Creating External Capabilities: Innovation and Vertical Disintegration in the Microcomputer Industry

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In a famous passage in *Capitalism, Socialism, and Democracy,* Joseph Schumpeter singled out the large capitalist firm as the principal source of economic progress since the nineteenth century.

> As soon as we go into the details and inquire into the individual items in which progress was most conspicuous, the trail leads not to the doors of those firms that work under conditions of comparatively free competition but precisely to the doors of the large concerns--which, as in the case of agricultural machinery, also account for much of the progress in the competitive sector--and a shocking suspicion dawns upon us that big business may have had more to do with creating that standard of life than with keeping it down [15, p. 82].

It is not surprising that business historians, with their focus on large enterprises, should be sympathetic to Schumpeter's argument. Indeed, Alfred D. Chandler, the dean of present-day business historians, paints a similar picture of the large firm as an engine of progress. In Chandler's story, however, the large enterprise comes across less as a generator of innovation than as an "institutional response" to innovation and growth whose superiority lies in its ability to create massive internal economies of high-volume production [2, p. 12].

Yet, there is another important tradition in economics that sees the sources of economic growth in a slightly different light. While never denying the importance to economic progress of internal economies, Alfred Marshall and his followers also highlighted the systemic interactions among

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a large number of competing and cooperating firms.[2] For Marshall such interaction could yield "external economies" that play an important role in economic progress quite in addition to that played by the economies internal to particular business organizations [10, book IV, chs. IX-XIII].

As William Lazonick suggested in his recent keynote address to the Business History Conference, economic progress requires the development of organizational capabilities.

> Organizational capabilities represent the power of planned and coordinated specialized divisions of labor to achieve organizational goals. Through planned coordination, the specialized productive activities of masses of individuals can coalesce into a coherent collective force. Through planned coordination, organizations can integrate the various types of knowledge needed to develop new products and processes. Through planned coordination, organizations can speed the flow of work from purchased inputs to sold outputs, enabling the enterprise to achieve lower unit costs [8, p. 1].

It is clear from the diction of this passage that Lazonick sees organizational capabilities as primarily a matter of conscious, centralized administrative coordination. By contrast, Marshall envisaged the creation of organizational capabilities much more broadly. For Marshall, as Brian Loasby points out, capabilities need not all reside within the boundaries of the firm. Not only do firms possess organizational assets--so also do *markets*. "Both are structures for promoting the growth of knowledge, and both require conscious organization" [9, p. 120]. Some important economic capabilities can reside within a network of competing and cooperating firms. And, although often "conscious" and not restricted to price signals alone, the coordination among these firms is far from centrally planned.

One area in which a decentralized, market-like organization may have advantages is in the generation of certain kinds of technological and organizational innovation. It is clear, as Marshall certainly understood, that some types of innovation take place more readily within the organizational structure of a firm. I have elsewhere argued for "dynamic" transaction-cost explanations of vertical integration, in which the difficulties of coordinating some types of innovative activity across market boundaries can make internal organization a cheaper alternative [5]. And a coauthor and I have explored one important case in which innovation--and rapid declines in product price--took place within the framework of internal economies and large-scale production: the moving assembly line and the Ford Model T [7]. But we also found episodes in the history of the automobile industry in which the existence of a variety of competing firms spurred innovation and

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[2] From a purely static point of view, it is true that external economies are external to particular firms not to the industry (appropriately defined) as a whole [4, p. 597]. Marshall and his followers did not reason in strictly static terms, however. See, for example, [16].

even forced some vertical disintegration upon the large firms. Moreover, a number of other cases come to mind in which rapid progress--rapid declines in product price and improvements in product quality--took place within a highly disintegrated structure.

As Nelson and Winter have argued, innovation in times of uncertainty is a matter of rapid trial-and-error learning that benefits from competition among many alternatives [12]. To this extent, the ability of a large organization to coordinate the implementation of an innovation, which is clearly an advantage in some situations, may be a disadvantage in others. Coordination means getting everyone on the same wavelength. But the variation that drives an evolutionary learning system depends on people being on different wavelengths--it depends, in effect, on outbreeding. This is something much more difficult to achieve in a large organization than in a disintegrated system. Thus, the ability to engage in rapid trial-and-error learning can sometimes be an external economy that cannot be traced back to economies internal to the individual firms: it is a property of the system as a whole.

