- Detailed measures of demand, production, and prices in the auto, housing, energy, and agricultural sectors.

- Detailed measures of industrial production in manufacturing, mining, and utilities as compiled by the Federal Reserve.

- Detailed wage rate and employment series from the Bureau of Labor Statistics.

With few exceptions, the data included in the Model are seasonally adjusted. No attempt is made to explain seasonal variations.

WEFA's INDUSTRY ANALYSIS MODEL

The Industrial Analysis Model is a combination input-output/stochastic model of business activity in 117 U.S. industries.

- The model forecasts demand, industrial production indexes, shipments, value of production, inventories, prices, manhours, output per hour, average hourly earnings, material cost, and operating margin for each manufacturing industry.

- Value of production, prices, manhours, and output per hour are forecast for nonmanufacturing sectors.

The industry aggregation follows the 73 manufacturing industries reported by the Department of Commerce in its monthly Shipments, Orders, and Inventories release, basically a three-digit SIC aggregation and a largely one-digit to two-digit scheme for 44 nonmanufacturing industries.

For the manufacturing industries, the model forecasts demand, industrial production indexes, shipments, value of production, inventories, prices, manhours, output per hour, average hourly earnings, material costs, and operating margins. For the non-manufacturing sectors, the model provides value of output, prices, manhours, and output per hour.

The input-output block at the core of the model serves two important purposes. First, it defines the linkages among all 117 industries in the model. That is, the input-output coefficients provide both a supply-side view (production function) and a demand-side view (market distribution) of each industry. Second, it translates macroeconomic forecasts of final demand based on the National Income and Product Accounts from The WEFA Group's U.S. Economic Model into demand for goods and services by industry. The input-output relationships contained in the model are also used to calculate composite input costs by industry which provide the cost basis for price forecasts by industry. All other concepts in the model are forecast using estimated statistical relationships and defined identities.

WEFA's BASELINE FORECAST

The Baseline Forecast covers the interval from 1994 through 2004. The assumptions and projections contained in this forecast constitute WEFA's regular long-term forecast. There are key differences in the methodologies employed to forecast long-term versus short-term economic activity. Short-run economic analysis focuses on issues related to fluctuations in the level and composition of final demands and incomes, while long-run analysis is concerned with expansion of potential output or aggregate supply. The short-run emphasis on measures of utilization rates of capital (capacity utilization) and labor (unemployment rate) have important implications for near-term wages and prices, interest rates and monetary policy, consumer and business sentiment, and investment activity. Potential output can be useful in a short-run context as well. Potential GDP can be compared to its actual level to determine the percentage difference or "GDP gap" in the evaluation of whether the gap is closing or expanding. However, the analysis of business cycle swings has little to add to our understanding of the growth of the economy in the long run. The growth of aggregate supply or potential output is the fundamental constraint on the long-run level of economic activity.

Potential GDP is a measure of the economy's ability to produce goods and services. Loosely defined, potential GDP is that level of output which could be achieved if resources were not underutilized. In an environment free of unexpected shocks, (such as the Baseline Forecast) equilibrating dynamics tend to cause productive capacity to converge to its potential or fully-utilized level. Consequently, the briskness in the expansion of output, real incomes, real expenditures, and the general standard of living of the population are determined by the growth rate of potential GDP. The long-range outlook is dominated by supply factors such as population growth and demographics, labor force participation rates, weekly hours, capital stock accumulation, labor output per hour growth, fiscal and monetary policies, foreign developments, and internationally determined prices.

WEFA's forecasts merge these two approaches, focusing on cyclical factors in the short-term and supply factors in the long term. Actual GDP has now been below potential since the first quarter of 1989. The 1990-91 recession included the two negative quarters in 1990 and the first quarter of 1991. This is the longest sustained below potential stretch in the post-war period. This suggests that economic activity could rise for a substantial period of time before bumping up against physical and financial constraints.

The actual U.S. GDP was 3.3% below its potential in the first quarter of 1993 and this shrunk to 1.8% in the last quarter of 1993. The average real GDP increase of 3.6% in the second half of 1993 appreciably closed this gap. The United States is not alone in experiencing a GDP gap: all the G-7 countries are operating below their potential to one degree or another.

The Baseline Forecast assumes that no unexpected shocks occur to the economy and that the economy expands at its long-run potential path in the absence of any business cycles. Business cycles will certainly occur in the future. But, predicting business cycle turning points far into the future are virtually impossible to predict accurately. The advantage of the trend scenario is that it allows business planners to evaluate the economic dynamics of key supply factors and how they might affect their businesses.

THE REVISED PRICE CAP SIMULATION

The Revised Price Cap simulation reveals a slightly more robust economy in an environment of a higher quality PTN and more rapid information/image transmission speeds. As network investment accelerates and service quality improves dramatically for the average user, businesses, households, and government agencies move toward more intensive telecommunications usage and more efficient processes.

Tables 4 through 6 and Figures 1 through 6 present and illustrate the changes that are expected as telecommunications investment rises, service quality and value increase, and technological change edges upward. In addition to the gains in economic aggregates, automobile sales increase 101,000 and housing starts increase 29,000 in 2004 relative to the Baseline forecast. Income gains and interest rate reductions make goods and services somewhat more affordable, and consumers and businesses take advantage of the change.

Foreign demand for U.S.-produced products also increases as inflation slows down a bit. The result is a net improvement in the nation's balance of trade of almost $6 billion in 2004 compared to the Baseline forecast.

