Information Technology and Productivity

The Case of the Financial Sector

By Lawrence R. Klein, Cynthia Saltzman, and Vijaya G. Duggal

Economists agree that technology, and particularly information technology, is important in raising productivity growth in the U.S. economy. Measuring the magnitude and extent of the impact of information technology on the U.S. economy and on specific industries continues to be an area of considerable interest and research.

Nobel laureate Lawrence Klein, professor emeritus of economics at the University of Pennsylvania, and Cynthia Saltzman and Vijaya Duggal, both professors at Widener University in Pennsylvania, examined the role of information technology on increasing productivity in the finance sector, using data from the benchmark and annual input-output accounts produced by the Bureau of Economic Analysis (BEA). Professor Klein presented the results of this study as an honored guest lecturer at BEA on March 24, 2003. His presentation was part of a ceremony recognizing the work of BEA staff in producing the 1997 benchmark input-output accounts.

This article is based on the material presented by Professor Klein. The views expressed in this article are those of the authors and do not necessarily reflect those of either BEA or the U.S. Department of Commerce.

THE role of information technology in increasing the overall productivity of the U.S. economy is now being widely recognized. Within the economics profession, there is an ongoing discussion as to whether or not information technology has increased the long-run speed limit of the economy or is simply a short-run phenomenon. In other words, do recent economic conditions support the notion of a *new* economy in which the improvement in productivity is secular rather than cyclical?

At the forefront of this discussion is the need to quantify the impacts of the underlying causes and to assess the effect on the changing structure of the new economy. However, the magnitude of the impact of information technology (IT) at both the aggregate and industry level, as well as the nature of the impact in terms of its effect on the returns to scale coefficient, are questions that have yet to be convincingly answered in quantitative terms. Although the contribution of IT is widespread and covers all industries, it is clear that it contributes more in some sectors than in others. We have already done an empirical analysis of such a contribution in the automobile and the transportation sectors.[1] This study measured the impact of using IT in the manufacture of a physical product. We would now like to study the impact of IT on the production of a service.

It is evident that finance is an outstanding sector that should provide interesting insight. IT is especially relevant in the financial industry in that it was one of the first sectors to use computer services on a large scale—taking off by about 1980 in using electronic transfer, ATM machines, automatic accounting systems and other automated “back office” services to keep abreast of global markets and provide almost instantaneous services to customers. Yet, industry studies to date have not been able to measure any meaningful productivity impacts from IT in the finance sector.

The Bureau of Economic Analysis (BEA) has prepared both benchmark and annual input-output (I-O) tables that are extremely important for analyzing the *internal* workings of the economy. Study of time series aggregates overlooks the strategic importance of some *intermediate* deliveries, in particular, the delivery of computer and data processing services to the finance sector. In terms of the ongoing debates and analyses of the contribution of IT to economic performance, this is often referenced as “business-to-business” (“B-to-B”) activity. The economic significance of such activity

1. Lawrence Klein, Vijaya Duggal, and Cynthia Saltzman, “Contribution of Input-Output Analysis to the Understanding of Technological Change: The Information Sector in the United States” in *Wassily Leontief and Input-Output Economics*, ed. Erik Dietzenbacher and Michael L. Lahr (Cambridge: Cambridge University Press, forthcoming).

is capable of being studied by virtue of the dynamics of I-O analysis, revealed in the time sequence of tables over the span of three decades.[2] BEA has supplied us with seven tables with identical classification of 90 sectors. These tables treat own-account software expenditures as intermediate flows within the I-O framework. As such, these expenditures are not treated as an enhancement of human capital, so deliveries to final investment demand are lower for that reason, but such outlays are consistently treated in all seven tables.

This unusual set of tabulations enables us to trace intermediate deliveries from the early beginnings of computer information activity to the present. It is encouraging to learn that the dynamic sequence of tables has been extended to 1999, for which a new annual table is now available.[3] In chart 1, we plot the dollar values for deliveries of computer and data processing services (no. 73A in the table) to the finance sector. For those who think that IT is something that began only in the second half of the 1990s, we recommend that they look at the impressive ascent of the curve for the finance sector, starting in the early 1980s.

