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You Say You Want A Revolution: Information Technology and Growth

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You Say You Want A Revolution: Information Technology and Growth

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Abstract

The information technology (IT) revolution has arrived, but how much will it change the world? It has been established that IT is contributing to labor productivity growth through both increases in the levels of IT capital per worker and total factor productivity (TFP) growth in the production of IT equipment. The main outstanding issue is whether IT is contributing to TFP growth more generally. Using data on IT expenditure and production for a broad sample of countries, we find a positive, large, and significant effect of IT expenditure on the acceleration in TFP in the late 1990s and a smaller—and significant—effect of IT production. We also find evidence that the impact of IT expenditure on TFP growth increases over time, suggesting that spillovers materialize gradually. Our results suggest that the increase in IT expenditure across industrial countries during 1995–2000 will eventually lead to an average increase in TFP growth of about one–third of 1 percent per year.

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I. Introduction

You say you want a revolution,
well, you know,
we all want to change the world.
—John Lennon, "Revolution" (1968)

The world is in the midst of an all-purpose technological revolution based on information technology (IT). At the core of the current IT revolution are increases in the power of semiconductors, which have led to rapidly declining semiconductor prices. Over the past four decades, the capacity of semiconductor chips has doubled roughly every 18-24 months. Cheaper semiconductors have allowed rapid advances in the production of computers and telecommunications equipment, leading to steep price declines in these industries as well. The rapidly falling prices of goods that embody IT have stimulated extraordinary investment in these goods, resulting in significant capital deepening. Moreover, the adoption and use of IT may be encouraging changes in the organization of production, which could lead to further increases in productivity growth.

Information technology (IT) can contribute to labor productivity growth through capital deepening, through increases in total factor productivity within the IT sector, and through increases in TFP across the economy. The analysis of past episodes of rapid technological change presented in the IMF's *World Economic Outlook* (October 2001) suggests that the impact of technological revolutions on labor productivity growth has generally occurred in three main stages. First, technological change raises growth in the innovating sector; second, falling prices for the new types of equipment produced by the innovating sector encourage capital deepening in the economy at large; and, finally, there can be significant reorganization of production around the capital goods that embody the new technology.

The existing literature on the impact of IT on labor productivity growth, which is largely based on growth accounting, has established that IT is contributing to labor productivity growth through both increases in the levels of IT capital per worker ("IT-related capital deepening") and TFP growth in the production of IT equipment, though the precise magnitudes of these contributions remain a subject of debate (Section II). The main outstanding issue is whether IT has contributed to TFP growth more generally by increasing the efficiency of production, either through usage or knowledge spillovers from the production of IT goods. While Brynjolfsson and Hitt (2000) and Litan and Rivlin (2000) provide microeconomic evidence of productivity gains associated with the invention of new processes, procedures, and organizational structures that leverage, there is as yet little macroeconomic evidence of an increase in generalized TFP growth.

The primary objective of this paper is to assess the cross-country evidence on the impact of the IT revolution on generalized TFP growth. Inspired by Marquez (2001), our approach is to examine the relationship between TFP growth and various measures of IT usage and production, using cross-section and panel regressions (Section III).[2] We have gathered data on expenditure on and production of electronic data processing (EDP) equipment for 20 industrial countries.

We find that both the production of and expenditure on EDP equipment are associated with a substantial increase in TFP growth (Section IV). The magnitude of the impact is large compared with previous (growth-accounting based) estimates, which did not (and could not) take into account the impact of IT on generalized TFP growth. We also find that the impact of IT expenditure on TFP growth increases over time, suggesting that spillovers materialize gradually.

II. Literature Review

Much of the existing literature on the impact of the IT revolution on labor productivity growth finds that IT-related capital deepening and TFP growth in IT production made important contributions to the acceleration in labor productivity in the late 1990s. This literature consists mostly of growth accounting exercises and broadly follows the pioneering studies on the United States. The literature can be divided into two main parts: country-specific studies and cross-country studies.