Greater domestic and foreign demand translate into a cumulative gain in industrial production of 1.3% over the ten year interval.

The increased economic activity creates more jobs over the next ten years. As noted in Table 5, all major industry groups in the economy gain some jobs in the Revised Price Cap simulation versus the Baseline forecast. The broad services sector, which currently supports over 31 million workers, gains 217,000 new jobs over the next 10 years in the Revised Price Cap simulation relative to the Baseline forecast. Table 6 shows that the Business Services sector gains the most jobs among services, claiming 153,000 new positions. Health Care is next in the service sector with 49,000 jobs.

Manufacturing gains a total of 58,000 jobs over the next ten years.

Construction gains 96,000 jobs as slightly lower interest rates boost both residential and business investment in structures. And mining gains 13,000 jobs as demand increases for metals and nonmetallic mineral products with the increase in the purchases of durable goods, houses, and commercial structures.

Financial services, which is a big user of telecommunication services and information technology, adds an additional 38,000 workers to the payroll. Wholesale and retail trade together add 40,000 jobs.

Finally, due to higher incomes and lower interest rates, the federal budget deficit shrinks by $33 billion in 2004 as tax revenues increase and debt service costs decline. Over the entire ten year interval, the cumulative improvement in the federal budget deficit is $149 billion.

Table 4
Annual Gains in Macroeconomic Activity
Price Cap Simulation Minus Baseline Forecast
(Billions of 1994 Dollars)

	Annual Gain		Cumulative Gain		Compound Annual Growth Gains
	1999	2004	1999	2004	1994-2004
Gross Domestic Product	24.0	60.5	52.8	278.2	0.07
Consumption Expenditures	13.5	30.3	32.7	148.5	0.05
Business Investment	5.5	14.2	15.5	69.2	0.14
Residential Investment	3.3	6.6	0.8	28.3	0.19
Exports	2.0	6.6	4.5	4.5	0.05
Imports	1.8	0.8	27.7	12.2	0.00
Auto Sales (Thousands)	123.5	100.6	410.9	988.4	0.09
Housing Starts (Thousands)	22.7	29.1	18.9	161.6	0.18
Federal Deficit	12.7	33.3	24.5	148.8	

Table 5
Annual Gains in Total Employment
Price Cap Simulation Minus Baseline Forecast

	Job Gains in Thousands		Compound Annual Growth Gains
	1999	2004	1994-2004
Total Employment	222	510	0.04
Mining	4	13	0.20
Construction	33	96	0.15
Manufacturing	47	58	0.04
Transp., Public Utilities	21	50	0.08
Wholesale, Retail Trade	40	40	0.02
Financial Services	10	38	0.05
Services	68	217	0.06

Table 6
Annual Gains in Detailed Industry Employment
Price Cap Simulation Minus Baseline Forecast
Services

	Job Gains in Thousands		Compound Annual Growth Gains
	1999	2004	1994-2004
Transportation	12	25	0.06
Telephone & Telegraph	11	32	0.33
Broadcast	1	5	0.21
Financial Services	10	38	0.05
Business Services	37	153	0.18
Health Care	12	49	0.04
Education	2	5	0.03
Other Services	19	11	0.00

Figure 1
Real Gross Domestic Product Improvement
Price Cap Simulation vs. Baseline
(Billions of 1994 Dollars)

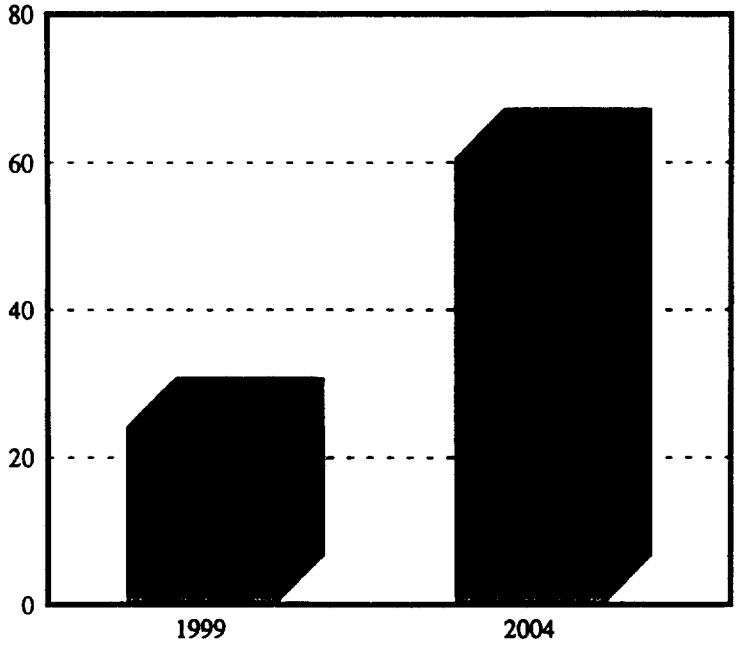


Figure 2
Total United States Employment Gains
Price Cap Simulation vs. Baseline
(Thousands of Jobs)

