coefficient is more precisely estimated, with a point-wise estimate of about 0.85 when the IT intensity indicator is the number of computers per worker in 1997. This indicates that IT usage may be positively associated to growth gains (or possibly the reverse). Yet the acceleration coefficient is not significant when the number of computers per household in 1994 – the most safely exogenous indicator we are endowed with - is used, unless the Barro and Sala-i-Martin outliers are left out of the sample. Even in this case, though, the coefficient is just significant at the 10% level.

The (occasional and rather weak) significance of the growth acceleration coefficient raises the issue of whether direct indicators are capturing something else, over and above the industry-based indices. A simple test for this idea is to check whether the statistical significance of the acceleration coefficient in the computer-at-work regression (the only one where this coefficient turns out statistically significant) varies, as state groups are dropped out of the sample one at a time. The response from these other regressions is in the negative. When states specialized in the production of IT goods & services as well as durable goods are dropped, the significance of the growth acceleration coefficient disappears, in the same fashion as in the main regressions above. *Vice versa*, as IT-using states are dropped, the growth acceleration coefficient falls in size (from 0.85 to 0.70) and remains weakly significant (at the 10% level). As the states specialized in IT production and use are left out as well, the significance vanishes, however.

4.3 Robustness checks

In this section, we test how sensitive the main results in this section are to some alterations of our testing framework.

4.3.1 Hours worked

In the data description section we mentioned that states data are not corrected for cyclical fluctuations. The number of average hours worked on a weekly basis is available, however, for each U.S. sector at the national, though not at the state, level. Hence, using these pieces of information, we proceeded to correct the denominator, allowing for sector-specific fluctuations of employment over time. Results with this other labor productivity growth variable closely replicate size and significance of the ones obtained with the non-cyclically-adjusted measure of labor productivity. Their similarity with those reported in **Table 6** through **11** is such that we omit reporting them for brevity.

4.3.2 A longer time horizon

It may be the case that, by constraining ourselves to analyze 1987-2000, we picked too narrow a period for the purpose at hand. It might in particular be the case that, with our data starting in 1987, we are already capturing some states well on track on their way out of the productivity slowdown. Lengthening backwards the period under consideration would allow us to evaluate whether the detected trend breaks from 1996 onwards continue to be there when the 1970s and the 1980s, *i.e.* the productivity slowdown decades, are included as well.

Luckily, the data published by the BEA for the U.S. states go back to 1977, thereby including the bulk of the productivity slowdown period. The reason why we have not considered these data in the first instance is that they refer to real GSP computed from fixed-weight indices. By augmenting our sample with these other data, we are able to test whether our conclusions, in particular those regarding the relative unimportance of IT usage as such, carry over to this extended sample.

Then, the same experiments as in **Table 9** (column [1], [3] and [4]), are repeated with the longer sample. The results from such regressions are reported in **Table 12** and can be contrasted with those in **Table 9**. To ease the comparison, the cells containing substantially different results are shaded in light grey. First of all, the pre-1996 period measured by the constants in **Table 12** refers to 1977-1995 and not to 1987-1995 as was the case in **Table 9**. The inclusion of the productivity slowdown years expectedly makes the group-wise constants smaller than in **Table 9**. This applies in particular to the constants relative to the states specialized in IT production, in IT production and use and to those states in the residual group. The acceleration coefficients do not change much, instead, between the two Tables. Exceptions are once again the coefficients of the states with shares of IT production and IT production & use above the national average, for which the 1996-2000 acceleration is now more evident than with the shorter time series. The view expressed above in previous sections that IT usage was relevant for the productivity acceleration only if coupled with either IT production or durable goods production significantly receives further confirmation, however. The acceleration coefficient for IT-using states is never significant, while the coefficients of both IT-using & IT-producing states as well as IT-using & durable goods producing states are usually significantly different from zero and their point-wise estimates range between one and two percentage points.

In addition to that, though, the two main previous results obtained in **Table 10** on the size of the acceleration as various categories of states are dropped of the sample also obtain with the longer sample. First, the crucial importance of IT and durable goods production is confirmed. When starting from the full sample, the states specialized in IT production, in durable goods production or both are sequentially dropped, the estimated mean growth for the period before 1995 remains roughly unchanged, while the acceleration disappears. Second, when IT-using states are dropped, size and significance of the estimated acceleration remain the same.

4.3.3 Classification of retail trade

The classification of retail trade inside or outside the group of the IT using sectors is a somewhat contentious issue. Stiroh (2001) includes retail among the IT-intensive sectors, while the sector classification provided by the Department of Commerce (and employed in this paper) does not.[10] As a result, retail trade belongs to 'non-IT services' in our sector classification. Given that retail

[10] Sieling, Friedman and Dumas (2001) document that the retail industry, as a result of increased concentration paralleled by fiercer competition, experienced higher productivity growth rates well before 1987. This partially occurred thanks to increased investments in information and communication technologies.

represents a non-negligible part of the U.S. economy (about 10% of total GDP) and that its labor productivity has grown at rates above 4% in the second half of the 1990s, it is important to verify how our conclusions change when retail trade is classified among the IT-using sectors, as Stiroh does.

When this is done, the share of the U.S. GDP produced by the IT-using sectors goes up by a few percentage points. This involves some shifting in the specialization pattern of various states. In particular, three U.S. states change their specialization, *i.e.* are assigned to different *SI* groups. The state of Washington, which used to belong to the group of states specialized in durable goods production, is now specialized in both durable goods production *&* IT use. The inclusion of retail among the IT using sectors is enough to make the SI_{ITuse} index for this state bigger than one for IT use. For the same reason, the state of North Dakota is no longer in the residual group of states (those with specialization indices for IT production, IT use and durable goods below to one) and is instead classified among the IT-using states. Finally, Illinois presents a GDP share of retail lower than the national average and thus shifts its specialization from IT production & use to IT production only.

Does this change the results of our tests for the presence of deterministic breaks in the growth rate of labor productivity? Not much. Our main findings in section 4.1 and 4.2 are confirmed in **Table 13**, which holds a similar structure to **Table 12** and **9**. Those states specialized in IT usage as such, *i.e.* with a presence of IT and durable goods production falling short of the national average, do not exhibit any productivity growth acceleration in 1996-2000. Accelerating productivity is observed instead for states specialized in IT production, in durable goods production and in both, irrespective of the weights employed in the regression, even excluding the Barro and Sala-i-Martin outliers. Somehow expectedly though, those states with a strong presence of IT use & durable goods production as well as of IT use & IT production also show accelerating productivity for about 1.5 percentage points, although this effect is not present for IT producing and using states when output (or employment) weights are used instead. Yet this lack of robustness was there already in **Table 9**.