Recent studies of the impact of IT on growth in the United States indicate that IT accounted for an increase in labor productivity growth of 1–1½ percent annually during the late 1990s (Table 1). The studies agree that IT capital deepening played a substantial role, and that this has been offset to some extent by a deceleration of non-IT-related investment. A second major component of the acceleration in labor productivity is productivity gains in the IT sector. However, there is no consensus on the effect of IT on generalized TFP growth. The debate focuses on whether the remainder of the acceleration reflects cyclical factors or an increase in underlying TFP growth, and the extent to which this acceleration in underlying TFP growth reflects IT. Gordon (2000 and 2002) attributes about ½ percent acceleration in labor productivity to cyclical factors, while U.S. Council of Economic Advisers (2001) views this acceleration as structural.[3] Basu, Fernald, and Shapiro (2001) find that little of the acceleration in labor productivity is due to changes in factor utilization, factor accumulation, or returns to scale, while Stiroh (2001) finds that virtually all of the acceleration is accounted for by IT-using and IT-producing industries. Thus, while IT-related capital deepening and productivity growth within the IT sector appear to have a significant impact on aggregate labor productivity growth,

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[2] To our knowledge, Marquez (2001) was the first to explore the cross-country evidence on the impact of the IT revolution on generalized TFP growth. Compared to that paper, we have a broader sample of countries, we have data on both IT expenditure and production, and we use both cross-section and panel regressions.

[3] The other two studies in Table 1 do not distinguish cyclical effects.

the evidence on whether the use of IT has already resulted in an increase in economy-wide TFP is mixed for the United States.

Table 1. Acceleration of Labor Productivity in the United States

	Gordon, 2002	U.S. CEA, 2001	Jorgenson and Stiroh, 2000	Oliner and Sichel, 2000
Period under study	1995–2000	1995–2000	1995–1999	1995–1999
		(percentage points)		
Acceleration	1.44	1.63	0.95	1.16
Capital deepening				
IT-related	0.60	0.62	0.34	0.50
Other	-0.23	-0.23	-0.05	-0.17
Labor Quality	0.01	0.00	0.01	0.04
TFP				
IT-related	0.30	0.18	0.24	0.31
Other	0.22	1.00	0.41	0.49
Contribution of Price Measurement	0.14	n.a.	n.a.	n.a.
Cyclical Effect	0.40	0.04	n.a.	n.a.

Australia has also seen an acceleration in labor productivity in the 1990s. Using data released by the Australian Bureau of Statistics, Cardarelli (2001) finds that IT-related capital deepening and generalized TFP growth played important roles in the acceleration in labor productivity. In particular, IT-related capital deepening increased rapidly during the 1990s, accounting in recent years for about two-thirds of the growth contribution of capital deepening. The case of Australia is instructive, as domestic IT production is very small. Thus, the productivity gains associated with IT need not arise to economies that are IT producers themselves.[4] Cardarelli also finds some evidence across Australian industries of a positive relationship between IT-related capital deepening and TFP growth, which would be consistent with the idea that increased IT use has been associated with a reorganization of economic activities.

In most other advanced economies, labor productivity has not accelerated in recent years, implying that any positive contribution of IT must have been offset elsewhere. In Japan, labor productivity growth did not increase during the 1990s, despite relatively high levels of overall and IT-related capital deepening. An official study by Japan's Economic Planning

[4] See Bayoumi and Haacker (2001) for a broader discussion of this point.

Agency (2000) finds that the contribution of IT-related capital deepening to growth increased by about ½-¾ percentage points between the early and late 1990s. However, the contribution of non-IT-related capital deepening declined by a corresponding amount. In France, labor productivity growth fell in the second half of the 1990s. Estevao and Levy (2000) attribute this fall to a decline in overall capital deepening, reflecting reduced investment in labor-saving equipment as wage growth remained moderate.[5] Although overall capital deepening fell, the contribution of IT-related capital deepening to growth increased from zero to ¼ percent. In the United Kingdom, labor productivity has not accelerated, despite a rate of investment in IT capital that is almost as high as in the United States. Kodres (2001) finds that the contributions of IT-related capital deepening and TFP growth in IT production to labor productivity growth in the late 1990s were offset by decreases in TFP growth outside of the IT sector.[6]

Cross-country studies also find that IT-related capital deepening and TFP growth in IT production contributed to labor productivity growth in the second half of the 1990s. Colecchia (2001), Daveri (2001), Roeger (2001), and Schreyer (2000) estimate the contribution of IT-related capital deepening using the conventional growth accounting framework, while Lee and Pilat (2001) and Van Ark (2001) focus on the role played by IT-using (and IT-producing) sectors.