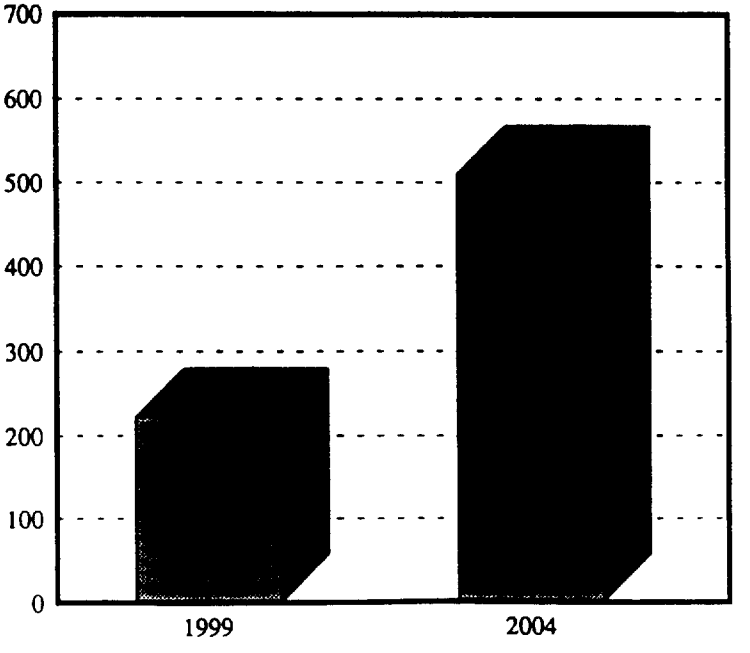


Figure 3
U.S. Unemployment Rate
Price Cap Simulation vs. Baseline
(Percent)

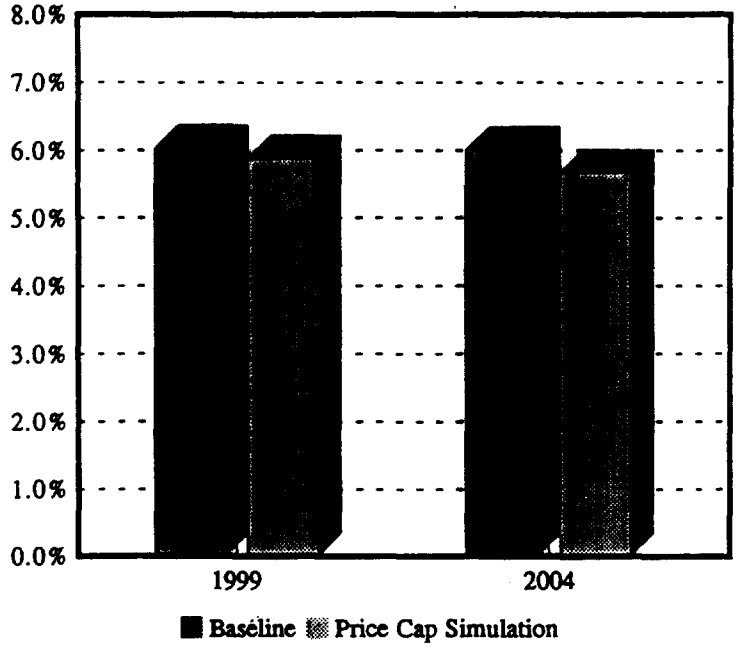


Figure 4
Consumer Price Inflation Rate
Price Cap Simulation vs. Baseline
(Difference)

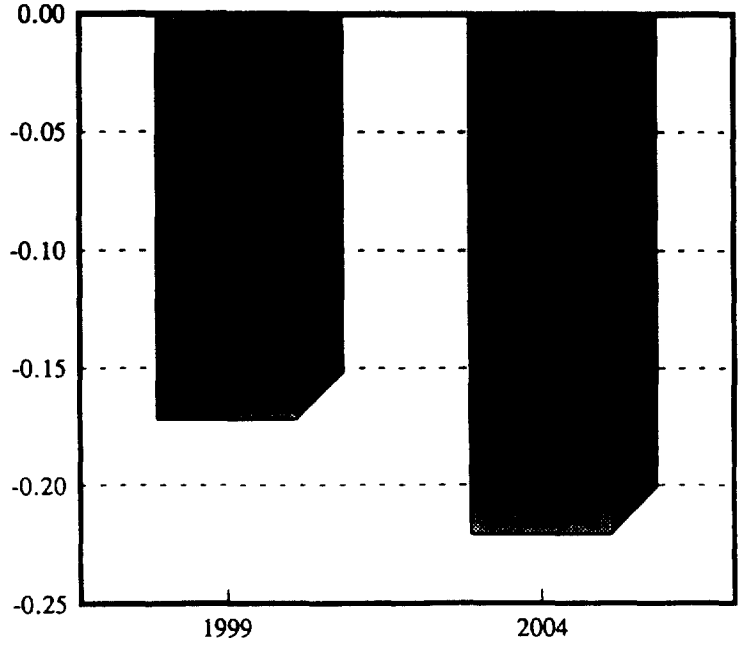


Figure 5
Prime Interest Rate
Price Cap Simulation vs. Baseline
(Difference)