4.3.4 Influential observations

In **Table 9** and in the previous robustness checks tables, we explicitly allowed for the possibility that some U.S. states may not belong to the same pool of which the rest of the U.S. states can be considered random drawings. Barro and Sala-i-.Martin left Alaska, D.C. and Hawaii out of their convergence regressions in their 1990 regressions; we tried the same here in one of our specifications. Yet the results of our testing procedures may be biased by the presence of other influential observations and is thus worth exploring this possibility.

Re-estimating the various equations with bootstrapped standard errors allows one to formally test for the presence and the bias consequences of such influential observations.[11] We chose to subject the results reported in column [1] of **Table 9** to such robustness check. In column [1] of **Table 14**, the coefficient estimates of the variables included in the basic regression in **Table 9** are reported first. In column [2], the respective biases of such estimates according to the application of bootstrapping techniques appear. They were computed from one thousand Monte Carlo repetitions with replacement from the original regression residuals. In column [3] the bootstrapped estimates, obtained subtracting the respective biases from the standard estimates, are reported. As apparent in column [2] and [3], biases are always very small compared to the estimated parameters. We interpret these results as meaning that our preferred formulation does not suffer from significant biases.

[11] Bootstrapping is a special Monte Carlo method designed to produce estimates of the bias and variance of an estimator. The estimated parameters are taken to be the true values of these parameters for the Monte Carlo study. The errors used for repeated sampling – the essence of Monte Carlo experiments - are the residuals from the original regression. The estimate of the bias produced by the bootstrapping can be subtracted from the original estimate to produce the bootstrap estimate.

5. Conclusions

This paper adds novel evidence on the role of information technologies in the U.S. productivity revival and, more generally, on the relation between new technologies and growth. The evidence put forward here is based on the dissection of industrial structures, direct information on computer diffusion and economic performances for the U.S. states in the last fifteen to twenty-five years.

Altogether, indirect and direct indicators of IT diffusion produce a coherent picture of the relation between IT and growth in the U.S. states. As previously emphasized by Gordon, while some relation between IT and growth is indeed there, this is mostly confined to IT production. Our results also suggest, however, that durable goods production has been a direct complement of the IT revolution. When states where IT production and non-IT durable manufacturing are mostly localized are excluded, the remaining states do not exhibit any significant acceleration in productivity. In particular, the association between productivity gains and IT use - documented in previous studies such as Stiroh (2001) and Nordhaus (2002) - is weak. Consistent with these results, when states are split into IT-intensive and non-IT intensive using Census data on computer diffusion at home and at work, not much is seen as well.

The potential reasons for why IT use may have not been beneficial are many. As suggested by Griliches (1992), Triplett (1996) and others since then, output in the IT-using service sectors (wholesale trade, finance, insurance, legal services) may be mis-measured. Alternatively, as argued by Gordon (2000), IT investment may be directed to unproductive activities, like market share protection, duplication of existing operations, or on-the-job consumption. Or, following Kiley (2000), the missing relation between IT use and productivity may be due to the presence of sizable adjustment costs. Any of these stories (possibly all of them) may be right: they all leave us wondering why sector data tend to show that IT use was indeed important in the acceleration of productivity growth in the United States, while states data say that IT use was not. Reconciling sector and state level evidence is an important area of future research.

Finally, our U.S. states centered study has far-reaching implications for the growth prospects and the technological policies in other areas of the world as well. If IT production, not IT use, matters for growth, a strong case can be made for all countries to engage in a technological race to become leaders in the production of (some) new technologies. In other words, learning how to use the new technologies, *i.e.* being fast adopters of them, may not be enough to grant a country or region fast growth, unless some IT or durable goods production is localized inside the country. Our U.S. state findings are suggestive that this area of research, also explored by Daveri and Silva (2002) in a related recent paper on the crucial role of Nokia in feeding rapid productivity growth in Finland, should be further developed.

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Appendix: Measuring output at the state level: where the issues are

As emphasized in the main text (section 3.1), the difference between income and production data is, to a large extent, minor at the national level, while this is not necessarily so at the state level. This appendix further elaborates this important point.

As mentioned above, GSP is produced from the income side of the accounts, as is the U.S. GDP by industry, and is thus the sum of the employees' compensation, indirect business tax and non-tax liabilities, and property type incomes. To estimate the employees' compensation item, the BEA relies upon two components of the State Personal Income series, namely 'Wage and salary accruals' and 'Other labor incomes'. 'Wage and salary accruals' is then used to allocate employer's contributions for social insurance – the other component of employees' compensation not measured in the personal income series – to states. Indirect business tax and non tax liabilities consists of a State and local government component and of a Federal Government component. The estimates of the State and local government component are based on Census Bureau data on taxes collected by types and states, and on data from the U.S. Department of Agriculture for taxes on farm property. As to the Federal Government component, data sources are many and include some departments (of Energy, Interior, and Transportation), the Federal Reserve Board, the BLS, and unpublished data by the BEA. The third component of GSP, property-type income, is made of proprietors' income and 'other capital charges'. Proprietors' income includes income of unincorporated establishments, rental income of persons, proprietors' inventory valuation adjustment, and non-corporate capital consumption allowance. Proprietors' income is based on BEA's Personal Income series. 'Other capital charges' includes corporate profits before taxes, net interest, corporate inventory valuation adjustment, corporate capital consumption allowance, business transfer payments, and subsidies. A variety of data sources and levels of aggregation, depending on the industry type, are used to derive this item. For private-goods producing industries, total GSP is estimated first, and then compensation of employees, indirect business tax and non tax liabilities, and proprietors' income are subtracted to derive other capital charges. Data sources used to estimate total GSP by industry are USDA data and Census Bureau data on value added in production. Since BEA's definition of value added is slightly different from that of the Census, adjustments are made to data for mining and manufacturing for detailed industries and for construction. Among these adjustments, data for headquarters of multi-establishment firms are reassigned from the states where establishments are located to the states where headquarters are located. For private services-producing industries, the estimates of other capital charges are based on data of revenues and payrolls from economic censuses, on data on income and expenses from financial reports that firms file with Federal agencies or on unpublished BEA estimates of wage and salary accruals by State.

For a proper measure of productivity, all the above mentioned components would be required be recorded by place of work or attributed to the place where the establishments are located in practice. In fact, wage and salary accruals, other labor income, and indirect business tax and non tax liabilities are mainly derived from source data that are reported and recorded by place of work. The estimates of proprietors' income, conversely, are derived from source data that are reported by the tax-filing address of the recipient - usually corresponding to the proprietors' residence. Due to the variety of data sources and estimating procedures, it is hard to say if 'other capital charges' is really attributed to states where production occurs. Nevertheless, as long as data are reassigned to states where the administrative offices of multi-establishment companies are located, even the 'other capital charges' item may be exposed to a bias.