Table 2 summarizes estimates of the impact of IT-related capital deepening on economic growth. The contribution of investment in IT-related equipment to growth is substantial, ranging from ¼–½ percentage point annually for Canada, France, Germany, Italy, and Japan to between ¾–1 percentage points for the United States. Given the rapid fall in the relative price of IT capital equipment, its contribution to the growth of the capital stock exceeds its nominal share in investment. For example, Colecchia (2001) finds that falling prices of capital goods accounted for about one third of the real growth of the capital stock in the United States between 1995–99.

An alternative measure of the economic impact of information technology is the contribution of the IT-producing and IT-intensive sectors to economic growth through capital deepening. In other words, the contribution of IT is measured as overall capital deepening by IT-related sectors, rather than the IT-related capital deepening of all sectors. Along these lines, the findings of Van Ark (2001) are reported in Table 3. This study suggests that industries producing IT equipment or industries using IT equipment intensively contributed between ½–1 percentage points to economic growth. For most G-7 economies, the contribution of IT-using sectors is much stronger than the contribution of the IT-producing sector.

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[5] Mairesse et al (2000) also use aggregate data to assess the impact of IT on labor productivity growth and gets similar results. Using micro data, Crépon and Heckel (2000) find a somewhat larger impact of IT on labor productivity growth.

[6] See also Oulton (2001).

Table 2. Contribution of IT-Related Capital Deepening to GDP Growth in the G-7 Economies

	Colecchia (2001), 1995–99	Daveri (2001), 1991–99	Roeger (2001), 1995–1999
	(percentage points)		
Canada 1/	0.4	...	...
France	0.4	0.4	0.3
Germany 2/	0.3	0.5	0.3
Italy	0.3	0.3	0.3
Japan	0.3	...	...
United Kingdom	...	0.8	0.4
United States	0.9	0.9	0.7

Note: Colecchia (2001) and Daveri (2001) refer to business sector growth, while Roeger (2001) uses GDP growth. In addition to computers and telecommunications equipment, Colecchia (2001) and Daveri (2001) include software, while Roeger (2001) includes semiconductors.
1/ The Colecchia (2001) estimate excludes software.
2/ The Daveri (2001) estimate refers to 1992–1999 only.

Table 3. Contribution of Capital Deepening in IT-Related Industries to GDP Growth, 1990–98

	Real GDP Growth	Contribution of IT-Related Industries		
		Total	IT-Using	IT-Producing
	(percent per year)			
Canada	2.1	0.8	0.6	0.2
Denmark	1.8	0.5	0.3	0.2
Finland	1.6	0.7	0.0	0.7
France	1.3	0.5	0.2	0.3
Germany	1.1	0.5	0.4	0.1
Italy	1.4	0.7	0.5	0.2
Japan	1.4	0.8	0.5	0.3
Netherlands	2.5	1.0	0.7	0.3
United Kingdom	2.1	1.0	0.6	0.4
United States	3.2	1.4	0.9	0.5

Source: Van Ark (2001). For Germany, the numbers refer to 1991–97

III. Methodology and Data

Our objective is to analyze the link between the acceleration of TFP growth in the late 1990s and various measures of IT-related activities. In other words, we focus explicitly on trying to explain the behavior of generalized TFP growth. By contrast, much of the existing literature addresses IT-related capital deepening and productivity gains in the IT-producing sector. These growth accounting exercises—by construction—cannot attribute generalized TFP growth (the residual) to any particular type of expenditure or production. We get around this problem by using cross-section and panel regressions to exploit the cross-country variation in TFP growth and IT-related activities. A potential methodological problem is that IT expenditure and production could be correlated with the business cycle and thus with cyclical fluctuations in TFP. To get around this problem, we use the beginning-of-period values for IT expenditure and production as explanatory variables.