We want to measure directly the impact of the information services input (software) in the form of the B-to-B service activity that has surged in the past decade, as depicted in chart 1. In addition, we need to measure separately the impact of the extensive and intensive use of information equipment (hardware). We propose to include IT hardware and software as separate factor inputs within the framework of a generalized KLEM production function. The function becomes KLEMI in this study. The structural specification of the production function will include strategic nonlinearities to allow for an S-shaped[4] curve when graphing total output with respect to the factor inputs. Such a specification produces a variable returns-to-scale coefficient whose value is dependent on the capital/labor ratio. Hence, we place no restrictions on the returns to scale, but in fact, we expect to find evidence of increasing returns to scale.

To test the model empirically and quantify such effects, we will use time series data for IT capital (hardware), other capital, and labor. Time series data do not exist for intermediate inputs and more specifically for direct deliveries from the information sector. Values for these variables will be extracted from the seven I-O tables provided by BEA. By investigating the internal workings of IT through the eyes of the I-O accounts, we have two data points each for the decades of the 1970s and the 1980s, together with three data points for the 1990s, as intermediate flows from the relevant sectors to the financial sector. These points have been interpolated to get pseudo annual figures. Similar time series can be constructed to “gross up” the output of the financial sector—“grossed up” by aggregating the real cost of the intermediate inputs to (real) value added—to obtain an appropriately corresponding gross measure of output.[5] We can then proceed with the empirical estimation of the expanded production function.

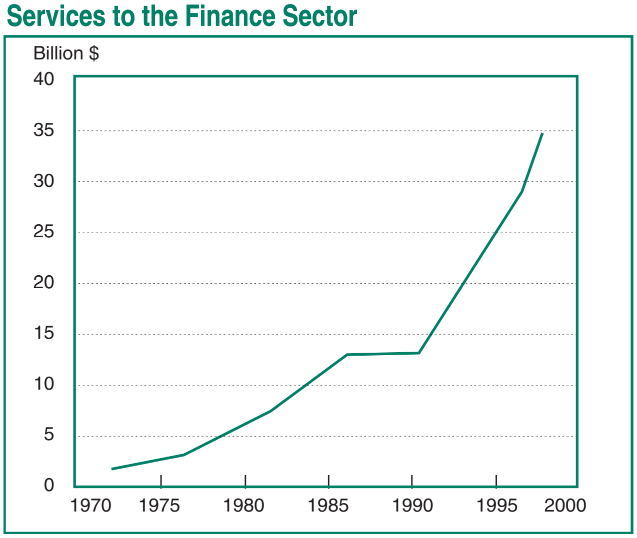
The financial sector is chosen for this technological analysis for several other reasons in addition to the fact that it was a large-scale user of IT at an early stage of the introduction of the new technologies. This sector presents interesting challenges for the economist and plays a key role in the economy. The specification of its inputs and outputs is easy enough to measure in nominal terms at current values, as entered in the I-O tables, but how should we define real output and real input for this sector? We have used price indexes of service flows, both to customers and to employees, that reflect wage costs and software prices. We have also deflated fixed capital services by an output deflator.

During the period of investigation, the sector underwent extremely large consolidation not only among banking units alone, among brokerage units, or among insurance units but also between different kinds of units to form large financial conglomerates that provide many kinds of financial services on demand. Mergers and acquisitions have been widespread, as the restrictions of the Glass-Stegall Act, which was created

2. We are indebted to Mark Planting of BEA for the preparation of the dynamic sequence on a consistent classification basis.

3. The research for the present paper was done when the table for 1998 was the latest available.

Chart 1. Deliveries of Computer and Data Processing Services to the Finance Sector



4. We first introduced an S-shaped production function in Duggal, Saltzman, and Klein, “Infrastructure and Productivity: A Nonlinear Approach,” *Journal of Econometrics* 92 (September 1999): 47–74.

5. To accompany gross input, we want to use gross output to preserve the adding-up principle. In the present context, when estimating the technical production function, gross output, rather than value added, is the preferred dependent variable.

to avoid the speculative excesses that led to the Great Depression of the 1930s, were removed one by one.

In 1980, there were 14,434 commercial banks in the United States, but by 1998 (the end of our sample span), there were only 8,794. A few very large banks dominate the sector and also control insurance companies and investment houses. At the same time, many thrift institutions were absorbed, and there was much rent seeking by the merged conglomerates. These are reasons why we are interested in estimating returns to scale under present structural conditions.