TABLE 1: GSP-based industry specialization indices (*SI*), 51 states, 1991-95 averages (U.S. economy: *SI*=1 for each group)

State	**Region**	IT Production	IT Use	Mining	Non-IT durables	Non-IT non-durables	Construction	Non-IT services
NM	Southwest	1.71	0.78	5.87	0.34	0.28	1.12	1.05
VT	New England	1.33	0.87	0.18	1.01	0.96	1.06	1.14
NH	New England	1.33	0.98	0.06	0.71	1.07	0.88	1.01
CO	Rocky Mountains	1.32	0.94	1.18	0.52	0.83	1.27	1.07
IA	Plains	1.31	0.85	0.16	1.05	1.69	1.01	0.99
WI	Great Lakes	1.18	0.83	0.14	1.41	1.88	1.06	0.93
AZ	Southwest	1.15	0.94	1.11	0.92	0.43	1.32	1.15
IL	Great Lakes	1.15	1.01	0.26	0.88	1.02	1.03	0.97
ID	Rocky Mountains	1.14	0.82	0.65	0.98	1.08	1.65	1.15
MA	New England	1.14	1.15	0.04	0.71	0.77	0.77	0.90
CA	Far west	1.10	1.12	0.39	0.63	0.70	0.88	0.96
OR	Far west	1.09	0.91	0.09	1.61	0.85	1.21	1.03
VG	Southeast	1.09	0.95	0.43	0.79	1.45	1.17	0.99
TX	Southwest	1.09	0.89	5.23	0.64	0.65	1.05	1.05
GE	Southeast	1.03	0.90	0.31	0.93	1.79	0.97	1.04
DC	Mid East	1.03	1.23	0.03	0.03	0.59	0.35	1.10
IN	Great Lakes	1.02	0.80	0.32	2.58	1.01	1.14	0.96
MN	Plains	1.02	0.96	0.35	0.96	1.37	1.08	1.02
OH	Great Lakes	1.01	0.88	0.29	2.22	1.10	0.93	0.94
CT	New England	1.00	1.16	0.04	1.15	0.69	0.80	0.84
NJ	Mid East	0.98	1.21	0.04	0.41	0.80	0.88	0.90
NC	Southeast	0.98	0.83	0.11	1.07	2.51	1.03	0.97
SC	Southeast	0.96	0.84	0.15	0.95	2.13	1.24	1.05
OK	Southwest	0.96	0.84	3.98	1.13	0.85	0.81	1.16
MD	Mid East	0.95	1.12	0.06	0.39	0.64	1.36	1.04
NY	Mid East	0.95	1.26	0.05	0.44	0.88	0.73	0.84
KS	Plains	0.94	0.86	1.16	1.34	1.30	1.01	1.12
FL	Southeast	0.93	1.07	0.16	0.44	0.55	1.19	1.19
RI	New England	0.93	1.03	0.04	1.57	0.88	0.92	0.94
MI	Great Lakes	0.92	0.87	0.30	2.94	0.89	0.89	0.87
MO	Plains	0.91	0.89	0.19	1.51	1.31	1.05	1.08
SD	Plains	0.89	1.01	0.93	0.61	0.73	1.05	1.20
TN	Southeast	0.88	0.88	0.22	1.60	1.55	0.93	1.06
PE	Mid East	0.88	1.01	0.37	1.14	1.05	0.99	1.03
UT	Rocky Mountains	0.88	0.84	2.45	1.28	0.62	1.31	1.22
AR	Southeast	0.88	0.73	0.61	1.62	2.01	0.99	1.18
AL	Southeast	0.85	0.82	0.98	1.59	1.78	1.06	1.05
KY	Southeast	0.84	0.76	2.30	1.82	1.87	1.03	1.00
WA	Far west	0.84	0.98	0.18	1.66	0.72	1.30	1.02
MS	Southeast	0.83	0.77	0.76	1.78	1.49	0.96	1.21
ND	Plains	0.71	0.97	2.73	0.36	0.56	1.22	1.31
ME	New England	0.66	0.92	0.02	1.11	1.77	1.12	1.14
HI	Far west	0.62	1.02	0.08	0.15	0.41	1.69	1.46
LA	Southeast	0.54	0.96	8.11	0.54	0.72	1.07	1.00
NV	Far west	0.53	0.78	2.61	0.32	0.24	1.73	1.77
MT	Rocky Mountains	0.51	0.88	3.95	0.83	0.40	1.24	1.42
NE	Rocky Mountains	0.51	0.88	3.95	0.83	0.40	1.24	1.42
WV	Southeast	0.49	0.89	6.07	1.13	0.36	1.15	1.21
AK	Far west	0.42	0.78	17.52	0.28	0.53	1.11	0.87
DE	Mid East	0.40	1.42	0.01	0.81	0.88	0.85	0.68
WY	Rocky Mountains	0.35	0.57	21.22	0.21	0.17	1.02	1.18

Table 2 Groups of states according to the GSP-based industry specialization index, 1991-95	
States specialized in IT-producing industries only *(ITprod>1, ITuse<1)*	Arizona, Colorado, Georgia, Idaho, Indiana, Iowa, Minnesota, Nebraska, New Hampshire, New Mexico, Ohio, Oregon, Texas, Vermont, Virginia, Wisconsin
States specialized in IT-using industries only *(ITuse>1, ITprod<1)*	Connecticut, Delaware, Florida, Hawaii, Maryland, New Jersey, New York, Pennsylvania, Rhode Island, South Dakota
States specialized in both production and use of IT *(ITprod>1, ITuse>1)*	California, District of Columbia, Illinois, Massachusetts

Notes to Table 1 and 2: Each specialization index is computed from the following formula:

$$SI_i^k = \frac{y_i^k / y^k}{y_i / y} = \frac{y_i^k / \sum_i y_i^k}{\sum_k y_i^k / \sum_i \sum_k y_i^k}$$

Table 3: Correlations between the indices of specialization (1991-95 averages)							
	ITprod	ITuse	Dg	Ndg	Min	Serv	Constr
ITprod	1.00						
ITuse	0.03	1.00					
Dg	0.08	-0.32	1.00				
Ndg	0.20	-0.24	0.42	1.00			
Min	-0.47	-0.44	-0.31	-0.39	1.00		
Serv	-0.27	-0.39	-0.26	-0.27	0.09	1.00	
Constr	-0.16	-0.36	-0.11	-0.17	0.06	0.61	1.00

Note: *Dg* is non-IT durable goods manufacturing, *Ndg is* non-IT nondurable goods manufacturing, *Min* is mining, *Serv* is non-IT private services, *Constr* is construction. All values are averages for the period 1991-95.