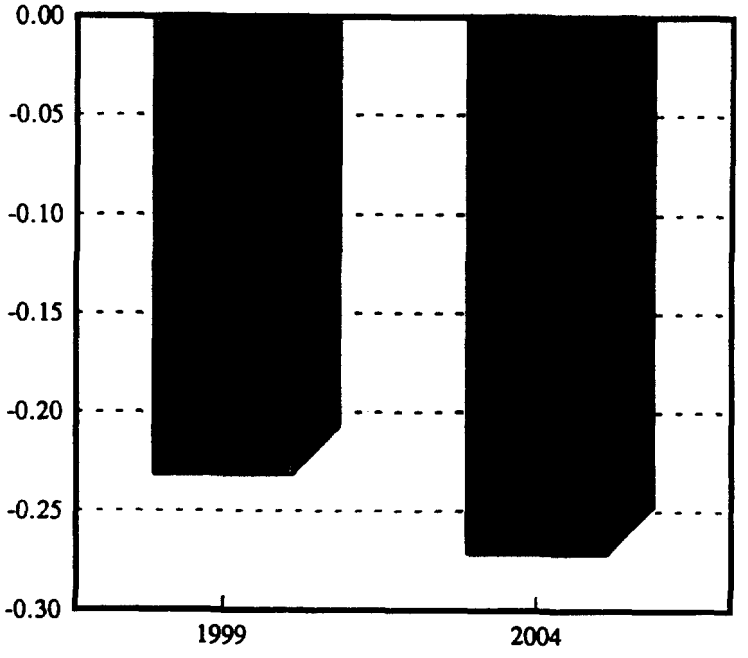
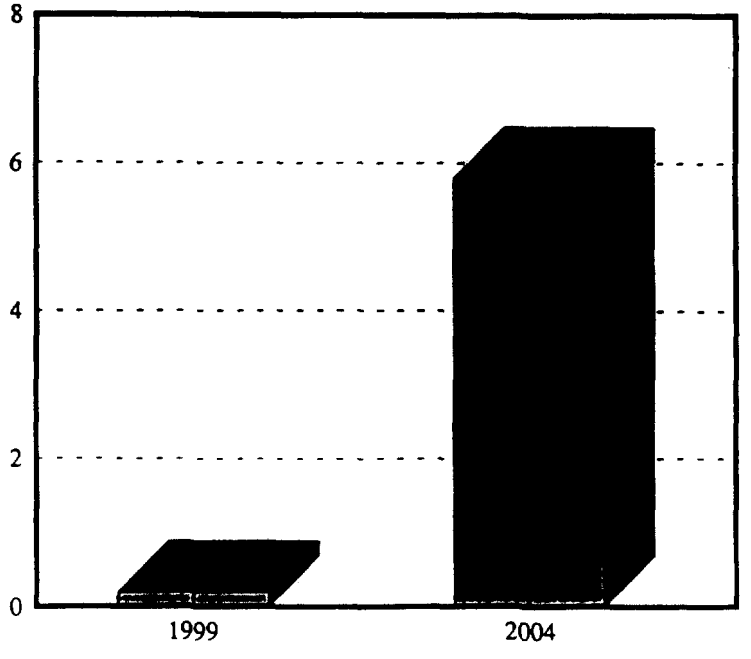


Figure 6
Merchandise Trade Balance Improvement
Price Cap Simulation vs. Baseline
(Billions of 1994 Dollars)



THE IMPORTANCE OF THE TELECOMMUNICATIONS INDUSTRY

The telecommunications industry has become a more important input to most production and service processes over the last ten years. As Figure 7 indicates, the percent of total real industry output in the U.S. economy that businesses spend on telecommunications has grown steadily. In 1983, businesses spent just over 0.8 of one percent of their total output on telecommunications services. By 1993, the percentage had increased to just over one percent. This upward trend reflects the efficiencies that telecommunications services lend to most processes in lieu of other productive inputs.

Table 7 provides a more detailed view of the commercial uses of telecommunications services. First, note that only 14 of 87 industry groups reduced the telecommunications share of industry output. Most of the 14 industries are minimal users of telecommunications services, consuming well below the national average relative to the industry's total output. Second, note that the industries with high information and data content are among the most intensive users of telecommunications services. These industries have both above average consumption as a share of total industry output and above average growth in the telecommunications share over the last ten years.

Over the next ten years, the total, economy-wide share of telecommunications spending as a share of total real industry output continues to grow and reaches almost 1.5% in 2004.

Figure 7
Real Telecommunications Purchases by Businesses as a Share of Total Real Industry Output

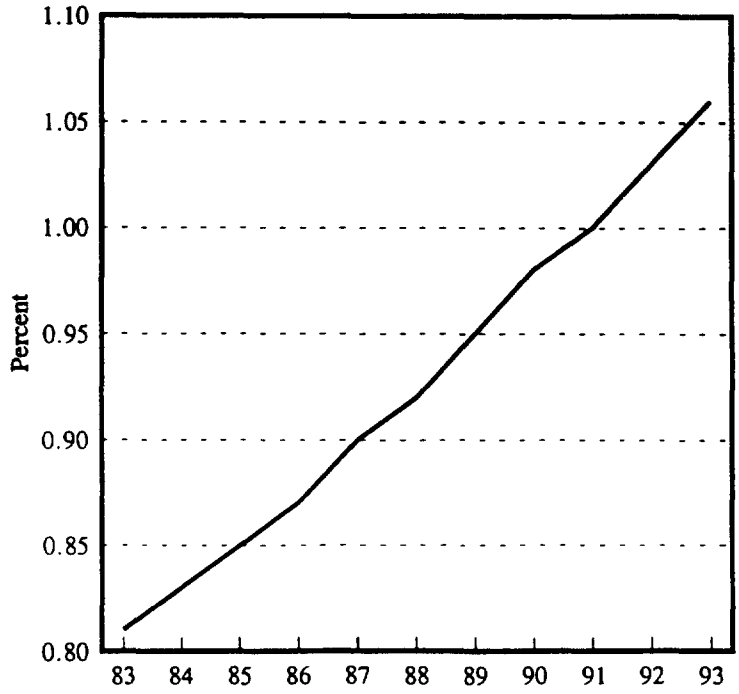


Table 7
Each Industry's Telecommunications Spending as a Percent of It's Own Real Industry Output

