Scale, Scope, and the Reuse of Knowledge

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Introduction.

The traditional notion of economies of scale, along with the more recently fashionable idea of economies of scope, both appear in neoclassical economic theory as purely technical flow relationships. For example, economies of scale in this theory reflect lower unit costs at higher rates of output: Q is really Q/t, even if this fact, and the complexities of what it might imply, are usually kept in the background. At the same time, however, economists have also toyed with the idea of the learning curve (Spence 1981), a quite different notion of "scale" in which unit costs decline as a function not of rate of output but of cumulative output. In effect, higher outputs generate lower unit costs because of the growth of knowledge such scale enables. Apart from the work of Alchian (1959), there has been little attempt to reconcile the standard account with the learning account.

This paper is an attempt to make a start at such a reconciliation. In order to so, it draws on a source that is relevant but not often seen as central, namely, recent work on the reuse of knowledge — as, for example, the case of the reuse of software code (Cusumano 1991). The paper will (1) sort through competing accounts of economies of scale and scope; (2) attempt to make sense of these concepts in terms of economies in the reuse of knowledge; and (3) make the bold claim that the important sources of economies of scale and scope — even those arising from purely technical causes — mostly boil down to the reuse of knowledge

Textbook wisdom.

It is instructive occasionally to read introductory economics textbooks. In professional conversations, jargon and technique standardize discourse in a way that often disguises what may actually be different underlying conceptions of economic ideas. But when economists speak to those with (as yet) no formal disciplinary training, they must step from behind the code words and attempt to lay out what they think ideas really mean.

The notion of economies of scale (and the related idea of economies of scope) are a case in point.[1] The more high-brow North American textbooks feel the least need to explain themselves or to go behind the terminology that professional economists use to talk to one another. Economies of scale are simply properties of the firm's (or plant's) production and cost functions. Apart from a passing reference to overhead costs, Joseph Stiglitz (1997, pp. 268-270), for example, offers no explanation whatever, only a discussion of the properties of the curves. Baumol and Blinder (1997) go only a little further, attributing economies of scale to "technology" and rehearsing the familiar parable of geometry.

> Technology generally determines whether or not a specific economic activity is characterized by economies of scale. One

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[1] For the moment, I will concentrate on economies of scale to simplify the exposition.

> particularly clear example is warehouse space. Imagine two warehouses, each shaped like perfect cubes with length, width, and height of Warehouse 2 twice as large as those of Warehouse 1. Now remember your high-school geometry. The surface area of any side of a cube is equal to the square of its length. Therefore, the amount of material needed to build Warehouse 2 will be 2^2, or 4 times as great as that needed for Warehouse 1. However, since the volume of a cube is equal to the cube of the length, Warehouse 2 will have 2^3, or 8 times the storage space as Warehouse 1. Thus, multiplying the inputs by 4 leads to 8 times the storage space — an example of strongly increasing returns to scale. (Baumol and Blinder 1997, p. 168.)

Paul Samuelson, who is no doubt the source of this parable (as of many other staples of the post-War principles textbook) tells the same story in terms of the dimensions of a pipe (Samuelson and Nordhaus 1989, p. 504).

But Samuelson (now writing with Nordhaus) also mentions briefly a couple of other possible sources of economies of scale: "as output increases, firms may break down production into smaller steps, taking advantage of specialization and division of labor. In addition, mass production allows intensive use of specialized capital equipment, of automation, even of robots, to perform simple and repetitive tasks quickly" (Samuelson and Nordhaus 1989, pp. 504-505). These two themes — the division of labor and the scale or specialization of machinery — figure prominently in most discussions.

Indeed, those textbooks aimed at a more general student audience tend to avoid the geometry story (what does that say about American undergraduates?) and talk exclusively about some combination of the Smithian division of labor and large-scale machinery. My colleague Will McEachern notes, for example, that “larger size often allows for larger, more specialized machines and greater specialization of labor” (McEachern 1997, p. 461). His example is the kitchen at McDonald’s in comparison with a household kitchen. Ruffin and Gregory (1990, pp. 543-545) cite Adam Smith on the benefits of the division of labor, adding also that the “optimal rate of utilization for some types of machinery may occur at high rates of output.” McConnell (1987, p. 534) tries the hardest, listing not only labor specialization and “efficient capital” but also managerial specialization (even though management is not logically distinct from other kinds of labor in this respect) and the superior ability of larger producers to use by-products (even though this speaks to economies of scope not to economies of scale).