We use data on IT expenditure and production from the *Yearbook of World Electronics Data*, compiled by Reed Electronics Research. The database provides annual data in U.S. dollar terms, starting in 1985. Data on electronic data processing (EDP) equipment cover computers, peripherals, accessories, and parts. However, there is one problem with the Reed expenditure data: the reported values are implausibly high for some of the main exporters of these goods (e.g. 8 percent of GDP for Singapore), which probably reflects misclassification of exports as domestic sales. We therefore adjust the expenditure data using data from *Digital Planet*, published by the World Information Technology Services Alliance (which covers only 1992–99 and does not have production data). For 1992–99, adjusted EDP expenditure is taken from WITSA, but scaled by a common factor for each year so that total adjusted EDP expenditure equals the total EDP expenditure from the Reed database.[7] For the years 1985–1991 and 2000, the data are taken from Reed, but scaled for each country, using the ratio of adjusted expenditure to expenditure as reported in Reed for 1992 (for the years 1985–91) or 1999 (for 2000). Finally, EDP production and adjusted EDP expenditure are specified as a percentage of GDP. In principle, the relationship between IT and growth could involve either the *level* of IT activities or the *increase* in IT activities. So, in the empirical work, we use both the average levels of EDP expenditure and production and the changes in EDP expenditure and production.

Data on TFP growth are based on the IMF World Economic Outlook database, which includes series on real GDP, real gross fixed investment, and the labor force. The capital stock series were constructed using the perpetual inventory method, assuming a depreciation rate of 6 percent. Total factor productivity growth was then calculated as

$$\hat{TFP} = \hat{RGDP} - \alpha\hat{K} - (1-\alpha)\hat{L}$$

[7] This scaling ensures that the adjusted expenditure data are comparable with the production data.

where "^" indicates a rate of growth. *RGDP*, *K*, and *L* stand for real GDP, the capital stock, and the labor force, respectively. The parameter α, indicating the elasticity of output with respect to capital, is set equal to 0.35.[8] The dependent variable in our empirical work is the change in average TFP growth between specified periods.

Differences in national accounting procedures could give rise to systematic biases in the measurement of TFP growth. Specifically, countries that do not use hedonic price indices for IT goods tend to understate real investment and real output relative to countries where such methods are used. The effect on TFP growth is ambiguous. Separately, countries that use fixed- (as opposed to chain-) weight aggregation methods tend to overstate real GDP growth, reflecting substitution bias. To address these two possible biases, we included dummy variables in the regressions for whether national accounts used hedonic prices or chain weighting. In practice, the coefficients on these dummy variables were small and nowhere near statistical significance. This result is consistent with Schreyer (2001), who finds that the overall impact of using hedonic prices and chain weighting on real GDP across industrial countries is small.

Our main sample consists of 20 industrial countries (the "OECD" sample): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States. As a sensitivity check, we also run the regressions for a sample of more homogeneous European countries (the "Europe" sample), which excludes Australia, Canada, Japan, and the United States.

Table 4 summarizes some of the key characteristics of the data. Across industrial countries, TFP accelerated by about 0.2 percent between 1985–1995 and 1996–2000, though the standard deviation is quite large (about 0.1 percent). EDP expenditure averaged almost 1 percent of GDP between 1985–95, while EDP production averaged about ¾ percent of GDP. Both EDP expenditure and EDP production (as a share of GDP) on average actually fell slightly between 1985–95 and 1996–2000.[9] The correlation matrix shows that the simple correlation between the change in TFP growth and the change in EDP expenditure is quite high (about ½), while the correlation between EDP expenditure and production is rather low (about 0.1).

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[8] Under constant returns to scale and perfect competition, the elasticity of output with respect to capital is equal to the share of capital in national income. However, the share of capital in national income is not available for some of the countries covered, and available data are not easily comparable across countries. Therefore, α has been set equal to 0.35 across countries, close to the average share of capital in national income for which these data are available. Regressions based on data using the reported capital shares to approximate α for each country yield very similar results.

[9] Since the price of EDP equipment fell, real expenditure and production rose considerably.