Table 4: Intensity of use of personal computers at home and work

State	Region	# PC per household (%), 1994	Intensity index (#PC per household)	# PC at work per employed (%, 1997)	Intensity index (# PC at work / employment)
		(1)	*(2)*	*(3)*	*(4)*
AK	Far west	39.5	1.56	43.4	1.05
NH	New England	38.9	1.54	48.7	1.18
UT	Rocky Mountains	38.1	1.51	41.9	1.02
HI	Far west	35.1	1.39	36.2	0.88
MD	Mid East	34.8	1.38	51.4	1.25
CO	Rocky Mountains	34.3	1.36	47.5	1.15
ID	Rocky Mountains	34.0	1.34	39.8	0.97
WA	Far west	33.4	1.32	47.5	1.15
CA	Far west	32.6	1.29	42.7	1.04
VT	New England	31.9	1.26	44.5	1.08
OR	Far west	31.8	1.26	41.4	1.01
WY	Rocky Mountains	30.6	1.21	37.9	0.92
VG	Southeast	30.4	1.20	44.5	1.08
CT	New England	30.0	1.19	40.4	0.98
MN	Plains	29.9	1.18	40.4	0.98
AZ	Southwest	28.9	1.14	45.6	1.11
KS	Plains	27.8	1.10	39.9	0.97
MA	New England	27.7	1.10	43.9	1.07
NJ	Mid East	27.0	1.07	45.5	1.11
MO	Plains	26.9	1.07	43.4	1.05
IA	Plains	26.7	1.06	37.1	0.90
NV	Far west	26.3	1.04	33.2	0.81
DE	Mid East	26.1	1.03	40.0	0.97
NM	Southwest	25.7	1.02	45.2	1.10
MI	Great Lakes	25.7	1.02	42.9	1.04
USA		**25.3**	**1.00**	**41.2**	**1.00**
WI	Great Lakes	24.5	0.97	42.9	1.04
MT	Rocky Mountains	24.2	0.96	37.4	0.91
NE	Rocky Mountains	24.2	0.96	37.4	0.91
IL	Great Lakes	24.0	0.95	39.9	0.97
TX	Southwest	23.7	0.94	43.0	1.04
DC	Mid East	23.7	0.94	18.5	0.45
ME	New England	23.7	0.94	41.1	1.00
RI	New England	23.6	0.93	38.7	0.94
FL	Southeast	23.4	0.93	39.5	0.96
ND	Plains	23.4	0.93	36.9	0.90
OK	Southwest	23.1	0.92	37.7	0.92
OH	Great Lakes	22.5	0.89	41.7	1.01
NY	Mid East	22.4	0.89	39.1	0.95
IN	Great Lakes	21.4	0.85	41.9	1.02
SD	Plains	21.0	0.83	35.7	0.87
PE	Mid East	19.9	0.79	41.1	1.00
GE	Southeast	19.8	0.78	40.8	0.99
SC	Southeast	19.3	0.76	35.9	0.87
NC	Southeast	19.2	0.76	34.9	0.85
TN	Southeast	18.9	0.75	35.7	0.87
KY	Southeast	17.6	0.70	39.5	0.96
WV	Southeast	17.3	0.69	37.8	0.92
AR	Southeast	16.7	0.66	30.3	0.74
LA	Southeast	15.8	0.63	36.2	0.88
AL	Southeast	15.6	0.62	40.8	0.99
MS	Southeast	13.9	0.55	33.7	0.82

Table 5: Labor productivity growth in the U.S. states; non-farm business sector, 1987-2000

State	Region	1996-2000	1987-95	(1996-2000)-(1987-95)
OR	Far west	5.57	1.09	+4.48
MN	Plains	3.40	0.44	+2.96
UT	Rocky Mountains	2.54	-0.03	+2.58
WA	Far west	3.30	0.74	+2.56
CA	Far west	3.44	0.91	+2.53
ND	Plains	2.11	-0.26	+2.37
NH	New England	4.55	2.30	+2.25
CO	Rocky Mountains	3.34	1.13	+2.22
MA	New England	4.01	1.83	+2.19
RI	New England	3.76	1.86	+1.90
NC	Southeast	2.98	1.09	+1.89
KS	Plains	2.05	0.16	+1.89
NY	Mid East	3.30	1.42	+1.88
MI	Great Lakes	1.86	0.06	+1.80
AZ	Southwest	3.10	1.37	+1.73
ID	Rocky Mountains	3.09	1.50	+1.59
MT	Rocky Mountains	0.79	-0.76	+1.55
NE	Rocky Mountains	0.79	-0.76	+1.55
WI	Great Lakes	2.33	0.80	+1.53
IN	Great Lakes	2.45	0.93	+1.52
NM	Southwest	3.29	1.93	+1.36
USA		**2.31**	**0.95**	**+1.36**
GE	Southeast	2.73	1.40	+1.33
OH	Great Lakes	1.76	0.57	+1.20
IL	Great Lakes	2.27	1.13	+1.14
SD	Plains	1.21	0.16	+1.05
TX	Southwest	2.06	1.22	+0.84
OK	Southwest	0.80	-0.04	+0.84
MD	Mid East	1.65	0.81	+0.84
VG	Southeast	1.80	1.03	+0.77
IA	Plains	1.78	1.03	+0.75
CT	New England	3.00	2.25	+0.75
VT	New England	2.14	1.41	+0.74
AL	Southeast	1.55	0.86	+0.68
AR	Southeast	1.63	0.97	+0.66
TN	Southeast	1.71	1.10	+0.61
ME	New England	1.07	0.59	+0.48
MO	Plains	1.56	1.10	+0.47
KY	Southeast	1.42	0.94	+0.47
NJ	Mid East	2.44	2.30	+0.14
PE	Mid East	1.51	1.46	+0.04
FL	Southeast	1.05	1.15	-0.10
WY	Rocky Mountains	0.21	0.35	-0.14
SC	Southeast	1.56	1.75	-0.19
MS	Southeast	0.69	1.06	-0.37
WV	Southeast	0.3	0.74	-0.44
NV	Far west	0.48	0.97	-0.49
DC	Mid East	0.59	1.35	-0.76
HI	Far west	-0.52	0.88	-1.40
LA	Southeast	-1.47	-0.03	-1.44
DE	Mid East	-0.27	1.76	-2.03
AK	Far west	-3.79	-1.06	-2.73

Notes: Labor productivity growth is computed as the growth rate of the ratio between the levels of real GSP and total employment in each state over the relevant periods.