	1983	1993	Share Growth
Agriculture, Forestry, & Fishing	0.24	0.25	0.21
Metal Mining	0.50	0.46	-0.82
Coal Mining	0.20	0.18	-1.39
Oil and Gas Extraction	0.16	0.09	-5.26
Nonmetal Minerals, except Fuels	0.40	0.42	0.56
Residential Construction	0.41	0.49	1.81
Nonresidential Construction	0.31	0.38	1.95
Public Construction	0.34	0.37	0.89
Meat Products	0.18	0.18	-0.19
Beverages	0.47	0.52	1.07
All Other Foods	0.23	0.25	0.98
Tobacco Products	0.10	0.22	8.07
Carpets and Rugs	0.29	0.30	0.26
All Other Textiles	0.24	0.26	0.70
Apparel/Other Finished Textiles	0.59	0.64	0.86
Wood Buildings, Mobile Homes	0.83	0.98	1.67
Other Lumber and Wood Products	0.32	0.45	3.67
Household Furniture	0.32	0.37	1.54
Furniture, except Household	0.46	0.56	1.98
Pulp, Paper, Paperboard Mills	0.31	0.34	0.87
Paperboard Containers and Boxes	0.39	0.45	1.40
Miscellaneous Converted Paper	0.34	0.43	2.35
Newspapers, Periodicals, Books	1.84	2.80	4.31
Other Publishing and Printing	0.43	0.56	2.69
Chemical Products	0.35	0.36	0.36
Paints and Related Products	0.35	0.43	2.08
Drugs, Soaps, Toiletries	0.42	0.63	4.09
Agricultural Chemicals	0.41	0.39	-0.42
Asphalt Paving/Roofing Materials	0.66	0.60	-0.99
Petrol Refining, exc. Paving/Roof	0.15	0.09	-4.80
Tires and Tubes	0.15	0.14	-0.68
Other Rubber and Plastic Products	1.25	1.37	0.89
Leather and Products	0.32	0.39	2.00
Glass Containers	0.36	0.40	0.97
Other Stone, Clay, and Glass	1.07	1.13	0.57
Blast Furnaces and Steel Mills	0.53	0.51	-0.26

Table 7 (Cont'd)
Each Industry's Telecommunications Spending as a Percent of It's Own Real Industry Output

	1983	1993	Share Growth
Iron and Steel Foundry Products	1.66	1.80	0.84
Nonferrous Metal Products	0.54	0.56	0.50
Building Materials and Wire	1.14	1.27	1.04
Other Fabricated Metal Products	1.45	1.58	0.86
Turbines/Turbine Generators	0.73	0.88	2.00
Internal Combustion Engines	0.51	0.57	1.23
Farm and Garden Machinery	0.35	0.40	1.32
Constr., Mining, Handling Equip.	0.63	0.70	1.01
Metalworking Machinery	0.70	0.79	1.34
Special Industry Machinery	0.79	0.99	2.25
General Industrial Machinery	0.71	0.85	1.78
Computer and Office Machines	0.99	0.90	-1.02
Refrigeration and Heating Equip.	0.62	0.70	1.16
Industrial Machinery, n.e.c.	0.48	0.53	0.97
Electrical Trans. and Distr. Equip.	0.79	0.90	1.36
Electrical Industrial Apparatus	2.94	3.55	1.92
Household Appliances	0.52	0.53	0.13
Electric Lighting/Wiring Equip.	0.73	0.84	1.45
Household Radio/Video Equip.	0.56	0.46	-1.79
Communication Equipment	1.06	1.11	0.45
Electronic Components	1.10	1.14	0.39
Misc. Electrical Equip & Supplies	0.78	0.84	0.72
Motor Vehicles and Parts	0.21	0.24	1.32
Complete Aircraft	0.54	0.69	2.50
Aircraft Parts	0.73	0.82	1.19
Shipbuilding and Tanks	0.42	0.48	1.32
Railroad Equipment	0.48	0.52	0.85
Other Transportation Equipment	0.34	0.40	1.46
Search and Navigation Equipment	0.99	1.18	1.79
Measuring/Controlling Devices	1.03	1.23	1.82
Medical Instruments and Supplies	0.67	0.83	2.24
Ophthalmic Goods	1.23	1.34	0.88
Photographic Goods	0.45	0.46	0.06
Other Durable Goods	0.40	0.43	0.85
Railroads	0.14	0.11	-2.51
Motor Freight and Warehousing	1.48	1.74	1.64

Table 7 (Cont'd)
Each Industry's Telecommunications Spending as a Percent of It's Own Real Industry Output