The Microcomputer Industry[3]

One of the most striking examples of externally created organizational capabilities is the present-day microcomputer industry. The history of the industry is rife with unintended consequences and what we might call unplanned coordination. It is a history in which the most successful products were those that took greatest advantage--and allowed users to take greatest advantage--of a large network of capabilities external to even the largest firms. And it is a history in which the greatest failures occurred when business enterprises bypassed the external network and attempted to rely significantly on internal capabilities.

In 1975 American firms possessed the world's most advanced capabilities in mainframe computers (IBM), minicomputers (DEC), and integrated circuits (Intel, Texas Instruments). But the microcomputer did not emerge from these enterprises. Instead, the industry sprang from a welter of small firms who assembled machines, supplied add-on parts, wrote software, and provided knowhow and service.

It is conventional to date the beginning of the microcomputer at January 1975, when that month's issue of *Popular Electronics* carried a cover story on the MITS/Altair computer. Run out of an Albuquerque, New Mexico storefront by one Ed Roberts, MITS provided various kinds of kits to the hobbyist market. The computer Roberts and his coworkers put together was little more than a box with a microprocessor in it. Its only input/output devices were lights and toggle switches on the front panel, and its memory was a minuscule 256 bytes (*not* kilobytes). But the Altair was, at least potentially, a fully capable computer. Like a minicomputer, it

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[3] For a much longer and better-documented history of the microcomputer, see [6], on which this section draws.

possessed a number of "slots" that allowed for expansion--additional memory, various kinds of input/output devices, etc. These slots hooked into the microprocessor by a system of wires called a bus; the Altair bus, which came to be known as the S-100 bus because of its 100-line structure, was the early industry standard of compatibility.

The Altair's impoverished capabilities did not deter buyers: the machine sold beyond all expectation. But the lack of functionality did give rise to two phenomena: third-party suppliers of add-ons and user groups. The latter were organizations of hobbyists who shared information and software. The third-party suppliers were also typically enterprising hobbyists, and the products these firms supplied--like memory boards--filled the gap left by MITS's tardy and low-quality add-ons. In a sense, then, the Altair was quickly captured by the hobbyist community and became not a self-contained product but a modular technological system. To accomplish anything, one needed not just the box itself but also the know-how, add-on boards, and software provided by a large network of external sources. The network character of the microcomputer was fostered by Roberts's design decisions, themselves a reflection of hobbyist attitudes toward information sharing. More importantly, however, the capabilities of MITS were puny compared to those of the larger community; and those larger capabilities were necessary to take full advantage of a product with such high demand and so many diverse and unforeseen uses.

The early success of MITS (and later a clone called the IMSAI 8080) cemented the popularity of the S-100 standard, especially among hobbyists, who were still the primary buying group. Indeed, proponents of the S-100 (and the Intel 8080 microprocessor it was built around) felt that their standard had reached "critical mass" and that competing chips and buses were doomed. But the predicted dominance of the S-100 never materialized. In 1977, a little more than two years after the Altair's debut, three important new machines entered the market, each with its own incompatible operating system, and two based around a different microprocessor. The almost simultaneous introduction of the Apple II, the Commodore PET, and the Tandy TRS-80 Model I began a new regime of technological competition and moved the industry away from the hobbyist into an enormously larger and more diverse market.

The most famous and important of the three machines was the Apple II. The early history of Apple Computer has become the stuff of legends. And some of the legends are in fact true. Apple was the creation of Steven Jobs and Stephen Wozniak, two college dropouts and tinkerers. And some of the company's early work did take place in a garage.