Table 6: Dummy Variable Tests of Productivity Acceleration for IT-producing states

Constant	0.79***	0.84***	-	-
	(0.16)	(0.13)		
Post-95 Dummy	0.52**	0.71***	0.52***	0.70***
	(0.23)	(0.20)	(0.21)	(0.19)
Group Dummy for IT production	0.44*	0.37*	-	-
	(0.23)	(0.22)	-	-
Post-95 dummy for IT production group	1.03***	0.98***	1.03***	0.98***
	(0.34)	(0.32)	(0.31)	(0.31)
Number of Observations	714	672	714	672
Number of States	51	48	51	48
		Drop AK, DC, HI		Drop AK, DC, HI
			Fixed effects	Fixed effects

Table 7: Dummy Variable Tests of Productivity Acceleration for states producing non-IT durable goods

Constant	1.00***	1.08***	-	-
	(0.19)	(0.17)		
Post-95 Dummy	0.72***	1.00***	0.72***	1.00***
	(0.27)	(0.24)	(0.24)	(0.22)
Group Dummy for non-IT durables	-0.10	-0.17	-	-
	(0.23)	(0.21)	-	-
Post-95 dummy for non-IT durable group	0.45	0.17	0.45	0.17
	(0.34)	(0.32)	(0.31)	(0.30)
Number of Observations	714	672	714	672
Number of States	51	48	51	48
		Drop AK, DC, HI		Drop AK, DC, HI
			Fixed effects	Fixed effects

Table 8: Dummy Variable Tests of Productivity Acceleration for IT-using states

Constant	0.80***	0.85***	-	-
	(0.15)	(0.12)		
Post-95 Dummy	1.05***	1.16***	1.05***	1.16***
	(0.21)	(0.19)	(0.20)	(0.17)
Group Dummy for IT use	0.58**	0.57**	-	-
	(0.23)	(0.23)		
Post-95 dummy for IT use group	-0.47	-0.30	-0.47	-0.29
	(0.36)	(0.37)	(0.33)	(0.34)
Number of Observations	714	672	714	672
Number of States	51	48	51	48
		Drop AK, DC, HI		Drop AK, DC, HI
			Fixed effects	Fixed effects

Notes to Tables 6, 7 and 8: The dependent variable is yearly productivity growth in state *k*, 1987-2000. The 'Post-1995' dummy equals 1 if t>1995, 0 otherwise. The 'Group dummy' equals 1 for states with $SI_{ITprod}>1$ (1991-95 average) and 0 otherwise in **Table 6**. The 'Group dummy' equals 1 for states with $SI_{dg}>1$ (1991-95 average) and 0 otherwise in **Table 7**. The 'Group dummy' equals 1 for states with $SI_{ITuse}>1$ (1991-95 average) and 0 otherwise in **Table 8**. Robust standard errors in parentheses.

Table 9: Dummy-variable tests of productivity acceleration for groups of states 1987-2000

		Group dummies [1]	Fixed effects [2]	Group dummies 1/output87 as a weight [3]	Group dummies Drop AK, DC, HI [4]
IT production only	Constant	1.34***	-	1.53***	1.34***
		(0.29)		(0.28)	(0.29)
	Post-95 Dummy	1.57***	1.57***	1.56***	1.57***
		(0.37)	(0.36)	(0.48)	(0.37)
IT use only	Constant	1.21***	-	0.82***	1.26***
		(0.28)		(0.31)	(0.30)
	Post-95 Dummy	0.05	0.05	-0.27	0.29
		(0.40)	(0.38)	(0.52)	(0.43)
Non-IT durables only	Constant	0.67***	-	0.62**	0.67***
		(0.17)		(0.27)	(0.17)
	Post-95 Dummy	1.01***	1.00***	0.85*	1.00***
		(0.24)	(0.23)	(0.45)	(0.24)
IT production & IT use	Constant	1.30***	-	1.38**	1.29***
		(0.28)		(0.64)	(0.33)
	Post-95 Dummy	1.27***	1.27***	-0.17	1.95***
		(0.48)	(0.44)	(0.48)	(0.49)
IT production & non-IT durables	Constant	0.97***	-	1.22***	0.97***
		(0.22)		(0.36)	(0.22)
	Post-95 Dummy	1.70***	1.70***	1.32**	1.70***
		(0.43)	(0.35)	(0.60)	(0.43)
IT use & non-IT durables	Constant	1.86***	-	1.90***	1.86***
		(0.28)		(0.57)	(0.29)
	Post-95 Dummy	0.89	0.89	1.58	0.89
		(0.67)	(0.66)	(0.96)	(0.68)
Other states	Constant	0.14	-	-0.10	0.14
		(0.53)		(0.23)	(0.53)
	Post-95 Dummy	-0.15	-0.15	0.55	-0.15
		(0.68)	(0.64)	(0.39)	(0.68)
R-squared		0.31	0.36	0.22	0.39
# of observations		714	714	714	672
# of states		51	51	51	48

Notes to Table 9: The dependent variable is productivity growth for state k, 1987-2000. The 'Post 1995' dummy equals 1 if t>1995, 0 otherwise. All estimates are weighted least squares. In column [1] and [2], weights are endogenously determined based on the size of the error term (robust standard errors in parentheses). In column [3], the inverse of nominal output in 1987 is employed as a weight (standard errors in parentheses). In column [4], the same regression as in column [1] is run again leaving Alaska, D.C. and Hawaii out of the sample (robust standard errors in parentheses).

Table 10: Estimates of aggregate productivity acceleration with varying sample size, 1987-2000