Table 4. Key Data Characteristics

	Mean	Standard Deviation
	(percent of GDP)	
Change in TFP growth, 1985–1995 to 1996–2000 (percent)	.18	.09
EDP expenditure, 1985–1995	.93	.29
EDP production, 1985–1995	.76	.17
Change in EDP expenditure, 1985–1995 to 1996–2000	–.04	.34
Change in EDP production, 1985–1995 to 1996–2000	–.04	.34

Correlation Matrix	ΔTFP	edpexp	edpprod	Δedpexp	Δedpprod
Change in TFP growth	1.00	.16	.03	.49	.28
EDP expenditure	.16	1.00	.11	-.25	-.18
EDP production	.03	.11	1.00	.09	-.19
Change in EDP expenditure	.49	-.25	.09	1.00	.08
Change in EDP production	.28	-.18	-.19	.08	1.00

Note: See text for variable definitions.

IV. Results

Our main result is that larger IT-related activities are associated with an acceleration in TFP. First, we estimate cross-section regressions linking the change in TFP growth to both the average levels of EDP expenditure and production and the changes in EDP expenditure and production. We find a positive, large, and significant relationship between the increase in EDP expenditure and the acceleration in TFP. The link between the level of EDP expenditure and the acceleration of TFP is positive but insignificant, while the coefficient on EDP production is very small and insignificant (Table 5, columns 1–2). For both the OECD and for Europe, the increase in IT activities is more powerful in explaining changes in TFP growth (columns 3–4). The change in EDP expenditure appears to matter more than the change in EDP production, which has a smaller coefficient and is not significant on a 5 percent level. If both the levels of and changes in IT variables are included in the regression, the coefficients stay largely the same, and neither dominates (columns 5–6).

Table 5. Cross-Section Results

	OECD	Europe	OECD	Europe	OECD	Europe
edpexp	0.94 (1.29)	0.79 (0.95)			**1.19** **(1.84)**	1.13 (1.52)
edpprod	0.03 (0.23)	0.06 (0.39)			-0.14 (0.68)	-0.20 (0.76)
Δ edpexp			**1.29** **(2.37)**	**2.33** **(1.86)**	**1.38** **(2.42)**	2.06 (1.41)
Δ edpprod			0.66 (1.23)	0.77 (1.29)	1.25 (1.53)	1.61 (1.45)
Observations	20	16	20	16	20	16
R-square	0.09	0.07	0.31	0.32	0.44	0.46

Note: The dependent variable is the change in TFP growth between 1985–95 and 1996–2000. The numbers in parentheses are absolute values of the t statistics. Bold numbers indicate estimates that are significant at the 5 percent level (in a one-sided test).

To interpret the magnitudes of the coefficients, we can assess the implications of *recent* changes in EDP expenditure and production. Between 1995 and 2000, EDP expenditure in industrial countries increased on average by about ¼ percent of GDP and EDP production increased by about 0.1 percent of GDP. Our results (Table 5, col. 5) indicate that this increase in IT-related activities would eventually be associated with an increase in TFP growth of ⅓ percent.[10] In the United States, where EDP expenditure increased by somewhat more, the increase in TFP growth would be closer to ½ percent. This compares with estimates of the impact of capital deepening on labor productivity growth in the United States of about ¼ to ½ percent, and of TFP growth in IT production of about ¼ percent (Table 1). Thus, these results that information technology can have an important effect on labor productivity growth through generalized TFP, as well as through other channels. The impact of information technology also compares favorably with the effect of the adoption of electricity, which is estimated to have had a peak impact on TFP growth in the United States (during 1919–29) of about ¾ percent (IMF, 2001).

As a robustness check, we add GDP per capita relative to the United States ("gdppc") to the cross-section regression. The rationale is that, because GDP per capita is positively correlated with EDP expenditure (as a ratio to GDP), the estimates of the impact of IT activities on TFP growth could simply reflect differences in income levels (i.e. TFP accelerated more in richer countries). We are also interested in whether IT has a differential impact depending on GDP per capita, so we include an interaction term.

[10] For the medium run (here: a 10-year horizon), the positive coefficients of the change in IT-related activities in Table 5 suggest that the effect on TFP growth could be higher.