The Apple II reflected in many ways a compromise between the divergent visions of the two founders. A quirky but determined entrepreneur, Jobs provided the drive to turn a hobby into a multi-million dollar corporation. He conceived of the computer as an appliance, a well-designed machine that was easy to comprehend but aimed at a few specific uses. Under Jobs's influence, the machine was compact, attractive, and professional in appearance. A gifted engineer, Wozniak was the actual designer of the Apple II. Like his fellow hobbyists, he believed in modularity, expandability, and an open sharing of information with buyers and outside suppliers. Thus, compared with earlier hobbyist machines like the Altair or the IMSAI, the Apple II was an integrated and understandable product. Yet, thanks to its eight expansion slots--the result of Wozniak winning an argument with Jobs--it was also still a system, able to draw on the large crop of external suppliers of software and add-ons that quickly sprang up. Indeed, Apple relied heavily on external suppliers for almost everything. Like the IBM PC a few years later, the Apple II was almost completely "outsourced." Apple President Mike Scott, who was in charge of production, did not believe in automated manufacturing and expensive test equipment: "Our business was designing, educating, and marketing. I thought that Apple should do the least amount of work that it could and that it should let everyone else grow faster. Let the subcontractors have the problems." [11, pp. 200-01.] The company engaged in board-stuffing on the putting-out system before turning to a contract board-stuffing firm in San Jose. Scott even used a contractor for the firm's payroll.

By 1981 the uses of the microcomputer were becoming clearer than they had been only few years earlier, even if the full extent of the product space lay largely unmapped. A microcomputer was a system comprising a number of more-or-less standard elements: a microprocessor unit with 64K bytes of RAM memory; a keyboard, usually built into the system unit; one or two disk drives; a monitor; and a printer. The machine ran operating-system software and applications programs like word-processors, spreadsheets, and database managers. The market was no longer primarily hobbyists but was increasingly businesses and professionals. Total sales were growing rapidly. But the Apple II--with only a 40-column display and little memory--remained at the fringes of the business market. There was room for a more capable machine targeted to business professionals. It was this gap that IBM attacked with its Personal Computer, a machine that would soon outdistance even the fantastically successful Apple in sales. But IBM's success stemmed not from the focusing of its great internal capabilities but rather from its willingness to abandon its capabilities in favor of those in the external network.

In July 1980 William Lowe met with IBM's Corporate Management Committee. John Opel, soon to become IBM's president, had charged Lowe with getting IBM into the market for desktop computers. Lowe's conclusion was a challenge to IBM's top management. "The only way we can get into the personal computer business," he told the CMC, "is to go out and buy part of a computer company, or buy both the CPU and software from people like Apple or Atari--because we can't do this within the culture of IBM" [3, p. 9]. The CMC knew that Lowe was right, but they were unwilling to put the IBM name on someone else's computer. So they gave Lowe an unprecedented mandate: go out and build an IBM personal computer with complete autonomy and no interference from the IBM bureaucracy. Philip Donald Estridge, who quickly succeeded Lowe as director of the project, later put it this way. "We were allowed to develop like a startup company. IBM acted as a venture capitalist. It gave us management guidance, money, and allowed us to operate on our own" [1, October 3, 1983, p. 86].

Estridge knew that, to meet its deadlines, IBM would have to make heavy use of outside vendors for parts and software. The owner of an Apple II, he was also impressed by the importance of expandability and an open architecture. He insisted that his designers use a modular bus system that would allow expandability and he resisted all suggestions that the IBM team design any of its own add-ons.

Another radical departure from IBM tradition was the marketing of the PC. Shunning IBM's staff of commission-sales agents, the PC group turned to retail outlets to handle the new machine. One outlet was Sears Business Centers; the other was ComputerLand. Here again, the project philosophy was to do things in keeping with the way they were done in the microcomputer industry--not the way they were done at IBM. Perhaps the most striking way in which IBM relied on external capabilities, however, was in the actual fabrication of the PC. All parts were put up for competitive bids from outside suppliers. When internal IBM divisions complained, Estridge told them to their astonishment that they too could submit bids like anyone else. With a little prodding, some IBM divisions did win contracts. The Charlotte, North Carolina plant won a contract for board assembly and the Lexington, Kentucky plant made the keyboard. But an IBM plant in Colorado could not make quality disk drives, so Estridge turned to Tandon as principal supplier. Zenith made the PC's power supply, SCI Systems stuffed the circuit boards, and Epson made the printer.