	1983	1993	Share Growth
Water Transportation	0.55	0.48	-1.36
Air Transportation	1.84	2.05	1.10
Pipelines, Except Natural Gas	0.10	0.10	-0.35
Local/Other Transp. Services	1.88	2.75	3.85
Radio/Television Broadcasting	0.81	1.08	2.93
Telecommunications Services	1.83	1.83	0.00
Electric Utilities	0.14	0.16	1.26
Gas Utilities	0.04	0.03	-0.97
Sanitary Services	0.78	1.13	3.70
Wholesale and Retail Trade	1.63	1.88	1.44
Finance, Insurance, Real Estate	0.87	1.28	4.04
Health Services	0.81	1.34	5.10
Business Services	1.60	2.17	3.07
Other Services	0.87	1.27	3.90
Public Administration	0.69	0.97	3.42
TOTAL ECONOMY	0.81	1.06	2.73

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ATTACHMENT 8

Accelerating Investment in the Telecommunications Network - Impacts of Technology Adoption and Service Quality

by

Lawrence K. Vanston

Accelerating Investment in the Telecommunications Network — Impacts on Technology Adoption and Service Quality

Lawrence K. Vanston, Ph. D.
President
Technology Futures, Inc.[1]

in support of the
United States Telephone Association
Proposals for Price Cap Reform
Federal Communications Commission
CC Docket No. 94-1

May 5, 1994

I. Introduction

The United States Telephone Association (USTA) has proposed revisions to the LEC price-cap plan that includes earnings incentives and market-based pricing[2]. These revisions are expected to stimulate additional investment by LECs in the public telephone network. According to the Darby Report[3], the likely annual investment increase will range from 5% in 1995 to 15% in 2004. These estimates are based on an assessment of how the investment community would react to regulatory reform and how LEC managers would, in turn, react to signals, such as stock prices, sent by investors.

At the USTA's request, Technology Futures, Inc. (TFI) analyzed the impact this increase in investment would have on LEC technology deployment plans and on the availability of

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[1] Technology Futures, Inc. (TFI) is a research institution established in 1978 and located in Austin, Texas. TFI specializes in technology forecasting and strategic planning in several industries, including the telecommunications industry. It has provided technology forecasts in the telecommunications area since 1984. TFI also conducts regular seminars in technology forecasting and publishes the annual review, *Communication Technology Update*, the research journal, *New Telecom Quarterly*, and research reports on various new technologies.

[2] A general economic analysis of these proposals is provided by Robert G. Harris, University of California, Berkeley and Law & Economics Consulting Group. Inc., *The Economic Benefits of LEC Price Cap Reform*, May 5, 1994, submitted in support of the USTA in this proceeding.

[3] Lawrence Darby, Darby Associates, *Price Cap Reform, Financial Incentives and LEC Investment*, May 5, 1994, submitted in support of the USTA in this proceeding.

digital communications services on the public telephone network. These services include narrowband Integrated Services Digital Network (ISDN) services and what we call Public ATM-Switched Multimedia Services (PAMS). The analysis shows that with this increased investment, new digital services will become widely available and adopted one to two years earlier than they normally would. Or, put another way, by the year 2000, we would see 29% greater ISDN adoption and, by 2004, 38% greater PAMS adoption.

As documented in the WEFA report[4], the increased investment in response to regulatory reform will have benefits to the US economy. These benefits come through the stimulation of further investment and job formation, and through the greater efficiency of the US economy afforded by digital communications. The WEFA Group modeled the latter factor by considering the improvements in the *quality* of telecommunications services as well as changes in real prices. TFI developed an overall telecommunications quality index that reflects the data rate improvements offered by digital communications services.

The quality index is similar to indices used to reflect performance increases in computers, except that the quality improvements are weighted by the percentage of businesses and households that actually adopt digital services. This leads to a more conservative index that gradually increases as digital services, once made available, are adopted. As one would expect, accelerated service availability, stimulated by increased investment, also accelerates service adoption and, therefore, improves the quality index. TFI concluded that the cumulative quality improvement by 2004 will be 19% greater with the increased investment than without it. This translates to the WEFA assumption of a 1% greater annual quality improvement in 1995, increasing to 3% by 2004.

For the analysis, TFI identified two scenarios: a base case and an accelerated case. The base case uses TFI's current forecasts for the deployment of new network technologies such as digital switch upgrades, fiber optics, Synchronous Optical Network (SONET) equipment, and Asynchronous Transfer Mode (ATM) switching. These forecasts use past technology deployment and adoption rates to estimate future rates of change. They also, in part, make use of LEC planning data, expert opinion, and other forecasting techniques. TFI analyzed the investment requirements implied by the TFI forecasts and found them to match the base case investments used in the WEFA model almost exactly.

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[4] Michael Raimondi, The WEFA Group, *The Economic Impact of Revising the Interstate Price Cap Formula for the Local Exchange Carriers*, May 5, 1994, submitted in support of the USTA in this proceeding.

The base case assumes that LECs invest in new technologies at a moderately higher rate than they have in the past. The base case provides a positive outlook for the availability and adoption of new digital services, and in itself, assumes a positive regulatory climate. The accelerated case reflects the application of the additional investment expected from the specific LEC price cap reforms proposed in this proceeding. The technology deployment curves in the base case were accelerated to match the investment increases. This provided the basis for estimating the improvements in service availability, service adoption, and the quality index.

II. The Mass Markets for Digital Services

The analysis assumes there is a mass market in the business and consumer sectors for digital communications services. By *mass market* we mean that users are measured in the millions or tens of millions, that large economies of scale are realized, and that the service is economical and easy-to-use. This, of course, is also the premise behind the "information highway".