Model

The standard KLEM production function is linear in the parameter coefficients when estimated in its natural log functional form:

$$(1)\ \ln X = c_1 \ln K + c_2 \ln L + c_3 \ln E + c_4 \ln M + c_5 t$$

where X represents real output, K is the real stock of capital, L is labor hours, E is the energy input, M is all other intermediate inputs, and t is the time trend to proxy disembodied technological change with $c_5 t$ representing the value of the technological index. Within this standard framework, the inclusion of IT services and the separation of IT hardware from the capital stock input would lead to the following structural equation:

$$(2)\ \ln X = c_1 \ln KO + c_2 \ln ITH + c_3 \ln ITS + c_4 \ln L + c_5 \ln E + c_6 \ln M + c_7 t$$

where ITH is the IT capital stock (hardware), KO is all other capital, and ITS is the IT service input (software).

There are, however, several constraints inherent to this functional form that render it inadequate to measure the productivity impacts from IT in the finance sector. In particular, the specification of equation (2) precludes the possibility of a range of increasing marginal productivity for the factor inputs: It confines the returns-to-scale coefficient to a constant value; it imposes a constant growth rate for technological change; and it ignores the possibility of IT's acting as an endogenous technological change component, as well as potential interactive effects. Our objective is to expand the KLEM production function in a manner that eliminates these constraints. To develop such a function, we look to the particular characteristics of the finance sector in its use of IT.

As previously noted, the finance industry was one of the first sectors to use computer services on a large scale. Accordingly, we felt it was important to focus on computers and therefore divided the IT capital stock (ITH) into the stock of computers (com) and all other IT capital stock $(oith)$. Thus, the total real capital stock K is equal to $KO + com + oith$. We hypothesized that the innovations in computer technology that led to continual increases in computer capacity should have generated a significant productivity impact with regard to the finance industry.

To try and capture this effect, we utilized Moore's Law,[6] which states that computer capacity doubles every 18 months to create an index for computer capacity. A mathematical feature of an index that doubles every 18 months is that the change, on an annual basis, as a ratio to the current-period index is a constant 37 percent. We then developed a functional form for the technological index whereby the increase in computer capacity over time could generate a productivity impact that initially increased at an increasing rate, that at some point, begins to increase at a decreasing rate, and that eventually reaches a plateau. Moreover, since increases in computer capacity pertain to the newest computers, larger increases in the computer stock should be associated with a longer time period for the function to increase at an increasing rate. Finally, the size of the total computer stock should impact the magnitude of the increasing range of the function. The following functional form for the technological index accommodates these hypothesized relationships:

$$(3)\ \ln A = -\exp\left[\left(\frac{1}{com}\right)^{c_{11}} - \left(\frac{1.37^t}{\Delta com^2}\right)^{c_{12}}\right]$$

where A represents the technological index.[7]

We then turned our attention to capturing the productivity impact of the increasing use of software in the delivery of automated "back office" services. Again, we wanted to develop a functional form that would allow for the possibility of a range of values over which the function could increase at an increasing rate. Additionally, we felt that software technology enhances the marginal productivity of labor, and consequently, there should be an interaction effect between the two. Finally, the overall magnitude of the productivity impact of software over time, should be affected by the size of the IT capital stock relative to the labor input utilized. To incorporate all of the characteristics discussed, the following specification is hypothesized for

6. G.E. Moore, "Cramming More Components into Integrated Circuits, *Electronics* 38, no. 8 (April 19, 1965). G.E. Moore, "A Pioneer Looks Back at Semiconductors," *IEEE Design & Test of Computers* 16, no. 2 (March 1999).

7. Standard growth accounting literature generally designates A as the technological shift factor to the production function. It is a measure of technological change, and as such, it is often used for the purpose of calculating multifactor or total factor productivity. The most common assumption is that A grows exponentially over time at a constant rate: $A = e^{ct}$. When taking the natural logarithm, this would enter the production function structural equation as ct, with c as the estimated coefficient for the growth rate of technology over time. This is the underlying assumption in equations (1) and (2).

the technological index:

$$(4)\ \ln A = \exp\left[\left(\frac{com \cdot oith \cdot L \cdot t}{ITH}\right)^{c_8} - \left(\frac{L}{ITS}\right)^{c_9} + c_{10}\right]$$

$$- \exp\left[\left(\frac{1}{com}\right)^{c_{11}} - \left(\frac{1.37^t}{\Delta com^2}\right)^{c_{12}}\right]$$