The IBM PC called forth a legion of software developers and producers of add-on peripherals. Beyond this, however, its early phenomenal success also called forth competitors producing compatible machines. The era of the clones falls into two distinct periods. The early makers of clones fed on the excess demand for PCs. With one brilliant exception (namely, Compaq), these manufacturers disappeared when IBM began catching up with demand and lowered prices in 1983 and 1984. The second wave of clones began a couple of years later when IBM abandoned its original design in favor of the PC AT, which was built around the faster Intel 80286 chip.

What is especially interesting is the diversity of sources of these compatible machines. Many come from American manufacturers who sell under their own brand names. These would include Compaq, Zenith, Tandy, and Kaypro, the latter two having dumped their incompatible lines in favor of complete IBM compatibility. Another group would be foreign manufacturers selling under their own brand names. The largest sellers are Epson and NEC of Japan and Hyundai of Korea. But there is also a large OEM (original-equipment manufacturer) market, in which firms--typically Taiwanese or Korean, but sometimes American or European--manufacture PCs for resale under another brand name.

Perhaps the most interesting phenomenon, however, is the no-name clone--the PC assembled from an international cornucopia of standard parts and resold, typically, through mail orders. Because of the openness and modularity of the IBM PC and the dominance of its bus and software standards, a huge industry has emerged to manufacture parts compatible with the PC. The resulting competition has driven down prices in almost all areas. Most manufacturers, even the large branded ones, are really assemblers, and they draw heavily on the wealth of available vendors. But the parts are also available directly and it is in fact quite easy to put together one's own PC from parts ordered from the back of a computer magazine. By one 1986 estimate the stage of final assembly added only $10 to the cost of the finished machine--two hours work for one person earning about $5 per hour [1, July 28, 1986, p. 64]. As the final product could be assembled this way for far less than the going price of name brands--especially IBM--a wealth of backroom operations sprang up.

The parts list is truly international. Most boards come from Taiwan, stuffed with chips made in the U.S. (especially microprocessors and ROM BIOS) or Japan (especially memory chips). Hard-disk drives come from the United States, but floppy drives come increasingly from Japan. A power supply might come from Taiwan or Hong Kong. The monitor might be Japanese, Taiwanese, or Korean. Keyboards might come from the U.S., Taiwan, Japan, or even Thailand.

It is tempting to interpret the success of the IBM PC as merely the result of the power of IBM's name. While the name was no doubt of some help, especially in forcing MS-DOS as a standard operating system, there are enough counterexamples to suggest that it was the machine itself--and IBM's approach to developing it--that must take the credit. Almost all other large firms, many with nearly IBM's prestige, failed miserably in the PC business. The company that Apple and the other early computer makers feared most was not IBM but Texas Instruments, a power in integrated circuits and systems (notably electronic calculators) [11, p. 228]. But TI flopped by entering at the low end, seeing the PC as akin to a calculator rather than as a multipurpose professional machine. When TI did enter the business market in the wake of the IBM PC, its TI Professional also failed because the company refused to make the machine fully IBM compatible. Xerox and Hewlett-Packard were both slow out of the blocks. But the case I want to focus on is the failure of Digital Equipment Corporation.[4]

DEC is the second-largest computer maker in the world, and the largest maker of minicomputers. The company was committed to a strategy of filling out its line of VAX minicomputers and, more broadly, to the idea of terminal-based time-sharing computing. In 1980, however, DEC President Ken Olsen became persuaded that the company should get into the personal computer business. The Professional 300 series was to be the company's principal entry into the fray. It would have a proprietary operating system based on that of the PDP-11 minicomputer, bit-mapped graphics, and multitasking capabilities. The Rainbow 100 was considered a lower-end alternative. It looked much like the Professional, but, rather than a proprietary DEC microprocessor, it used two Intel chips, enabling it to run some existing outside software. Although the Professional was targeted to bring in 90 per cent of the profit, most of the 300,000 PCs DEC sold

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[4] There is in fact a similar story to be told about the development of the Apple III. See [6].

were Rainbows, and many of those were sold at fire-sale prices. All told, the company lost about $900 million on its foray into microcomputers [13, p. 238].