The last decade has seen many products and services make the transition from niche to mass markets. Examples include:

Fax	VCRs	SLR Cameras
Computers	Laser Printers	Cellular Telephones
Video Cameras	Answering Machines	Modems
LANs	Digital Audio	On-line Info Services

Each of these technologies was at first limited to large organizations who could justify the cost of the equipment or services. Today each is widely available and used by millions. We are on the verge of the same type of shift in telecommunications. Today, digital services are the province of large organizations with private networks. In the near future, small and medium-sized business, and homes, will have access to the same benefits. However, like the manufacturers or service providers in each of the above examples, LECs will have to make tremendous investments in technology, at substantial risk, to achieve the economies necessary for the mass market provision of digital communications services.

Hundreds of applications have been identified for digital communications services. Just a few general categories of particular importance and widespread appeal are mentioned here. The compelling benefits of each of these applications, to both business and residential customers, is why TFI believes that digital communications services truly represent a mass market.

Modem Replacement

For the mass market, the only option today for wide-area data communications is to use a modem and the voice telephone network. Tremendous progress has been made in modem technology; the latest mass market technology can usually transmit at 14.4 Kb/s over the public telephone network (up from only 300 b/s at the beginning of the personal computer revolution). However, we are quickly reaching the limit of how fast data can be transmitted over the voice telephone network. The first mass market digital communications service, ISDN, on the other hand, will immediately bump the rate up to 64 Kb/s per channel). To the customer, ISDN will be contained in a computer card or a separate modem-like unit. Thus, for most customers, ISDN will appear to be the next step or two in modem technology, except that they will subscribe to ISDN telephone service also. The faster data rate will have immediate benefits to customers. For example, graphical user interfaces and image browsing will become much more practical on the Internet.

Fax

Today's fax machines typically take about 15 to 20 seconds to transmit a page at low resolution. The next generation, Group 4 fax, will transmit the same page in a few seconds, about as fast as a laser writer prints or a copier copies. With Group 4 fax, it will be faster and cheaper to fax a 100-page document than to copy and mail it. Alternatively, Group 4 fax can send high-resolution images in about the same time as today's fax. For many documents, this will make the difference in whether a fax version is just as good as the hard copy. Whether the user chooses quantity or quality, the impact will be a four-fold improvement in value. Group 4 fax machines are available today, but will remain a niche market until public digital networks are a reality.

Image Applications

Apart from fax, there are many computer-based applications of image transmission. Computer-based imaging, also called electronic imaging, is the storage, manipulation, and retrieval of images on computers. Anyone who deals with large quantities of documents or pictures can benefit from the economy, the immediacy, and the remote access afforded by electronic imaging. Potential heavy users include government agencies, schools, libraries, hospitals, clinics, doctors, financial institutions, manufacturers, law firms, realtors, insurance agents, researchers, foresters, geologists, engineers and architects, to name a few. Today, most of the documents and images are transported physically; within ten years most will be transmitted electronically. The size of these markets vary, but together they comprise a mass market.

Video Communications

Videoconferencing is already well-established as a niche market for internal communications within large, multi-location organizations. This is because both equipment and communications costs have been high. However, desktop videoconferencing is coming. This will put videoconferencing within the reach of small and medium-sized businesses, offering them the same savings in time, expense, and efficiency now enjoyed by large business. Although more speculative, there are also residential applications such as visiting with your parents in Florida or your daughter at Michigan State. Also, given demographic and social trends, in-home monitoring and security applications could become important.

Interactive Multimedia

Interactive multimedia has now reached the mass market stage, but we are just beginning to realize all of its benefits in education, training, knowledge acquisition, marketing, and entertainment. At first, multimedia was seen as a stand-alone technology served by CD-ROM or laser disks. Recently, however, people have begun to recognize the power of networked interactive multimedia, which provides both interaction among people and remote access to oceans of information. Interactive multimedia and text-based, networked information services (like Internet) have both emerged as mass market technologies. Given the availability of digital communications services, networked interactive multimedia will likely emerge as one also.

Video Dialtone

Video dialtone has much in common with interactive multimedia, but, to most people's thinking, revolves around a television instead of a personal computer. With video dialtone, entertainment and information are customized rather than channelized, giving the viewer control of scheduling and content. Video on demand, pay-per-view, interactive television, interactive entertainment, and home shopping are all potential applications. Whether provided over cable television networks, telephone networks, or other media, video dialtone requires digital communications. Early applications will be limited to one-way transmission of video from a local head-end transmitter to the television. Ultimately though, video dialtone may be available on end-to-end digital networks, allowing highly specialized programming to become widely dispersed (for example, televised FCC hearings).

Telecommuting and Home Offices

Many of the above are business applications that will be used by people working at home, including telecommuters. Telecommuters are people who are employed by companies, but spend a significant portion of their time working at their home instead of driving to work every day, wasting time and gasoline and generating pollution. According to Link Resources Corporation, more than 6.6 million people called themselves telecommuters in 1992, and that number is expected to grow to 9.4 million by 1998. And this does not include other people who work at home or have home offices.

The adoption of digital communications services will not explode overnight. Like the other mass market technologies mentioned above, digital services will have to work their way up the adoption curve. However, the adoption of digital services is self-reinforcing. The more adopters, the more useful these services become to current and prospective users alike.