	[1] Robust std.errors	[2] Robust std.errors	[3] Robust std.errors	[4] Robust std.errors	[5] Weight= 1/output87	[6] Weight= 1/output87	[7] AK, DC, HI out	[8] AK, DC, HI out
Panel A: Dropping states specialized in production of IT goods and services and durables								
Constant	0.96***	0.86***	0.97***	0.96***	0.77***	0.46***	0.99***	1.06***
	(0.12)	(0.13)	(0.17)	(0.21)	(0.13)	(0.21)	(0.13)	(0.17)
Post-1995 Dummy	0.92***	0.77***	0.64***	0.34	0.78***	0.34	1.08***	0.66**
	(0.18)	(0.19)	(0.27)	(0.31)	(0.21)	(0.31)	(0.19)	(0.28)
Drop states w/ IT production only		Yes	Yes	Yes		Yes		Yes
Drop states w/ non-IT durable manufacturing only			Yes	Yes		Yes		Yes
Drop states w/ IT-production & non-IT durable manufacturing				Yes		Yes		Yes
# observations	714	574	378	294	714	294	672	252
# states	51	41	27	21	51	21	48	18
Panel B: Dropping IT-using states								
Constant	0.96***	0.92***	0.88***	0.80***	0.77***	0.67***	0.99***	0.85***
	(0.12)	(0.13)	(0.13)	(0.15)	(0.13)	(0.15)	(0.13)	(0.12)
Post-1995 Dummy	0.92***	1.06***	1.04***	1.05***	0.78***	0.98***	1.08***	1.16***
	(0.18)	(0.19)	(0.20)	(0.21)	(0.21)	(0.25)	(0.19)	(0.19)
Drop states w/ IT use only		Yes	Yes	Yes		Yes		Yes
Drop states w/ IT use & IT production			Yes	Yes		Yes		Yes
Drop states w/ IT use & non-IT durable manufacturing				Yes		Yes		Yes
# of observations	714	616	560	518	714	518	672	504
# of states	51	44	40	37	51	37	48	36

Notes to Table 10: The dependent variable is productivity growth for state k, 1987-2000. The 'Post 1995' dummy equals 1 if t>1995, 0 otherwise. All estimates are weighted least squares. In column [1]-[4], weights are endogenously determined based on the size of the error term (robust standard errors in parentheses). In column [5] and [6], the same regressions as in column [1] and [4] are run taking the inverse of nominal output in 1987 as a weight (standard errors in parentheses). In column [7] and [8], the same regressions as in column [1] and [4] are run leaving Alaska, D.C. and Hawaii out of the sample (robust standard errors in parentheses).

Table 11: Dummy Variable Tests of Productivity Acceleration for IT-intensive states

Alternative indicators of IT intensity	Computers per household 1994 (IT Intensity>1)	Computers per household 1994 (IT Intensity>1)	Computers per household 1994 (IT Intensity>1)	Computers per household 1994 (IT Intensity>1)	Computers at work 1997 (IT Intensity>1)	Computers at work 1997 (IT Intensity>1)
	Robust std.errors	1/output87 as a weight	Robust std.errors Drop AK, DC, HI	1/output87 as a weight Drop AK, DC, HI	Robust std.errors	1/output87 as a weight
Constant	0.87***	0.51***	0.85***	0.46***	0.92***	0.68***
	(0.13)	(0.18)	(0.13)	(0.16)	(0.12)	(0.15)
IT intensity dummy	0.18	0.52**	0.30	0.72***	0.10	0.35
	(0.24)	(0.25)	(0.21)	(0.22)	(0.26)	(0.28)
Post-1995 Dummy	0.74***	0.96***	0.80***	1.06***	0.58***	0.63**
	(0.19)	(0.30)	(0.20)	(0.26)	(0.19)	(0.28)
(Post-1995 dummy) times	0.37	-0.36	0.58*	-0.11	0.86**	0.55
(IT intensity dummy)	(0.35)	(0.42)	(0.31)	(0.38)	(0.39)	(0.47)
Number of Observations	714	714	672	672	714	714
Number of States	51	51	48	48	51	51

Notes to Table 11: the dependent variable is productivity growth for state *s* for 1987 to 2000. The 'Post-1995' dummy equals 1 if t > 1995, 0 otherwise. In column [1] through [4], the IT intensity variable is measured as the ratio between the number of personal computers per household in state *s* and the number of PCs at the national level. In column [5] and [6], the same indicator is computed using the number of personal computers at work (per employed).

Table 12: Dummy-variable tests of productivity acceleration for groups of states 1977-2000

		Group dummies [1]	Group dummies 1/output87 as a weight [2]	Group dummies Drop AK, DC, HI [3]
IT production only	Constant	1.00***	1.13***	1.00***
		(0.19)	(0.25)	(0.19)
	Post-95 Dummy	1.99***	2.18***	1.99***
		(0.32)	(0.53)	(0.32)
IT use only	Constant	1.10***	1.03***	1.17***
		(0.17)	(0.34)	(0.18)
	Post-95 Dummy	0.22	-0.94	0.50
		(0.34)	(0.73)	(0.36)
Non-IT durables only	Constant	0.77***	0.76***	0.77***
		(0.13)	(0.21)	(0.13)
	Post-95 Dummy	1.03***	0.81	1.03***
		(0.22)	(0.47)	(0.22)
IT production & IT use	Constant	1.02***	0.66	1.22***
		(0.20)	(0.52)	(0.24)
	Post-95 Dummy	1.57***	0.57	2.04***
		(0.44)	(1.12)	(0.43)
IT production & non-IT durables	Constant	0.75***	1.08***	0.75***
		(0.20)	(0.32)	(0.20)
	Post-95 Dummy	2.14***	1.65**	2.14***
		(0.43)	(0.68)	(0.43)
IT use & non-IT durables	Constant	1.35	1.49***	1.26***
		(0.87)	(0.51)	(0.24)
	Post-95 Dummy	0.77***	2.04*	1.35
		(0.13)	(1.09)	(0.87)
Other states	Constant	0.71**	0.50**	0.80***
		(0.33)	(0.17)	(0.25)
	Post-95 Dummy	-0.08	0.29	0.37
		(0.50)	(0.36)	(0.40)
# of observations		1173	1173	1104
# of states		51	51	48

Notes to Table 12: The dependent variable is productivity growth for state k, 1977-2000. The 'Post 1995' dummy equals 1 if t>1995, 0 otherwise. All estimates are weighted least squares. In column [1], weights are endogenously determined based on the size of the error term (robust standard errors in parentheses). In column [2], the inverse of nominal output in 1987 is employed as a weight (standard errors in parentheses). In column [3], the same regression as in column [1] is run again leaving Alaska, D.C. and Hawaii out of the sample (robust standard errors in parentheses).

