Information Technology and Productivity: Where Are We Now and Where Are We Going?

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Introduction

- Growth of labor productivity picked up in the second half of the 1990s.

- Using data through 1999, our paper in the *Journal of Economic Perspectives* attributed about two-thirds of the pickup to the use and production of IT capital.

- This paper updates the results in our *JEP* paper and engages in some "structured guessing" about the pace of productivity growth going forward.

Main Empirical Findings

- Data through 2001 continue to show that the use and production of IT capital have made a large contribution to the acceleration of labor productivity since 1995.

- However, the contribution from use of IT capital likely will shrink somewhat in 2002, reflecting the slowdown in investment.

- We use steady-state analysis to estimate a lower bound for labor-productivity growth over the longer term. This analysis points to roughly 2 percent per year as a reasonable lower bound.

Model

- Four sectors produce final goods and services:
  - Computer hardware
  - Software
  - Communication equipment
  - Rest of nonfarm business
- Within each sector, output is a mix of investment goods and consumption items.
- Semiconductors are explicitly modeled as an input to each final-output sector.
- Intensity of semiconductor use varies across sectors, as does the rate of MFP growth. Otherwise, production functions are the same across sectors.
- Impose usual neoclassical assumptions:
  - Perfect competition in all markets
  - Constant returns to scale
  - No adjustment costs
  - Realized returns to capital equal expected returns.

Key Theoretical Results

Growth in Aggregate Labor Productivity

- $\underline{Y} - \underline{L} = \Sigma_i \, a_{K,i}(\underline{K}_i - \underline{L}) + a_L \underline{q} + M\underline{F}P$

- The a's are income shares.

- Standard result: Labor-productivity growth equals contributions from capital deepening, labor quality (q), and MFP.

Growth in Aggregate MFP

- $M\underline{F}P = \mu_S \, M\underline{F}P_S + \Sigma_i \, \mu_i \, M\underline{F}P_i = \Sigma_i \, \mu_i \, (M\underline{F}P_i + ß_{i,S} \, M\underline{F}P_S)$
- The μ's are current-dollar ratios of sectoral output to total final output; the ß's are semiconductor cost shares in the final-output sectors.

- Standard "Domar" weighting. Aggregate MFP growth equals a share-weighted average of sectoral MFP growth, with an adjustment for MFP gains in producing intermediate inputs (here, only semiconductors).

- In effect, the Domar scheme vertically integrates semiconductors with each final-output sector.

Steady-State Growth

- Conditions imposed to derive steady-state growth:

- Output in each sector grows at a constant rate (which differs across sectors).

- For each type of capital, investment and capital stock grow at the same rate (which differs across types of capital).

- Labor input grows at the same rate in every sector.

- All current-dollar shares are constant.

➢ Our model extends recent work on steady-state growth in two-sector models (e.g., Martin (2001) and Whelan (2001))

➢ Key result:

$$\underline{Y} - \underline{L} = \Sigma_i (a_{K,i} / a_L)(M\underline{F}P_i + ß_{i,S}\, M\underline{F}P_S) + \underline{q} + M\underline{F}P$$

➢ Shows that labor-productivity growth equals growth in MFP and labor quality, plus capital deepening induced by MFP growth.

➢ Extends result from the standard, one-sector model:

$$\underline{Y} - \underline{L} = (a_K / a_L)M\underline{F}P + \underline{q} + M\underline{F}P = \underline{q} + (M\underline{F}P/a_L)$$

Data and Empirical Strategy

➢ We rely heavily on data from BLS and BEA. These data provide measures of real output, capital input, labor input,

and prices for the nonfarm business sector.

- Our dataset runs through 2001:Q3 and incorporates the July 2001 revision of the National Income and Product Accounts.

- As in our *JEP* paper, we use the "dual" method to compute sectoral MFP growth.