Putting aside Alchian and Allen (1969), which will warrant special attention below, the best treatment of scale economies among the mainstream textbooks I canvassed is that of Lipsey *et al.* (1990, pp. 205-206). As befits a text with a reputation for being challenging, the authors recite a version of the parable of geometry. They also mention the Smithian division of labor, which, for them, includes the use of “large, specialized machinery.” But they also include a third source of economies of scale that other texts seldom mention: fixed factors or “overheads.” An example would be development costs, which can be spread over an arbitrarily large number of units.

It appears, then, that there are four explanations for economies of scale: (1) the Smithian division of labor; (2) the substitution of “larger, more specialized machines"; (3) fixed factors or "overheads"; and (4) the laws of geometry. Let us take these as our starting point.

Economies of scale, economies of learning.

As Brian Loasby has long pointed out, modern Marshallian economics is not the economics of Marshall. This is nowhere more clear than in the analysis of increasing return (Loasby 1989, pp. 52-53). For Marshall, increasing return is not a purely technical relationship between inputs and outputs with given knowledge and organization. Rather, increases in labor and capital lead to greater-than-proportional increases in output because of the changes in knowledge and organization that arise in the process of increasing the inputs: "An increase of labour and capital leads generally to *improved organization*, which increases the efficiency of the work of labour and capital" (Marshall 1961, IV.xiii.2, p. 318, emphasis added).

Like Smith, for whom greater "dexterity" and the invention of new machinery were the natural results of increases in the extent of the market (Smith 1976, I.i.5, p. 17), Marshall saw technical change and the growth of knowledge as necessary byproducts of increases in output. In defining the long run, Marshall excludes "any economies that may result from substantive new inventions; but we include those which may be expected to arise naturally out of adaptations of existing ideas" (Marshall 1961, V.xii.3, p. 460). Thus Marshall did not subscribe to the sharp distinction in modern neoclassical theory between “static” economies of scale (which occur in a timeless fashion as a function of increases in the rate of output, holding knowledge and organization constant) and learning economies (which occur as a function of cumulative output). For Marshall, scale and time cannot be separated.

The neoclassical partitioning of scale and time causes a problem for the textbook writer. It is one thing to talk about increased division of labor and the substitution of big machines for small in a general chapter focusing on the sources of economic progress. But it is quite another thing to trot out explanations (1) and (2) in a chapter on production functions and cost curves after having just carefully attributed economies of scale to the shapes of those curves, not to factor substitution (Loasby 1989, p. 53). Increasing the division of labor (holding the technique of production constant) is in fact capital saving (Leijonhufvud 1986, p.), and substituting larger machinery for small is typically labor saving. This is not to say that there is no such thing as pure, static economies of scale; but it is to say that explanations (1) and (2) confute static economies of scale with a more complicated historical process that involves both learning and factor substitution.

The most sophisticated attempt to reconcile static economies of scale with dynamic learning effects is that of Alchian (1959), which is reflected in his textbook with Allen (1969). Influenced by his work in the military and at the

Rand Corporation during 1940s, where he had studied the effects of production volume on the cost of airframes (Alchian 1977, chapter 13), Alchian was an early proponent of the idea of the learning curve. In the airframe industry, as in many others, average costs seemed to decline simply as a function of the number of units cumulatively produced. As Smith and Marshall would have understood, this is because the producers learn through experience to fine-tune the production system. The existence of learning effects introduces time (measured by cumulative volume if not by the clock), which, if those effects are taken seriously, makes a stable, "timeless" cost function impossible. Alchian (1959) attacks this problem by increasing the dimensionality of the analysis. Instead of looking only at rate of output (Q/t), he proposes looking at rate, at planned volume, and at the planned production period.

