When technologies converge

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Pregnancy makes expectant parents nervous. Much medical technology plays to their anxiety and medical needs. Since my wife and I have recently gone through this for a second time, I know something about it, and she fills in the holes in my knowledge when I ask. (She's a physician.)

New medical technologies let expectant parents and their doctors probe, record, and investigate many details about an unborn child's ultrasound has received much attention from commentators. In practice, most expectant parents see only the tip of the technological iceberg during an ultrasound exam. Here, I consider only that tip. More to the point, ultrasound technology motivates my discussion about technological convergence.

Convergence and markets

Two products converge in substitutes when users consider the products to be interchangeable. This happens when a product develops features increasingly similar those of other products. It also occurs when users put together common components to perform functions already performed by existing products.

Two products converge in complements when they increasingly work together better than they worked alone. This occurs when different firms develop products or subsystems within a product that forms a larger system. The system's output can potentially exceed output from the sum of the parts.

A modern PC performs most of a typewriter's functions. A modern cell phone performs most of the same functions as a landline phone. At a simple functional level they are examples of convergence in substitutes.

Modern medical imaging equipment, such as an ultrasound or CT scanner, combines advanced processing capabilities with traditional sensor devices. This marriage of capabilities provides an example of convergence in complements.

Convergence in complements is often associated with the creation of new capabilities. Yet, rarely is such creation not associated with at least some convergence in substitutes. For example, the increasing replacement of the X ray by the CT scanner is an example of convergence in substitutes. At the same time, the CT scanner evolved so as to permit many functions previously unobtainable with even the best X-ray technology.

In most markets convergence is difficult to date because there is always unavoidable ambiguity about the feasibility of specific products at a particular price at any given time. In addition, these products often are technically complex, so they produce an inherent ambiguity about what users know and when they know it. Similar issues arise in dating progress in the diffusion of new innovations through their life cycles. As such, the issues are not unique to convergence.

System and market levels

Convergence may occur simultaneously at the functional and system levels. In a particular instance, convergence may be construed as convergence in complements at one level of analysis and, equally appropriately, as convergence in substitutes at a different level. For example, an operating system (say, Windows) may be a complement to a particular hardware platform (say, an Intel x86 chip), together performing the functions of a server. At the system level, different combinations of operating systems and hardware may also perform similar server functions. Hence, the Wintel-based servers converge with servers using older operating systems such as mainframes.

In a "network of networks" system such as those linked by Internet protocols, convergence typically occurs over time due to the actions of different decision makers. This happens because the necessary scope and breadth of technical and market expertise are widely dispersed among firms and users, raising the possibility of initiatives for technological or market convergence from many corners.

For example, the Internet was first used primarily for electronic mail and later for World Wide Web applications. The first developers and users of these capabilities were academics and researchers. Developments in commercial applications, which exploded with the Internet's privatization by the US National Science Foundation, came from different sources and were aimed at nontechnical users. These new capabilities replaced some old communication methods and also offered

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new channels for communicating. Faxing, broadcasting, and telephony using Internet protocols came later, building new capabilities onto the larger system.

Since market and technological risks in any technically evolving market are already high, particularly when capabilities are widely dispersed in a network of networks, there is an open question over whether convergence in a network of networks raises any additional strategic and managerial issues. In this respect, one factor seems particularly salient: convergence in complements on a network of networks can lead to significant discontinuities in the competition for delivery of and how we evaluate the relative performance of traditional products. This arises due to the emergence of new capabilities having little precedent.

Discontinuous change alone is not unusual in a market for technically complex goods. However, such discontinuity might arise due to initiatives from many providers of complementary goods. This would then feed the perception among established companies that markets can change rapidly for unanticipated reasons. This is a market risk that cannot be reduced significantly. At best, management can be alert to changes in external conditions by making strategic investments in information gathering, in tools for tracking market and technological trends, and in flexible organizational structures. That does not, however, eliminate the risk that a garage entrepreneur may invent a piece of software that will obliterate an established firm.

More than technological determinism

As noted, convergence may arise, in part, due to changes in key technological constraints. These could be increases in computing capabilities, reduced cost of data transmission, and technical improvements of integrated circuits. As shorthand for describing convergence at a system level and for making predictions about market developments, analysts often make a sweeping generalization and ascribe causation for convergence to a very few technological trends.

This shorthand can carelessly become an incomplete theory of convergence with strong elements of technological determinism. The development of new technical opportunities must play a role in any analysis of the computer industry's history. For example, the development of technological opportunities cannot provide, by itself, much of an explanation for changes in a firm's behavior, changes in buyer choices of vendors, and changes in the locus of profitable opportunities.

A subtler problem with technological deterministic arguments is that they may also fail to point at nontechnical bottlenecks to further developments. For example, many worldwide communications and broadcasting systems involve significant government regulation of partially or wholly monopolized communications markets. This means that the rate and direction of convergence in networking applications often depends on critical government decisions. The historical emergence of convergence in complements in wireless technology in the United States depended on rules governing the development of analog cellular and digital wireless applications over the publicly governed spectrum. Similarly, convergence in substitutes in alternative modes of voice transmission depended on rules opening market segments, such as long-distance telephony, to entrants using technologies other than traditional land-line-based facilities.

The next time you hear about convergence, consider carefully. Is it about putting things together or about replacing the old with the new? Is it about a single product or about sweeping changes to an entire system or market? Focusing on the questions' scope and precision will help you understand the market factors that organize the evolution of change.

Ultrasound revealed

Ultrasound combines specialized sensors with microprocessor-based computing hardware and display technology. As you probably know, the sensors emit sound waves, then record the echoes bouncing off biological structures. The computer reassembles these signals on the screen in a form meaningful to humans. In brief, this technology resulted from the marriage of routine display technology with some clever technical advances in signal processing, workstations, and sensors. If ever there was an example of the convergence of medical equipment with computing, this is it.

Despite its apparent novelty, ultrasound is a relatively mature technology. In most offices a "technician" operates the ultrasound equipment, which is moderately expensive. It's so easy to use that the technician only needs a year or two of training to learn how to get the equipment to produce a meaningful image in real time. Like much training in medicine, the basics don't take long to learn. Most of the training time focuses on preparing the technician for rare, but terribly important, nonroutine events.

Ultrasound has become a routine experience for modern parents-to-be. Like magic, out comes an image of the baby growing inside the mother (and every image looks like the alien inside Sigourney Weaver). Next comes the agonizing debate about whether to have the technician reveal the baby-to-be's gender. You might even hear comments from expectant grandparents about how this wasn't possible in their day.

Three desires usually motivate our using ultrasound: a picture for the parents, pictures for the grandparents, and clues about gender. However, a fourth, less prominent, motivator is medical necessity. Ultrasound reveals information about things such as the heart, kidneys, bone structure, and even the amount of amniotic fluid. The technician routinely checks all this, and if everything looks fine, says nothing. If there are problems, the technician alerts a doctor.

Ultrasound exemplifies a useful convergence of medicine and computers, hence its development. This extraordinary tool assists in one of life's most basic and nerve-wracking experiences. In fact, convergence in various forms has found its way into many routine areas of our lives. That ubiquity makes it worth trying to understand the moving parts that go into convergence.