Cells shaded in light grey contain substantially different results (as to size and significance of the estimated coefficients) from those in Table 9

Table 13: Dummy-variable tests of productivity acceleration for groups of states 1987-2000, Retail trade among the IT-using sectors

		Group dummies [1]	Group dummies 1/output87 as a weight [2]	Group dummies Drop AK, DC, HI [3]
IT production only	Constant	1.32***	1.53***	1.32***
		(0.26)	(0.28)	(0.27)
	Post-95 Dummy	1.57***	1.55***	1.53***
		(0.34)	(0.47)	(0.34)
IT use only	Constant	1.03***	0.47	1.05***
		(0.27)	(0.26)	(0.30)
	Post-95 Dummy	0.34	0.58	0.59
		(0.38)	(0.43)	(0.40)
Non-IT durables only	Constant	0.66***	0.61**	0.66***
		(0.18)	(0.27)	(0.18)
	Post-95 Dummy	0.89***	0.78*	0.89***
		(0.24)	(0.45)	(0.24)
IT production & IT use	Constant	1.36***	1.40**	1.37***
		(0.33)	(0.67)	(0.44)
	Post-95 Dummy	1.32**	-0.27	2.36***
		(0.60)	(1.12)	(0.62)
IT production & non-IT durables	Constant	0.97***	1.22***	0.97***
		(0.22)	(0.36)	(0.22)
	Post-95 Dummy	1.70***	1.32**	1.70***
		(0.43)	(0.60)	(0.43)
IT use & non-IT durables	Constant	1.58***	1.73***	1.58***
		(0.24)	(0.53)	(0.24)
	Post-95 Dummy	1.31***	1.73**	1.31***
		(0.58)	(0.89)	(0.58)
Other states	Constant	0.20	-0.04	0.45
		(0.61)	(0.27)	(0.38)
	Post-95 Dummy	-0.57	0.12	-0.14
		(0.77)	(0.46)	(0.53)
# of observations		714	714	672
# of states		51	51	48

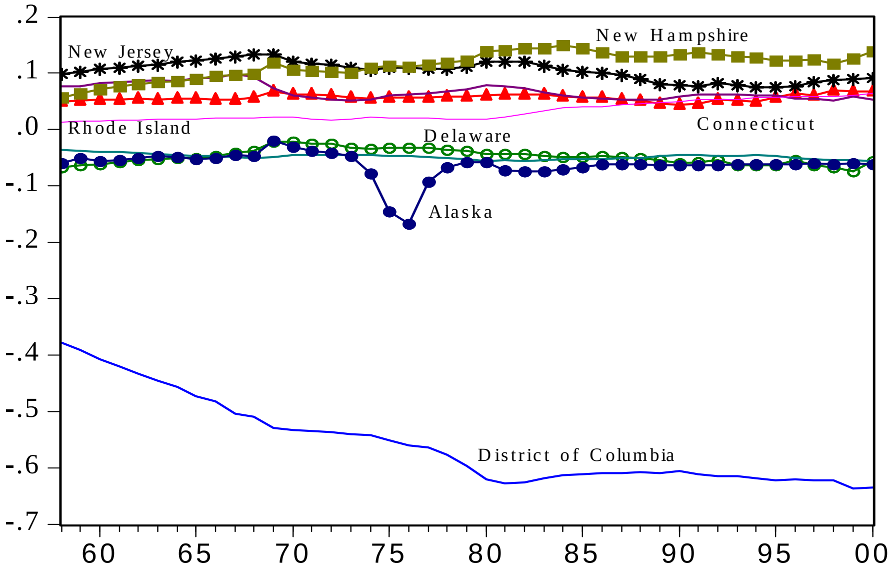
Notes to Table 13: The dependent variable is productivity growth for state k, 1987-2000. The 'Post 1995' dummy equals 1 if t>1995, 0 otherwise. All estimates are weighted least squares. In column [1], weights are endogenously determined based on the size of the error term (robust standard errors in parentheses). In column [2], the inverse of nominal output in 1987 is employed as a weight (standard errors in parentheses). In column [3], the same regression as in column [1] is run again leaving Alaska, D.C. and Hawaii out of the sample (robust standard errors in parentheses).

Cells shaded in light grey contain substantially different results (as to size and significance of the estimated coefficients) from those in Table 9

Table 14: Bootstrapping estimates

		1987-2000		
		[1] Standard Estimates	[2] Bias	[3] Bootstrapped estimates
IT production only	Constant	1.34*** (0.29)	-0.001	1.34*** (0.28)
	Post-95 Dummy	1.57*** (0.37)	-0.013	1.56*** (0.36)
IT use only	Constant	1.21*** (0.28)	0.002	1.21*** (0.29)
	Post-95 Dummy	0.05 (0.40)	-0.007	0.05 (0.40)
Non-IT durables only	Constant	0.67*** (0.17)	-0.003	0.66*** (0.17)
	Post-95 Dummy	1.01*** (0.24)	0.003	1.00*** (0.24)
IT production & IT use	Constant	1.30*** (0.28)	-0.001	1.30*** (0.27)
	Post-95 Dummy	1.27*** (0.48)	0.002	1.27*** (0.47)
IT production & non-IT durables	Constant	0.97*** (0.22)	-0.002	0.97*** (0.22)
	Post-95 Dummy	1.70*** (0.43)	-0.005	1.70*** (0.43)
IT use & non-IT durables	Constant	1.86*** (0.28)	0.026	1.83*** (0.30)
	Post-95 Dummy	0.89 (0.67)	0.010	0.88 (0.71)
Other states	Constant	0.14 (0.53)	0.006	0.13 (0.54)
	Post-95 Dummy	-0.15 (0.68)	0.002	-0.15 (0.70)
Repetitions			1000	
# of observations		714	713	

Notes to Table 14: The estimates in column [1] are those previously reported in **Table 9**, column [1]. In column [2], the bias of such estimates, calculated with bootstrapping techniques, is reported. In column [3], bootstrapped estimates are reported.



Ratio of adjustment by place of residence to total earnings by place of work, selected states, 1958-2000