The incorporation of equation (4) into the KLEM framework leads to the KLEMI structural specification for the production function:

$$(5) \ln X = c_1 \ln K + c_2 \ln L + c_3 \ln E + c_4 \ln M$$

$$+ \exp\left[\left(\frac{com \cdot oith \cdot L \cdot t}{ITH}\right)^{c_8} - \left(\frac{L}{ITS}\right)^{c_9} + c_{10}\right]$$

$$- \exp\left[\left(\frac{1}{com}\right)^{c_{11}} - \left(\frac{1.37}{\Delta com^2}\right)^{c_{12}}\right]$$

Data

The data for this research are generated by the intensive use of the seven I-O tables provided to us on a consistent basis by BEA.[8] We focused on the finance industry (70A), which does not include insurance and real estate. In addition, we have used estimates of nonresidential fixed assets by industry and by type that are available at the BEA Web site.

Gross output (X). The seven I-O figures for energy, for software (73A, including other high tech), for intermediate flows other than energy and software, and for value added in nominal dollars were linearly interpolated to generate pseudo annual data for the series. We then imposed the accounting identity: Gross output is the sum of intermediate inputs and value added, in nominal terms. The annual energy flows were converted to 1996 dollars by deflating them by the producer price index for energy. The software flows were converted to 1996 dollars by the price index for custom software. The intermediate flows, excluding energy and software, were deflated by the producer price index for intermediate inputs other than energy to generate the 1996 dollar series. The novel approach is in our using the interest-rate spread (ratio form) between the cost of loanable funds and the base return on assets as the deflator for value added. An index, with 1996 as 100, was made of the ratio of the prime rate to the federal funds rate to use as a proxy measure for the profit margin.[9] This index was used to convert the nominal finance value-added series to the corresponding 1996 value-added figures. The 1996 dollar gross output for the finance sector was computed as the aggregate of the 1996 dollar series for energy, software, other intermediate flows, and value added.

Intermediate flows excluding software (ME). The intermediate flows excluding software were the sum of energy and intermediate flows excluding energy.

Information technology service flows (ITS). This series was the sum of I-O flows from computer and data processing services (73A); computer and office equipment; audio, video, and communication equipment; and communication except radio and TV industries. The series was converted to 1996 dollars by deflating it by the price index for custom software. Computer and data processing services flow is the dominant component. The ratio of this component to gross output is presented in table 1, together with those for all intermediate inputs and value added.

Labor (L). Labor is expressed in billions of hours on an annual basis. It is the product of the Bureau of Labor Statistics data on employment for the finance sector and average weekly hours of production workers for finance, insurance, and real estate.

Capital stock (K). The capital stock for the sector was aggregated from the 1996 dollar BEA estimates of nonresidential fixed assets: Detailed industry by detailed type. Excluded from K is the B-to-B software consisting of prepackaged software, custom software, and own-account software. These are now considered part of investment in capital stock in national income analysis).

IT hardware (ITH). ITH is part of the total capi-

8. We would have liked to use annual I-O tables in our analysis for the entire period from 1972 to date, but annual tables are only now becoming available. To stay within the framework of I-O tables for the whole period of our analysis, we deemed it best to interpolate (linearly) between table readings for missing values of the variables that we use in our production functions. In this way, we achieve annual mutual consistency among the variables, even though some aggregate observations are separately available, apart from I-O tabulations, each year over the range of our sample. They are in the BEA listing of time-series estimates of gross output, intermediate inputs, and value added for individual industries. The definitions of industry classification used by BEA change in the middle of our sample span, causing a need for some judgment and approximation in building industry aggregates of gross production, value added and intermediate inputs for years between published I-O tables. The conservative solution of using uniform linear interpolation between tables seemed preferable because it preserves mutual consistency. Also, the special treatment of own-account software, which is important for our investigation, was not available for the published aggregates in the years between tables.

9. A price index for the finance sector is available from BEA; however, it includes insurance and real estate, and therefore we did not feel it was an appropriate deflator. Additionally, given the research by Gullickson and Harper (1999 and 2002) on bias in banking industry productivity trends, we felt that our index, representing the gross margin price in banking, conceptually captures the change in net revenues that the producer price index is meant to measure. See the *BLS Handbook of Methods*, chapter 14.