If we hold constant the rate of output and the planned production period, Alchian reasons, costs ought to decline as we increase the planned volume of output. This is so for two reasons: variety of techniques and learning-by-doing *per se* (Alchian and Allen 1969, p. 231). "Variety of techniques" means that some techniques are more appropriate (more cost effective) at low volumes of output and some more appropriate at high volumes. Moreover, there is an asymmetry involved. Techniques appropriate for small volumes can produce large volumes by simply replication, but techniques appropriate to large volumes cannot be "miniaturized" to produce small lots at the same unit cost. If an artisan can make one widget in a year, we can make a thousand widgets by setting to work 999 more identical artisans for one thousand times the cost of one widget. But if we make the thousand widgets with a giant widget-stamping press, we cannot then make one widget for one one-thousandth of the cost by somehow scaling that machine down. Why? A “case in point,” say Alchian and Allen (1969, p. 231), is the initial set-up cost, which is fixed (and large) no matter how many units we produce. (I return to this point below.)

The authors see the variety-of-techniques explanation as distinct from the idea of the learning curve. In analogy with Marshall’s long run (in which no “substantive inventions” take place), learning economies for Alchian and Allen do not involve major changes in technique but only minor improvements in such areas as “managerial functions, production scheduling, job layouts, material-flow control, on-the-job learning, and physical skills” (Alchian and Allen 1969, p. 231). Clearly, however, there is no sharp line between learning-by-doing and changes in technique, since learning-by-doing involves changes in technique and changes in technique require — and lead to — learning.

One benefit of Alchian’s account of costs is that it clarifies the notion of “rate of output” that lies behind the neoclassical Q. In fact, Q is not rate of output at all but rather a simultaneous increase in rate *and* volume in constant proportions. Only under this assumption do cost curves have the shapes asserted in the textbook. For if one holds constant both planned volume and the date at which production is to be completed, then increasing the rate of output always *increases* unit costs. Producing 1000 widgets by next month at 1000 widgets per day is always more expensive than producing the same amount by then at 100 per day. But if we increase the planned volume by the same factor as the rate of output, then the familiar textbook story is plausible: "At first the average cost may fall as the rate and volume of output are both increased, but increases in the rate of output, even though accompanied by a proportionate increase in the volume, will ultimately dominate and cause higher costs" (Alchian and Allen 1969, p. 233).

Division of labor, volume, and overheads.

The division of labor and the use of high-volume machinery are related in that, as Alchian and Allen (and others) point out, these techniques are more effective for high volumes of output and cannot be "miniaturized" or scaled down effectively to small volumes. Consider the division of labor.

What Smith seemed to have in mind is that, when the extent of the market is small, labor is undivided in the sense that a single artisan performs a wide variety of tasks. As the extent of the market expands, it pays to subdivide labor in the sense of assigning artisans each to a particular task. The benefits of doing so are several (Smith 1976, I.i.5, p. 17). Some are in the nature of static economies of scale, some in the nature of learning economies, and some mixed. For example, assigning artisans to particular tasks economizes on set-up costs, including a lessened need for the artisans to "saunter" from one work station to another. These benefits arise in effect from shared overheads. Another benefit is the increase in "dexterity" that comes with increased repetition of the same task, a clear learning-curve effect.[2] And a third class of benefits comes from the tendency of specialized workers to perceive opportunities to mechanize their tasks and to improve their tools.[3] This is also a learning-curve effect, albeit one involving technical substitution.[4]

Thus, as far as Smith was concerned, most of the benefits of the division of labor are in the nature of learning-curve effects, not economies of scale in the neoclassical sense. But, even apart from the benefits of reduced "sauntering," there are nonetheless static economies of scale arising from the division of labor. As Axel Leijonhufvud (1986) has shown, these "parallel-series scale economies"

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[2] A radical empiricist like his friend David Hume, Smith believed that, as a first approximation a least, all abilities are *created* by experience, and "the very different genius which appears to distinguish men of different professions, when grown up to maturity, is not upon many occasions so much the cause, as the effect of the division of labor" (Smith 1976, I.ii.4, p. 28). Charles Babbage (1835) noticed that, if workers start out with different innate abilities, then the division of labor would allow assigning workers to tasks according to their Ricardian comparative advantages, which is another source of economies.