One might be tempted to see this as a matter of strategic mistakes. But the real mistake was the company's unwillingness to take advantage of external economies. A technical perfectionist, Olsen believed that DEC could be successful by creating a superior product. This had worked in minicomputers: put together a machine that would solve a particular problem for a particular application. The PC is not, however, a machine for a particular application; it is a machine adaptable to many applications, including some its users hadn't imagined when they bought their machines. Moreover, Olsen underrated the value of software. In minicomputers DEC could generate adequate software inhouse, and users, who are highly skilled technically, could write their own applications. But this was not the case in the wide-open microcomputer market. And, unlike IBM, DEC chose to ignore existing third-party capabilities. Except for the hard disk and the line cord, DEC designed and built every piece of the Professional. The company tooled the sheet metal and plastics, manufactured the floppy drive, and even developed the microprocessor.

Conclusion

Although dependent on, and in many ways driven by, economies internal to the semiconductor industry, the rapid growth and development of the microcomputer industry is largely a story of external economies. To put it another way, it is a story of the development of capabilities within the context of a decentralized market rather than within large, vertically integrated firms. Indeed, the microcomputer industry represents in many ways a case exactly opposite to the picture of economic progress one gets from reading Schumpeter, Chandler, or Lazonick. Rather than a few large firms supplanting a decentralized market in an act of innovation, we find instead the large firms lagging behind the small, especially in the beginning. And when large, vertically integrated firms do enter the picture, even the largest of them is forced to rely on a multitude of outside suppliers for parts, software, knowhow, and sales.

There are, I think, a number of reasons for the importance of external economies in this industry. First of all, the size, diversity, rapid development, and unknown character of the market for microcomputers meant that no single organization could develop the necessary capabilities with anything like the speed those capabilities could develop in a decentralized market. Henry Ford was forced to integrate vertically because the external markets could not create new capabilities as fast as he could. But IBM was forced to disintegrate almost completely to make the original PC because the company could not create capabilities nearly as fast as the market could.

Second, microcomputers are not appliances--in the way toasters are appliances--but are modular systems. This is not because of any technological necessity but because modularity allows for a minute and well-coordinated division of labor in the market, which in turn allows for the rapid creation of new capabilities. It is misleading to think of a computer as an end-product. A computer is a means to an end--or to a variety of ends. We thus need to think of computers in hedonic or Lancasterian terms. Computer makers offer a mixture of attributes that consumers can choose among to produce their favored combinations. For most kinds of products--toasters or automobiles, say--manufacturers offer preset packages. One can choose from a multiplicity of packages, but one cannot choose the engine from one kind of car, the hood ornament from another, and the front suspension from a third. Not only are there transaction costs of such picking and choosing, there are also economies of scale in assembling the parts into a finished package. In microcomputers, however, both the transaction costs of knowing the available parts and the scale economies of assembling the package are low for a wide segment of the user population. As a result, the real winners in the evolutionary process--like the Apple II and the IBM PC--were protean machines that could be tailored to specific user demands and could be upgraded easily as new end-uses and technological possibilities emerged.

Finally, as I have already argued, a decentralized and fragmented system can have advantages in innovation to the extent that it involves the trying out of many alternate approaches simultaneously, leading to rapid trial-and-error learning. This kind of innovation is especially important when technology is changing rapidly and there is a high degree of both technological and market uncertainty. And this kind of innovation certainly characterized the microcomputer industry.

That the microcomputer industry partook of external economies of learning and innovation is in many ways a familiar story that need not be retold. Popular accounts of Silicon Valley sound very much like Marshall's localized industry in which the "mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously" [10, IV.x.3, p. 225]. Compare, for example, Moritz's discussion of the effect of Silicon Valley culture on one particular child, Wozniak. "In Sunnyvale in the mid-sixties, electronics was like hay fever: It was in the air and the allergic caught it. In the Wozniak household the older son had a weak immune system" [11, p. 29]. One could easily multiply citations. This learning effect went beyond the background culture, however. It included the proclivity of engineers to hop jobs and start spinoffs, creating a pollination effect and tendency to biological differentiation that Marshall would have appreciated. Moreover, the external economies of ideas were not in fact restricted to the physical realm of Silicon Valley--or even Silicon Valley plus Route 128. As Austin Robinson anticipated long ago, external economies in a developed economy are increasingly intangible and therefore, in his phrase, "mobile" [14, p. 142].

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