TFI's forecasts for the adoption of digital services are similar to the historical adoption patterns of similar mass market technologies in both business and the home. For example, Exhibit 1 shows a forecast of the adoption of desktop video communications, along with the adoption history of other desktop computer technologies. This forecast, as with forecasts for similar services, assumes the timely availability of public digital services.

III. Digital Communications Services

Two generic service types that can support the mass market for digital communications services were the focus of TFI's analysis. The generic types are narrowband Integrated Services Digital Network (ISDN) services and Public ATM-Switched Multimedia Services (PAMS). Both provide end-to-end switched digital channels on the public telephone network. ISDN provides circuit-switched channels of 64 kilobits per second (Kb/s) to 1.5 megabits per second (Mb/s). PAMS will provide Asynchronous Transfer Mode, cell-switched channels of 1.5 Mb/s to 150 Mb/s.

Narrowband ISDN

Narrowband ISDN is built on the foundation of today's digital voice telephone network. It will provide good, economical digital communications for the mass market in a timely manner with moderate requirements for infrastructure upgrading.

The *basic rate* narrowband ISDN interface provides two B-channels of 64 Kb/s each, and a D-channel of 16 Kb/s that is used primarily for exchanging call control information. The B-channels provide circuit-switched, end-to-end digital channels for communications between customers. A B-channel can also be used to interface with the voice telephone network. For example, a typical customer would probably use one B-channel for voice calls and another for non-voice applications. The *primary rate* ISDN interface provides twenty-three 64 Kb/s B-channels and one 64 Kb/s D-channel, for a total of 1.544 Mb/s. It is for customers that have larger communications needs and is analogous to standard DS1 access.

Being a circuit-switched service, ISDN provides a continuous digital transmission path for the duration of a call. This type of switching is ideal for applications such as voice, videoconferencing, fax, and image transmissions. Packet switching is preferred for the bursty communications characteristic of many data applications. Still, ISDN can provide access to packet-switched networks at higher data rates than modems on voice lines.

In many ways, ISDN is analogous to the early personal computers. Like the personal computer, ISDN will:

> Provide the mass market with economical access to capabilities that were previously the province of large organizations.
>
> Stimulate a host of new applications, both foreseen and unforeseen.
>
> Spawn the development and purchases of associated hardware, software, and services.
>
> Prove the market, thus stimulating additional growth and competition.

Public ATM-Switched Multimedia Services

Loosely defined, PAMS will provide a collection of end-to-end digital services that have greater bandwidth and more flexibility than narrowband ISDN. Whereas narrowband makes heavy use of the existing network infrastructure, PAMS will require major changes in the network infrastructure and the methods by which the network is operated. Thus, the greater benefits of PAMS will be longer in coming, and more expensive—at least initially. For our purposes, PAMS is defined as a service that:

> Uses internationally standardized user interfaces and protocols.
>
> Provides a user interface and end-to-end digital connectivity of at least 1.5 Mb/s, initially, and evolving to rates as high as 150 Mb/s.
>
> Efficiently supports a variety of both packet-switched and circuit switched applications with a variety of characteristics using Asynchronous Transfer Mode (ATM) cell switching.

PAMS will be able to support ISDN as well as other specific services such as frame-relay and SMDS. One might think of PAMS as the super-set of high-performance digital services that are offered on the public telephone network of the future.

To carry forward the personal computer analogy, PAMS will be like today's multimedia computers, offering economical performance, efficiency, and almost limitless possibilities for new applications. The relative advantage of PAMS over ISDN will be similar to that of today's PCs over the original PC. And like with PCs, it will take time for the

cost/performance trends to allow full realization of the possibilities of digital communications services.

IV. Measuring Quality Improvements from Digital Services

The benefits of public digital services to end-users are immense and will easily total billions of dollars per year, once these services become widely available or adopted. Some benefits, such as replacing physical transport, can be estimated relatively easily. Others are less measurable, such as the greater effectiveness and efficiency in the operation of individual industries, ancillary benefits of stimulating non-telecom investment in new technology, and benefits to our environment and resources.

Rather than attempt to quantify all of these benefits, TFI projected quality improvements in digital communications services as a proxy for customer benefits. This approach is common for the computer industry. For example, the price of a personal computer has stayed reasonably stable, while the performance has greatly increased. Roughly speaking, in 1984, a few thousand dollars would buy an IBM XT with an 8086 processor running at about 6 MHz, a 10 Mb hard disk, and 64 Kb/s of memory; ten years later, the same money buys a 33 MHz 484 processor, a 240 Mb hard disk, and 4 Mb of memory, corresponding to improvement factors of five, 24, and 62, respectively.

For voice telecommunications, we have seen a continuous pattern of quality improvements in terms of less distortion, less cross-talk, lower call setup times, and expanded billing features, to name a few examples. While these types of improvements are expected to continue, TFI concentrated on increases in the quality of digital services, because, over time, these services will increase in importance.

The most straightforward way to measure digital service quality is by the data rate (assuming an acceptable error rate). Narrowband ISDN provides a 64 Kb/s end-to-end digital channel compared to a maximum of 14.4 Kb/s on modems. If this four-fold technical improvement is perceived by the customer as a proportional increase in quality, we can also say ISDN provides a four-fold increase in quality. For most applications, this is a safe assumption. With ISDN and Group 4 fax, you can send a fax of the same quality in one-quarter the time, proportionally saving long-distance charges. (If a customer instead decides to send a higher-resolution fax in the same time as today's fax, he is, in effect,