Figure 1

Chart 1 IT production and use in the U.S. States, 1991-5

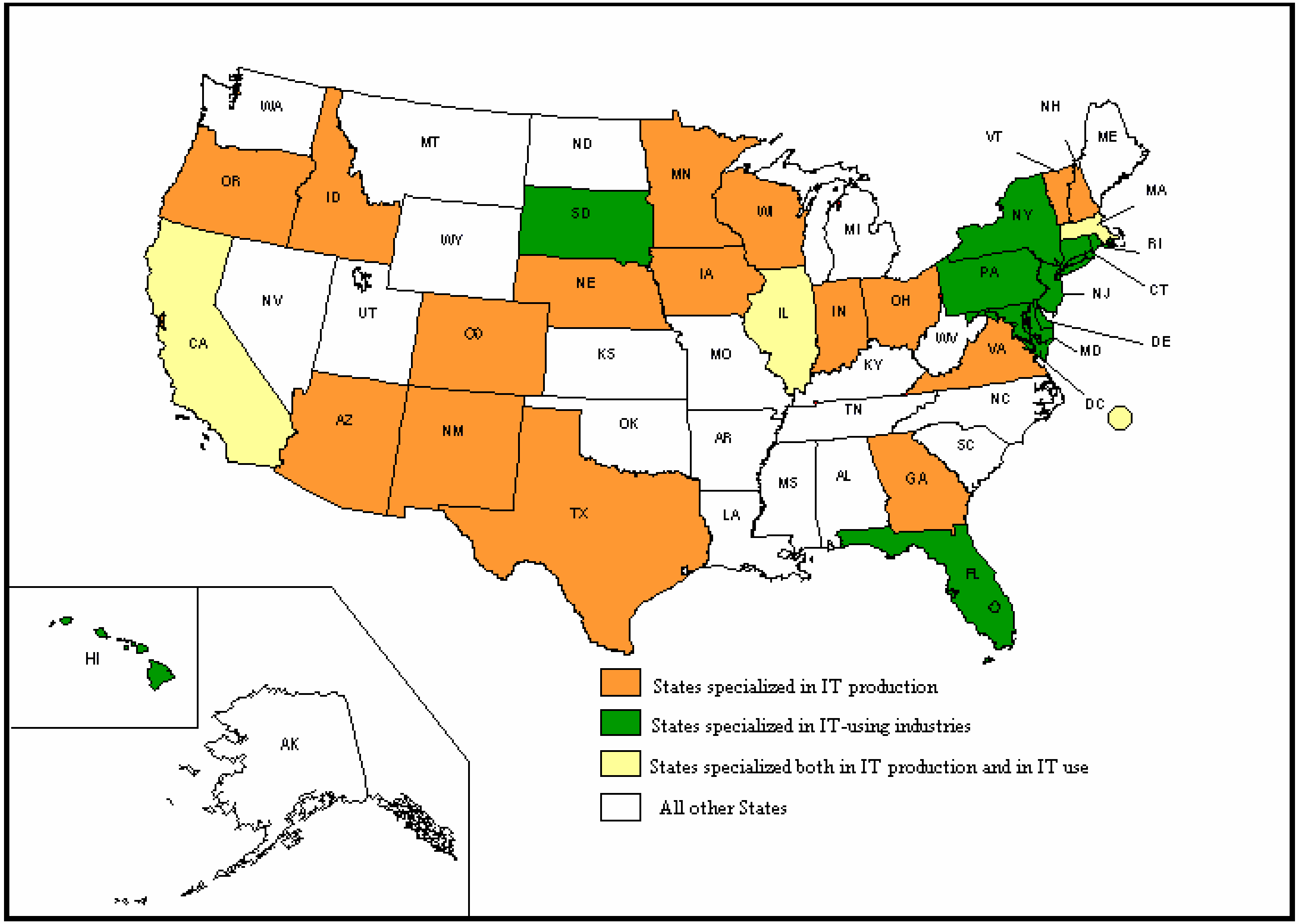


Chart 2 Production of durable goods manufacturing in the U.S. States

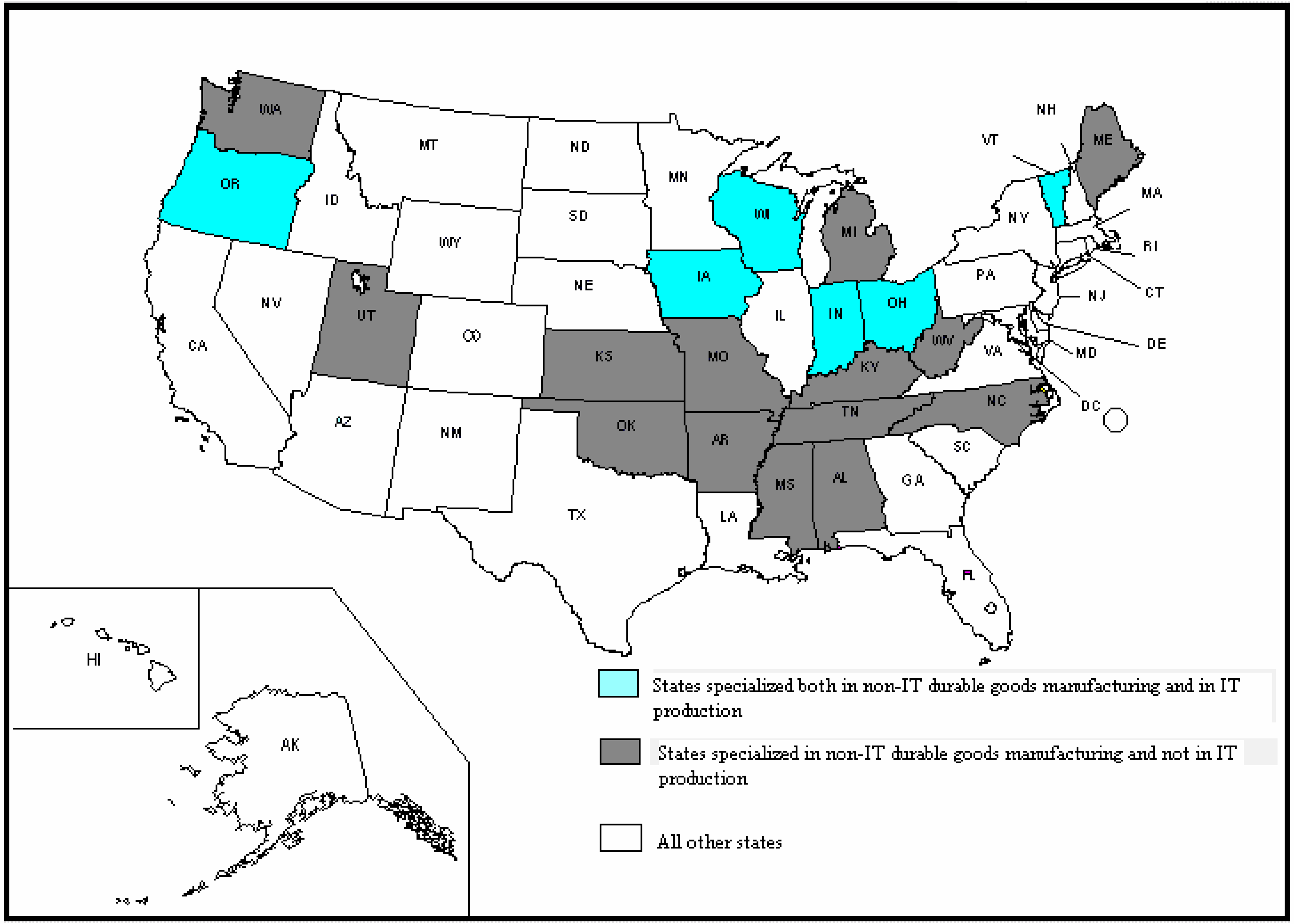


Chart 3 Computer use per household in the U.S. States

Chart 4 Acceleration in labor productivity growth, 1996-2000 vs. 1987-95