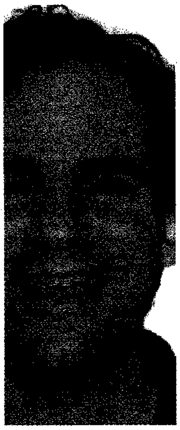

Forecasting commercial change

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Why is so little in the commercial world as dependable as Moore's law? Doesn't that seem odd? Why is it that a savvy engineer can forecast the rate of technical change, but it is impossible to find a market analyst who can correctly (and reliably) forecast anything about market events?

Three very important facts shape this pervasive uncertainty. They are well known, though they are so obvious that nobody thinks to comment on them any longer.

Fact 1: Information technology comprises a stunning variety of distinct technologies—much more than just the microprocessor. These technologies define the technical frontier. They include hardware, software, networking and communications, digital and analog systems, operating systems, operations software, tools and applications, communications software, central switches and PBXs, mainframes and microcomputers, storage devices, input devices, routers and modems, TCP/IP-based technologies, proprietary and other open standards, among others. In addition, a very wide variety of technical specialties, kinds of IT firms, and modes of invention help to advance these technologies.

This variety means that simply characterizing the rate and direction of technical progress in IT is not a trivial activity. Rates and directions differ across products and components. Frontier technology may involve new products or processes, combinations of existing ones, retrofits on vintage components, or new systems of interrelated components.

Fact 2: Users adopt new IT for different reasons. In many applications IT advances are not primarily aimed at reducing costs. Often the use of new IT permits improvements in the quality and reliability of products or, especially, services. Furthermore, frontier IT frequently enables the invention of entirely new services and products, which some users value and others avoid.

At the firm level, these new services may provide permanent or temporary competitive advantages. When the new services are reasonably permanent, the firm may see returns to the investment in the form of increases in final revenue or other strategic advantages. If all firms in an industry imitate a new product or service, it quickly becomes a standard feature of doing business in a downstream market. The benefits from the new technology are quickly passed on to consumers in the form of lower prices and better products. In this case, the benefits to a firm do not appear as a revenue increase; but they exist, nonetheless, in the form of losses the business avoided.

Fact 3: Adopting complex IT also involves a variety of investments by users and vendors. Many of the highest-value uses involve more than simply buying and adapting market IT capital goods. Complex IT is rarely sold as a turnkey system. More typically, it involves taking general technology and adapting it to unique or complex circumstances for which it may or may not have been designed. Users often contribute substantially to this adaptation process.

These last two factors mean there is no direct relationship between investment in IT and productivity. More generally, the future does not arise solely because something is invented; it also comes from the adoption and adaptation of technology by users. The importance of the point is not to debunk the importance of invention, but to increase our understanding of the unpredictable factors that influence the flow of services from new technology.

More to the point, changes to the flow of services evolve slowly. Only after the passage of time, and the gradual accumulation of many incremental improvements in processes and outputs, will the result be a dramatic change. It takes time to translate an invention into a viable commercial product. Business models must be developed and new distribution channels created to spread the invention geographically from its region of origin, one set of users must learn from another distinct group, and so on.

Waves of IT advances

Due to its complexity and variety, there is not one adoption pattern for characterizing all IT, nor are patterns necessarily

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similar to some important historical episodes of diffusion, such as those of radio, television, and the automobile. It is tempting to think of IT as the simultaneous diffusion of several tightly coupled, interconnected technologies, each with an adoption curve strongly dependent on the other. It is true for the interrelated development of airframes and jet engines, but this model too is deceptively simple.

In reality, new waves of IT invention set off other new waves of IT invention by users, and each wave has its own diffusion curve of adaptation and adoption. For example, the invention of cheap fiber optic cable, one of the key elements in the communications revolution, did not immediately change the capability of phone service nationwide. Performance and features changed in fits and starts, as digital-switching technologies, repeaters, and other software that increased fiber's capabilities were developed and adopted. Economic value changed slowly too, because new fiber networks brought about new services from phone companies and, more importantly, investments from users in digital equipment. These new services and new investments could only be built, tested, and marketed after the underlying infrastructure improved.

Similarly, such important contemporary technologies as the World Wide Web and enterprise resource planning (ERP) have set off entirely new waves of invention. The Web is inducing a great deal of new application development. Along with TCP/IP-based technologies, new business models are emerging for delivering and using data-related services. Similarly, the unification of distinct systems associated with ERP is permitting a new wave of IT and business control. These changes are not merely the tail end of a diffusion curve that began long ago; they represent a renewed process.

Why forecasting is difficult

When a new wave advances, it enables applications that have no historical precedents. So, today's users of a new technology find it difficult to imagine or estimate the future demand for complementary products arising out of future inventiveness. Even if early versions of a general-purpose technology have partially diffused to leading adopters, whose inventive activities have been carefully observed, it will still be difficult to forecast the future population of adopters. They will be using the technology when the prices drop and the capabilities expand, and may have different characteristics and needs from the first users.

History is full of such examples. Among the best known are those in which early users and industry leaders badly misforecast future demand. In the US cellular phone industry, leading industry experts at AT&T and at the Federal Communications Commission vastly underestimated the demand for inexpensive cellular-based mobile communications. The consensus of many experts was shaped by their observation of mobile phone use over radio bands. The largest users of radiophones were ambulances, taxis, and wealthy real-estate agents. As it turned out, these were hardly a representative group of users for predicting the adoption pattern for cellular phones as prices declined.

In another well-known example, IBM's management vastly underestimated the demand for inexpensive personal computing. Again, this was quite understandable in historical context. Even at the world's largest and most commercially successful computer manufacturer, it was difficult to foresee the character of the demand for low-cost personal computing technology by extrapolating from the demand for high-cost, centrally managed computing in minicomputers and mainframes. The former had an independent software industry developing many custom and shrink-wrapped applications, and the latter had the manufacturers controlling the supply of both hardware and software.

It is easy to bring the examples forward to recent events. It is very difficult now to forecast even the qualitative nature of the demand for inexpensive, capable long-distance networked computing applications. Forecasters can look at earlier experiences with inexpensive computing (PCs and workstations) and with expensive and difficult networked computing applications (NetWare and Electronic Data Interchange). However, this hardly represents the cost conditions and economic opportunities that future users will face after the deployment of extremely inexpensive computing capabilities and low-cost, high-bandwidth fiber and wireless communications technologies.

These deployments will induce (and already have to some extent) the entry into this market of thousands of firms trying to solve previously nonexistent issues. The early users of TCP/IP were scientists and engineers, primarily in higher education and laboratories. These user groups engaged in inventive activity, to be sure, but the issues found in an engineering setting differ significantly from those found in today's business setting.

Epilog

These observations are about more than forecasting under conditions of extreme uncertainty; they also relate to the central role of market behavior in producing that uncertainty and resolving it. Investment and use differ over time and are associated with different economic goals. The final output from organizations that use IT may also change over time. Some changes may generate new revenue; some may induce the entry into the market of new firms with business models using the new IT in a radical way; and some may induce a market exit. The key features of the final output of the new IT may, therefore, change radically over time.

This makes measuring the information economy difficult, to say the least. It makes comparisons across countries almost impossible. So, we'll have this topic with us for a long time.

If you are curious, feel free to consult a much longer set of musings about the topic on my Web page: http://skew2.kellogg.nwu.edu/greenste/. The paper, written with Tim Bresnahan for the Organization for Economic Cooperation and Development, is called "The Economic Contribution of Information Technology: Issues in International Comparisons."