  - The "dual" measures MFP growth as the difference between growth in a sector's input costs and its output price. For example:

    $MFP_1 = Cost_1 - p_1$

    $MFP_2 = Cost_2 - p_2$

  - We use data on differences in sectoral price inflation, assuming semiconductor usage is the only source of differences in cost growth. For example:

    $MFP_1 - MFP_2 = (Cost_1 - Cost_2) - (p_1 - p_2)$

Empirical Results

We address the following questions:

- Do the latest data still support the basic story in our *JEP* paper? (Tables 1 and 2)

- How is the growth contribution from IT capital deepening likely to evolve in 2002? (Table 3)

- What is a reasonable range of estimates for steady-state growth in labor productivity? (Table 4 and associated text)

Table 1
Contributions to Labor Productivity Growth, Using Latest Data

		1991-1995	1996-2001	Change
1. Growth of labor productivity[1]	1.54	2.40	.86	
Contributions from:[2]				
2. Capital deepening		.51	1.17	.66
3. IT capital		.48	1.04	.56
4. Computer hardware		.20	.53	.33
5. Software		.23	.38	.15
6. Communication equipment	.05	.12	.07	
7. Other capital		.03	.14	.11
8. Labor quality		.44	.31	-.13
9. Multifactor productivity		.59	.92	.33
10. Semiconductors		.13	.42	.29
11. Computer hardware		.13	.18	.05
12. Software		.09	.10	.01
13. Communication equipment	.02	.00	-.02	
14. Other sectors		.22	.23	.01

1. In nonfarm business sector. Measured as average annual log difference for years shown multiplied by 100.
2. Percentage points per year.
Note: Detail may not sum to totals due to rounding.
Source: Authors' calculations based on BEA and BLS data.

Table 2
Acceleration in Labor Productivity between 1991-95 and Post-1995 Period, Effect of New Data and Revisions

		JEP Paper Through 1999	*JEP* Paper Through 2001	This Paper
1. Acceleration in labor prod.[1]			1.04	.86
Contributions from:[2]				
2. Capital deepening			.48	.66
3. IT capital			.45	.56
4. Computer hardware			.36	.33
5. Software			.04	.15
7. Communication equipment	.05		.07	
7. Other capital			.03	.11
8. Labor quality			-.13	-.13
9. Multifactor productivity			.68	.33
15. Semiconductors			.27	.29
16. Computer hardware			.10	.05
17. Other sectors[3]			.30	.00

1. In nonfarm business sector. Measured as percentage points per year.
2. Percentage points per year.
3. Includes communication equipment and software sectors.
Note: Detail may not sum to totals due to rounding.
Source: Authors' calculations based on BEA and BLS data.

Table 3
Contributions of IT Capital Deepening to Labor Productivity Growth[1]

	1991-1995	1996-2000	2001	2002[2]
1. Total IT capital	.48	1.03	1.08	.49-.73
2. Computer hardware	.20	.55	.46	.12-.22
3. Software	.23	.37	.43	.26-.35
4. Communication equip.	.05	.11	.19	.11-.16

1. In nonfarm business sector. Contributions measured in percentage points per year.
2. Bottom of range computed by setting growth of real investment spending in 2002 at 2001 pace. Top of range computed by setting growth of real investment spending in 2002 at 1996-2000 average pace.
Note: Detail may not sum to totals due to rounding.
Source: Authors' calculations based on BEA and BLS data.

Steady-State Growth of Labor Productivity

- Note that the "steady state" does not refer to a specific time period.
  - In particular, the steady-state results are ***NOT*** forecasts of productivity growth over the next couple years.
  - These results merely identify a plausible range for productivity growth over a long period of time.

- The steady-state results depend on many parameters in the model (e.g., the various shares defined above and the rate of price change for each sector's output).
  - We selected "conservative" parameter values – which we use to estimate a lower bound for the steady-state rate of productivity growth.
  - Values of key parameters are shown in the table below.

Table 4
Value of Key Inputs for "Conservative" Estimate of Steady-State Growth in Labor Productivity

	1991-1995	1996-2000	2001[1]	Steady State
Computer prices[2]	-15.6	-25.3	-21.9	-15.6
Semiconductor prices[2]	-19.7	-43.3	-39.7	-19.7
Semiconductor output as a percent share of NFB output[3]	.54	.93	.94	.93

1. Based on available 2001 data, at an annual rate.
2. Percent change, annual rate.
3. In current dollars. Calculated as an average of the value for the year shown and the prior year, to conform with the Tornqvist aggregation formula used in our growth accounting.

- With "conservative" parameter values, the steady-state growth of labor productivity is a touch below 2 percent per year.

- As a sensitivity test, we calculated how the result would change with more optimistic assumptions for the parameters in the table.

  - Set price declines for computers and semiconductors at the more rapid 1996-2000 pace.

  - Allow the semiconductor share of output to rise further, reaching 1-¼ percent of nonfarm business output.

  - With these parameter values, the steady-state growth of labor productivity rises to nearly 2-¾ percent, illustrating the sensitivity of the results.