Table 1. Input-Output Coefficient, Current-Dollar Ratio, Percent

	1972	1977	1982	1987	1992	1997	1998
Computer and data processing services including own-account software: 73A	2.74	3.95	4.61	4.36	3.06	3.96	4.44
Total intermediate inputs	38.06	35.65	43.53	49.55	39.90	43.87	46.01
Value added	61.94	64.35	56.47	50.45	60.10	56.13	53.99

tal stock K and includes the following categories of stock:

Mainframe computers
Personal computers
Direct access storage devices
Computer printers
Computer terminals
Computer tape drives
Computer storage devices
Other office equipment
Communication equipment
Instruments
Photocopy and related equipment
Telecommunications

All other capital (KO). $KO = K - ITH$

Computers (com). The stock of computers is part of the information technology hardware capital stock ITH and in the finance sector includes the following:

Mainframe computers
Personal computers
Direct access storage devices
Computer printers
Computer terminals
Computer tape drives
Computer storage devices
Integrated systems

All other IT hardware ($oith$). $oith = ITH - com$

Estimation

Because of the comparatively low energy use in the finance sector, for estimation purposes, the energy input was combined with all other intermediate inputs and defined as the variable ME. The initial estimation of equation (5) did not produce statistically significant estimates of the parameter coefficients in the first exponential term—c_8, c_9, and c_{10}. Upon further consideration, two changes were made. First, all IT variables were lagged one period to reflect a learning effect in the use of both IT hardware and software. Second, because labor represents a flow variable, changes in the IT hardware variables were used instead of the stock values. The estimation results are presented below (t-statistics are in parentheses):[10]

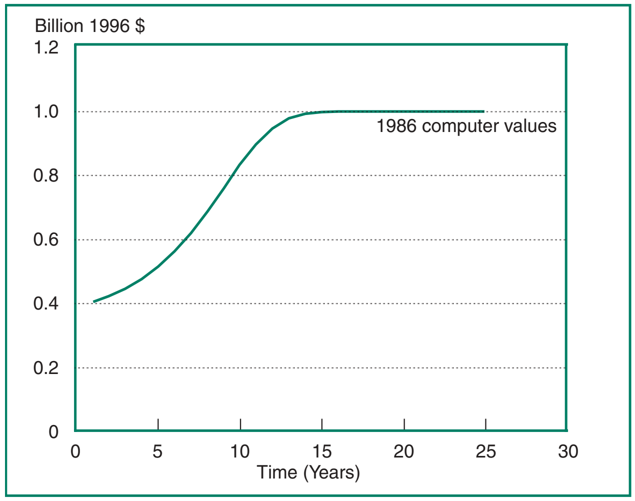
$$(6)\quad \ln X = \underset{(4.7)}{.27\cdot\ln K} + \underset{(4.1)}{.51\cdot\ln L} + \underset{(3.5)}{.23\cdot\ln M}$$

$$+\exp\left[\underset{(2.4)}{\left(\frac{\Delta com_{-1}\cdot\Delta oith_{-1}\cdot L\cdot t}{\Delta ITH_{-1}}\right)^{.01}} - \underset{(8.7)}{\left(\frac{L}{ITS_{-1}}\right)^{.32}} + \underset{(3.1)}{.51}\right]$$

$$-\exp\underset{(40.6)}{\left[\left(\frac{1}{com}\right) - \left(\frac{1.37^t}{\Delta com^2}\right)^{.83}\right]}$$

The estimated coefficients from the exponent employed to capture Moore's Law were used to graph the interactive effect between time and computers. This is presented in chart 2. One can clearly identify the S-shaped path of the interaction of computers with disembodied technological change that is proxied by the time variable.