Table 6. Cross-Section Results with GDP Per Capita

	OECD	Europe	OECD	Europe	OECD	Europe
edpexp	0.37 (0.43)	0.27 (0.26)				
edpprod	-0.05 (0.24)	-0.11 (0.39)				
Δ edpexp	**1.57** **(2.74)**	2.07 (1.43)	**1.60** **(3.25)**	**2.30** **(2.07)**	**1.73** **(3.45)**	**2.49** **(2.17)**
Δ edpprod	1.15 (1.44)	1.45 (1.31)	**1.01** **(2.03)**	**1.10** **(1.99)**	**1.02** **(2.07)**	**1.09** **(1.96)**
gdppc	1.19 (1.36)	1.13 (1.12)	**1.46** **(2.48)**	**1.33** **(2.12)**	-0.07 (0.05)	0.06 (0.04)
gdppc∗(Δ edpexp)					1.06 (1.15)	0.89 (0.83)
Observations	20	16	20	16	20	16
R-square	0.51	0.52	0.50	0.51	0.54	0.54

Note: The dependent variable is the change in TFP growth between 1985–95 and 1996–2000. The numbers in parentheses are absolute values of the t statistics. Bold numbers indicate estimates that are significant at the 5 percent level (one-sided test).

We find that the large, positive, and significant relationship between IT and growth is robust to the inclusion of GDP per capita in the regression. The estimates reported in Table 6 (columns 1–2) show that TFP growth did accelerate more in higher-income economies. Moreover, the positive association between the change in TFP growth and the *level* of EDP expenditure suggested in Table 5 appears to reflect in part differences between higher-and lower-income economies. If GDP per capita is included in the regression, this positive association almost disappears, whereas the coefficients on the increase in IT-related activities barely change. If the *levels* of IT-related activities are excluded, the coefficients of the remaining variables change little, but the respective t-ratios increase considerably (columns 3–4). In columns 5–6, the coefficient on the interaction term is positive, while the coefficient on GDP per capita vanishes as a result, suggesting that higher-income countries have had more success in adopting EDP equipment. In other words, TFP appears to have accelerated more in higher income countries, plausibly reflecting the fact that they were better positioned to realize the efficiency gains associated with using IT.

Next, we estimate panel regressions to exploit both the cross-sectional and cross-time variation in TFP and IT-related variables. As we now use annual data, business cycle effects are a greater concern. To address this potential problem and the possibility that the impact of IT activities on TFP growth may not be immediate, TFP growth is related to the average IT-related activities in the *preceding* 3-, 5-, or 7-year periods. In addition, all regressions include fixed time effects.

Table 7. Panel Results

	Lag = 3		Lag = 5		Lag = 7	
	OECD	Europe	OECD	Europe	OECD	Europe
edpexp	0.46	0.35	**0.90**	**1.00**	**1.35**	**1.62**
	(1.57)	(0.93)	**(2.37)**	**(2.06)**	**(3.54)**	**(3.51)**
edpprod	**0.22**	**0.23**	**0.23**	**0.24**	**0.23**	**0.26**
	(4.26)	**(4.07)**	**(3.52)**	**(3.43)**	**(3.68)**	**(3.92)**
gdppc	**-0.90**	-0.71	**-1.11**	**-0.97**	**-1.29**	**-1.13**
	(2.74)	(1.79)	**(2.71)**	**(1.94)**	**(3.22)**	**(2.42)**
Observations	260	208	220	176	180	144
R-square	0.24	0.25	0.24	0.25	0.31	0.38
F-test	1.77	1.72	2.00	1.99	2.98.	3.04

Note: The dependent variable is TFP growth. The numbers in parentheses are absolute values of t statistics. Bold numbers indicate coefficient estimates that are significant at the 5 percent level (in a one-sided test). The F-test applies to the restriction that the coefficients on *edpexp* and *edpprod* are equal across countries.

