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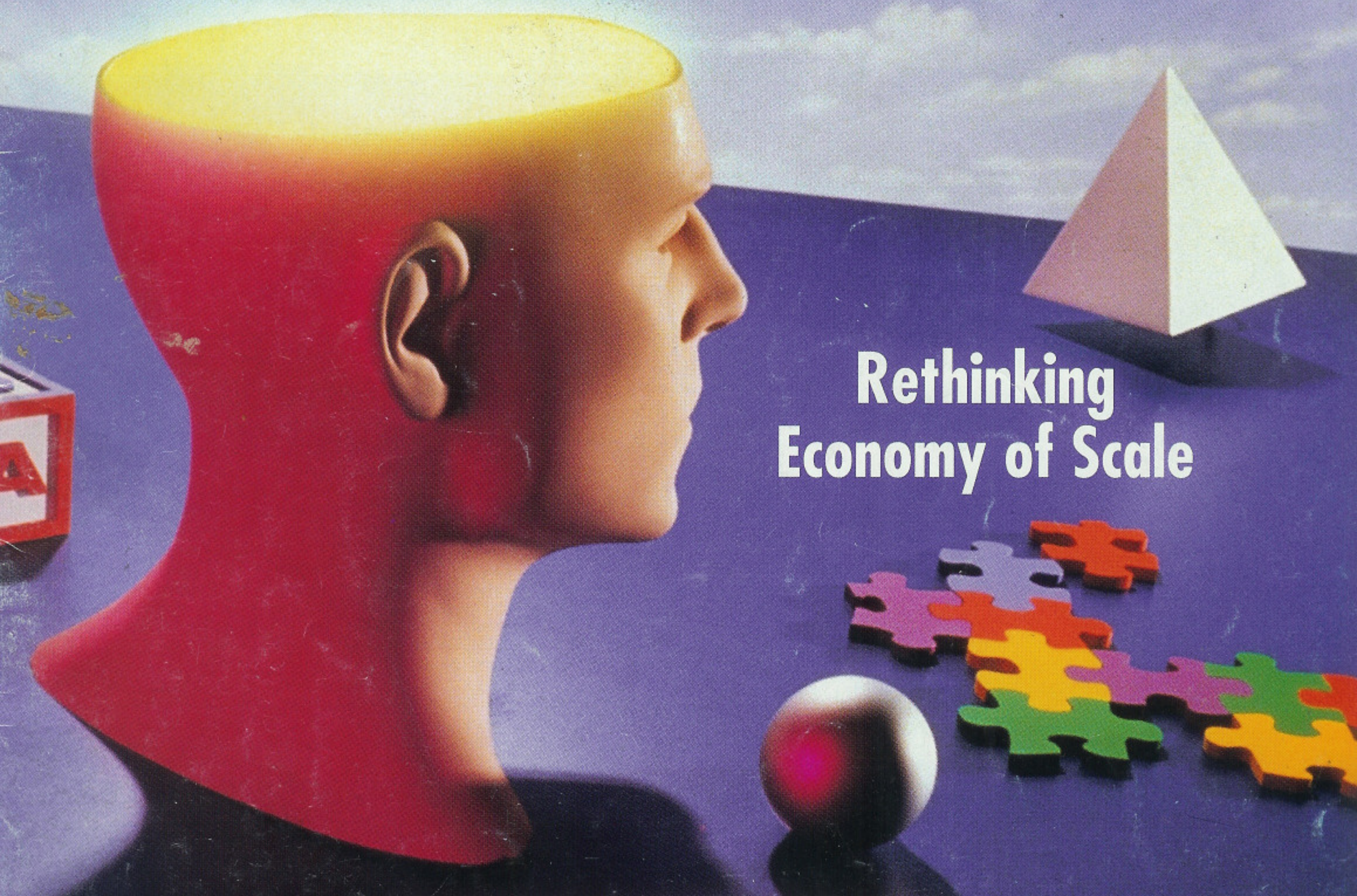

Rethinking Economy of Scale

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Rethinking Technological Economy of Scale

Until about a decade ago American business still believed in the "economy of scale." Big was better in every aspect of industry. This myth has been crumbling in view of the decline in U.S. industrial competitiveness.

In *The Bigness Complex* [1], Walter Adams and James Brock suggested that "economy of scale" embraces three elements: the size of the firm, the size of the manufacturing plant, and the size of the machine. For example, although total employment in American car manufacturing firms is much larger than that of their Japanese counterparts, the smaller Japanese firms have larger manufacturing plants. This seems to indicate that larger car manufacturing plants are more efficient. Yet, at the same time, in other industries, smaller manufacturing plants have proven to be more successful.

Despite this controversy, it remains the accepted view that bigger machines are better. Adams and Brock used pipeline transportation of petroleum to show how the economy of scale works. The cost of building a pipeline is proportional to the radius of the pipe, while its capacity to transport petroleum is proportional to the square of the radius. A 24 inch diameter line would cost about three times as much as an 8 inch line, but could transport more than nine times as much petroleum. This reality and other similar engineering rules also apply, with some variations, to the flow of fluids other than petroleum and to the transfer of electricity and heat [2]. The "bigger is better" principle, thus, makes an appearance in many technologies and equipment. The conventional wisdom holds that it is economically more advantageous to use one big machine than many small ones to achieve the same output. This is the reasoning behind the claim that big machines have a "natural monopoly."