Chart 2. Moore's Law—The Interaction Between Time and Computers Implied by the Estimated Equation



Unfortunately, the complexity of the estimated equation makes it extremely difficult to calculate the factor productivity impacts of the inputs. This was particularly true of the exponent representing Moore's Law. We therefore estimated the equation without this exponent. The results are presented in equation (7):

$$(7)\quad \ln X = \underset{(5.1)}{.31\cdot\ln K_{-1}} + \underset{(4.5)}{.58\cdot\ln L} + \underset{(3.0)}{.21\cdot\ln ME}$$

$$+\exp\left[\underset{(1.8)}{\left(\frac{\Delta com_{-1}\cdot\Delta oith_{-1}\cdot L\cdot t}{\Delta ITH_{-1}}\right)^{.009}} - \underset{(7.9)}{\left(\frac{L}{ITS_{-1}}\right)^{.35}} + \underset{(2.0)}{.38}\right]$$

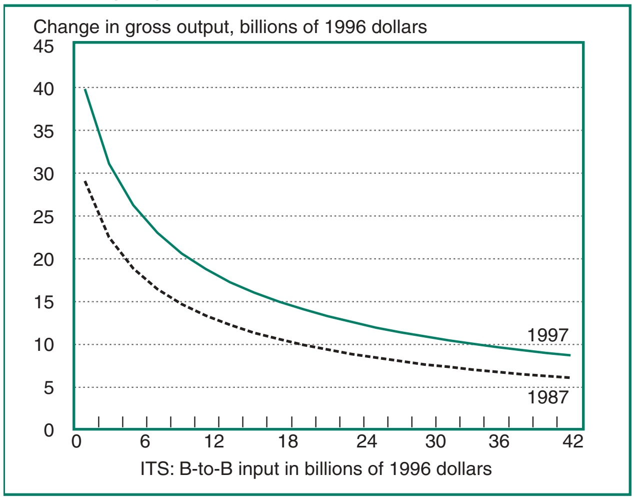
The estimation results of equation (7) are quite similar to those of equation (6), although equation (6) does have a somewhat lower standard error of the regression and higher t-statistics for the IT variables. However, the marginal productivity estimates of the IT service flows are almost identical for each estimated equation.

Marginal productivity of IT services

Using equation (7), chart 3 traces out the marginal

10. For comparison purposes, equation (2) was also estimated, with mediocre results: There was no statistically significant difference in the coefficient estimates on KO and ITH, the time trend was not significant, and the Durbin-Watson statistic was very low.

Chart 3. Marginal Product of Information Technology Services (ITS) in 1987 and 1997



productivity of the information service flow, holding all other variables constant at their 1987 and 1997 values respectively. The actual values of IT services in 1987 and 1997 were $17.6 billion and $37.7 billion in 1996 dollars. It should be noted that at recent levels of economic conditions, the marginal impact of IT services flow on gross output is large when used sparingly, and the impact declines asymptotically with greater use. Also, the more developed the economy, the larger is the marginal impact of IT service flow on gross output for a given use.

Factor productivity

The factor productivity implications of the estimated equation are presented in table 2. The table shows the percent change in output contributed by the various components over the period 1977–98. The percent change is averaged over four 5-year intervals that are bounded by the benchmark I-O tables. The calculation for the most recent sample period is made for 1997–98. The IT services flow is the single most important contributor to growth over all the subperiods examined and reaches as much as half the overall growth in output.

To estimate *returns to scale*, we increased all inputs by 10 percent over the most recent period and computed the resulting increase in output over two periods to be 16.86 percent.

Table 2. Factor Productivity Implied by the Estimated Equation

	1997–98	1992–97	1987–92	1982–87	1977–82
Average percentage change in output	14.7	14.4	3.1	20.6	17.2
Contribution from					
L	.66	.20	–.08	.94	.70
ITS	7.23	7.44	1.13	8.10	8.70
com	.94	1.07	–.43	1.64	.69
ITH	.51	.48	.68	1.85	.89
KO	1.42	2.02	1.50	3.23	2.80
ME	3.77	2.45	.23	4.67	3.10
time	.10	.33	.13	.82	.41
Percentage of growth accounted for by *ITS*	49.2	51.7	36.5	39.3	50.6

NOTE. Columns may not add up because of rounding.

Conclusions

A special incentive to undertake a study of the *finance* sector on the basis of three decades of its role in the I-O configuration of the U.S. economy was the longevity of its increasing use of computer and data processing services. This long record of use indicated that it has been a trend phenomenon. Our studies confirm this characteristic through 1998, and we remain confident that we shall continue to observe this result as BEA extends the historical record. We already have a 1999 annual table and look forward to studying future tables in this respect.

Over the most recent period in our sample, we find evidence of increasing returns to scale and also of the large contribution to overall productivity in finance that comes from the economic process of delivering output from computer and data processing services to the finance sector.

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