The panel results confirm that IT activities have a large, positive, and significant impact on TFP growth and provide evidence that the impact of IT usage on TFP growth grows over time. The first row of Table 7 shows that the coefficients on EDP expenditure rise substantially as the lag length increases. Thus, EDP expenditure appears to have a strong and growing impact on TFP growth. EDP production has a positive coefficient in all regressions, though it is smaller than the impact of EDP usage. The coefficient does not change as the lag length increases, suggesting that the impact of IT production on TFP growth materializes quickly and is persistent. The coefficient on GDP per capita consistently takes a negative value, suggesting technological catching-up. The F-tests reject the hypothesis that the coefficients on EDP expenditure and production are equal across countries.

As a robustness check, we run the panel estimation with fixed country effects (and thus lose the cross-country variation in TFP growth and IT-related activities). While the pattern of the coefficients on IT-related activities in Table 8 is ambiguous and less consistent than for the estimates reported in Table 7, some features are similar. For example, the coefficients on IT production (i.e. its deviation from the respective country's average) are consistently positive, although the value is less stable over time than for the earlier regression. Overall, the additional evidence for IT-related spillovers from Table 8 is weak.

Table 8. Panel Results with Fixed Country Effects

	Lag = 3		Lag = 5		Lag = 7	
	OECD	Europe	OECD	Europe	OECD	Europe
edpexp	0.06	-1.30	0.15	0.16	-0.87	2.78
	(0.09)	(1.28)	(0.17)	(0.10)	(0.79)	(1.35)
edpprod	**1.23**	**1.35**	**2.11**	**2.36**	1.83	1.59
	(2.38)	**(2.48)**	**(2.43)**	**(2.57)**	(1.47)	(1.23)
gdppc	**-11.94**	**-11.42**	**-14.79**	**-14.82**	-4.88	-4.96
	(7.36)	**(6.55)**	**(6.16)**	**(5.80)**	(1.64)	(1.63)
Observations	260	208	220	176	180	144
R-square	0.43	0.25	0.43	0.44	0.52	0.56
F-test	1.02	0.94	0.92	0.86	1.83	2.12

Note: The dependent variable is TFP growth. The numbers in parentheses are absolute values of t statistics. Bold numbers indicate coefficient estimates that are significant at the 5 percent level (in a one-sided test). The F-test applies to the restriction that the coefficients on *edpexp* and *edpprod* are equal across countries.

V. Conclusions

The IT revolution has arrived, but how much will it change the world? Previous empirical work on the impact of IT on growth has established that IT has contributed to labor productivity growth through both increases in the levels of IT capital per worker and TFP growth in the production of IT equipment. The main outstanding issue is whether IT has contributed to TFP growth more generally. Using data on expenditure on and production of EDP equipment for 20 countries over 1985–2000, we employ cross-section and panel regressions to examine the impact of IT on generalized TFP growth.

We find a positive, large, and significant effect of IT expenditure on the acceleration in TFP growth in the late 1990s, and a smaller—and significant—effect of IT production. This relationship is robust to the inclusion of GDP per capita in the regression. Our results also indicate that TFP growth accelerated more in higher income countries, suggesting that they were better at realizing the efficiency gains associated with using IT. Finally, we find evidence that the impact of IT expenditure on TFP growth increases over time, suggesting that spillovers materialize gradually. One important caveat to our results is that, despite our efforts to avoid simultaneity by using beginning-of-period IT variables, we may not have been fully successful in stripping out the cyclical effect (the fact that the expansion of the late 1990s was associated with both higher TFP growth and higher IT expenditure).

Our results suggest that the average actual increase in IT expenditure across industrial countries between 1995–2000 will eventually lead to an increase in generalized TFP growth of about $^{1}/_{3}$ percent per year, though we cannot say how long these higher rates of TFP growth will last.[11] In the United States, which experienced a higher-than-average increase in IT expenditure, the increase in TFP growth would be closer to ½ percent per year, compared to estimates of the impact of IT on capital deepening of about ¼ to ½ percent per year and on TFP growth within the IT sector of about ¼ percent per year. In other words, the gains in overall economic efficiency associated with the IT revolution are substantial—similar in magnitude to the gains from the reorganization of production experienced during the adoption of electricity in the early 20th century.

[11] IT production as a percentage of GDP stayed approximately constant across OECD countries between 1995 and 2000.

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