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After their inception many industries start with big machines. However, after a few decades, when the technical knowledge becomes diffused, and the product or service offered by the big machine becomes a necessity of life, smaller-scale machines replace or supplement their predecessors, even though initially they may be less economical. The following list of pairs of technologies illustrates the point.

- personal computer vs. mainframe computer
- photocopy machine vs. conventional printing
- fax vs. telex
- co-generation and small independent power generation systems vs. large centralized power plants
- mini steel mill vs. large steel plant
- VCR vs. movie theaters
- automobile vs. railroad

In many of the preceding examples, there is a shift from centralized, big machines and capital-intensive processes to smaller systems characterized by "do it yourself" and, in some cases, "just in time" operations.

This might seem to fly in the face of logic. When a small machine is first introduced, it is usually more expensive per unit of output than a big machine. It is at present still less expensive per passenger mile to use a train than a car; likewise it costs less per page for large jobs to use a printing press rather than a photocopy machine, and less to use one big centralized computer that can serve thousands of users than thousands of PCs. The initial investment in small technologies is higher per production unit and

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they cost more to operate when first introduced. Nevertheless small machines win out.

Why does this happen? The developers of the first big machine enjoy a "natural monopoly" before the big technology becomes common knowledge. The natural course of the monopoly leads to two business activities: first, developing and selling the big machine itself, then selling the use of it. As it turns out, sooner or later an entrepreneur will see an opportunity and develop a smaller scale "do-it-yourself" version of the technology or another technology to provide the same product. The small scale technology takes advantage of the demand created by the big technology and may prosper because it can offer some advantages over larger machines, even though the unit production cost may remain higher.

Note that:

- ▼ Small machines greatly increase the demand created by existing big machines because they make the technology easier to use or more accessible to end users (like photocopiers vs. printing process, or fax vs. telex).
- ▼ Small machines enjoy an accelerated rate of innovation and improvement, often by users who become familiar with the technology.
- ▼ Small machines allow decentralization of investments. The smaller initial fixed capital costs make the technology more convenient and thus lower the indirect costs.
- ▼ Small machines reduce the need for centralized infrastructures, thus cutting transportation costs and reducing logistical and infrastructure requirements.
- ▼ Output capacity can be added to small machines in small increments more affordable for small investors.
- ▼ Small machines are operated by end-users who *do not* place a price on the time they spend in operation. In other words, labor cost for operating small machines is minimal.
- ▼ Small machines allow the commercial exploitation of marginal inputs not otherwise utilized by big machines. It was not until excess long-distance telephone capacity in the 1980s was offered at marginal prices that fax technology expanded dramatically even though the technology had been invented some half century earlier.
- ▼ Small machines are mass manufactured while big machine are individually constructed. Therefore, for the long term the capital cost of the small machine is vastly reduced in comparison to the customized big machine.
- ▼ Personal use of small machines is usually perceived as enjoyable, even exciting, partly for the individual control and power it allows. Think of the initial thrill of using VCRs, fax machines and PCs, for example.

We all know the failure of IBM and Arthur D. Little to anticipate the success of the Xerox photocopier [3]. IBM was also late in anticipating the success of another small machine, the PC. Ironically, formal quantitative analyses which are usually done by large corporations and government analysts cannot justify development of small machines because they indicate that unit output cost would be higher. This makes it extremely difficult for the small machine entrepreneur to convince investors to fund his/her development. Measured in such terms, small machines may be developed and financed by "irrational" people. Yet the many successes of small machines indicate that standard quantitative analysis has serious limitations in this case.

A debate took place a few years ago on the need for a U.S. industrial policy, similar to the policies practiced by Japan and European nations. An earlier version of this debate discussed the future of the American computer industry. One view was that the U.S government must intervene to stop the fragmentation of the computer industry in order to create an economy of scale to compete successfully with Japan [4-6].

Another view maintains that the natural course of computer technology lies in fragmentation and smallness [7]. In this view the computer industry will be characterized in the future by a profound "diseconomy of scale" with which the American start-up culture of small enterprises can deal much better than the Japanese/IBM style large computer corporations.

What is true for the computer industry has been taking place for many decades virtually in every technology. The natural course of almost any technology leads to fragmentation and smallness. Technological economy of scale is temporary, but has been perpetuated for too long both by monopolists and advocates of centrally planned economies.

References

[1] Walter Adam and James W. Brock, *The Bigness Complex: Industry, Labor and Government in the American Economy,* Pantheon Books, New York, 1986.

[2] In chemical engineering a similar principle is named the "six-tenth rule," which states that the capital cost of typical chemical processing equipment is proportional to their capacity raised to the power of 0.6. This dictates that it is more economic to use one big facility than many small ones in order to obtain a certain capacity.

[3] John H. Dessauer, *My Years with Xerox: The Billions Nobody Wanted,* Doubleday, Garden City, N.Y., 1971.

[4] Kevin P. Phillips, "U.S. Industrial Policy: Inevitable and Ineffective," *Harvard Business Review,* p. 104, July-August 1992.

[5] Lewis M. Branscomb, "Does America Need a Technology Policy?" *Harvard Business Review,* p. 24, March-April 1992.

[6] Charles H. Ferguson, "From the People Who Brought You Voodoo Economics," *Harvard Business Review,* May-June 1988.

[7] George Gilder, "The Revitalization of Everything: The Law of Microcosm," *Harvard Business Review,* p. 49, March-April 1988.

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