[3] As Smith points out, the division of labor in the larger sense leads to "substantive new inventions" as well as to minor technical improvements. "All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade; and some by that of those who are called philosophers or men of speculation, whose trade it is, not to do any thing, but to observe every thing; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects." (Smith 1976, I.i.9, p. 21.)

[4] As I will suggest below, however, technical change within the division of labor can also lead to static economies of scale to the extent that mechanical innovation creates excess capacity — and thus a potential shared "overhead" — in a stage of production.

also have to do with shared overheads. Subdividing tasks and assigning them to specialized workers requires that the "interfaces" between the stages be closely coordinated. Since the various stages are unlikely to be uniformly efficient, however, some stages may be bottlenecks. More interestingly, some stages may be anti-bottlenecks, that is, they may have excess capacity. Suppose one stage of production — stage 4, for example — is running at half capacity. If the firm were to double its sale of final product, it could run two assembly lines, both feeding into the same stage 4. (See Figure 1.) The doubled output comes at the expense of less than twice the inputs, since stage 4 is an "overhead" that is shared between the two lines.

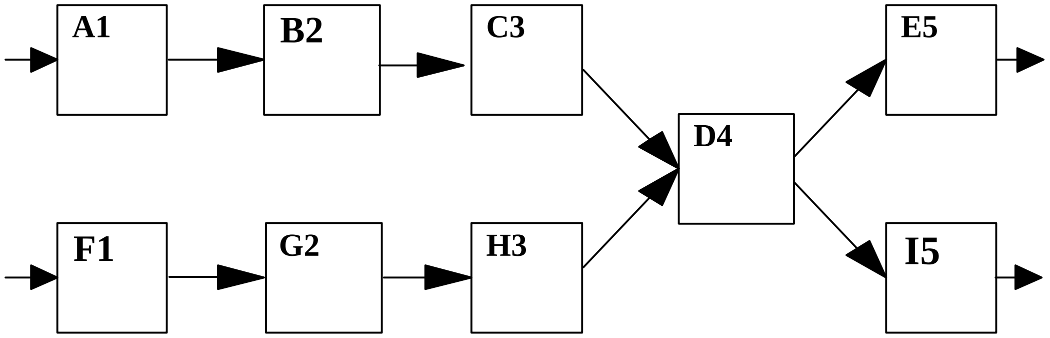

Figure 1. Parallel-series scale economies.
Source: Leijonhufvud (1986).

In Smith, the division of labor is principally an organizational innovation. It is a way of changing the flow of work without necessarily changing the tools of production. Smith tacitly assumes that, in crafts production, tools are (already) specialized but labor is not; the division of labor is about specializing workers to tools, or at any rate reducing the number of specialized tools each worker uses.[5] As Ames and Rosenberg (1965) make clear, however, this scenario is by no means the only possible one. If we take the degree of specialization of a worker to reflect the number of different tasks the worker engages in, then Smith's division of labor is a transformation from unspecialized to specialized labor, with tools remaining specialized. But it is also possible to think of machines as becoming less specialized. A single machine might take over the work of what had been several specialized workers with specialized tools. For example, the production of pins, which featured so prominently in Smith's account of the division of labor, is much more efficient today than in the late seventeenth century; but the technology of production involves not a finer division of labor (or of tools) than in Smith's day but rather the use of machinery that integrates many of what had been separate steps of production (Pratten 1980). Textbook writers thus need to be careful in equating large machines with specialized machines.[6]

It may be well to summarize the argument so far. Explanations (1) and (2) — the division of labor and the mechanization of production — have in common that they reflect learning-curve effects as much as, and perhaps more than, static economies of scale Moreover, in both cases, the causes of the static

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[5] It is true, of course, that the division of labor à la Smith does tend to lead to *even more specialized* tools, since innovation by the worker will tend to optimize the machinery used for the task. What may have started out as an ordinary hammer may become a unique sort of hammer as it is fine-tuned for its specialized job.

[6] Of course, "specialized" may mean many things. Indeed, what textbook authors probably have in mind by this term is something more like "dedicated" — a highly specific asset in the sense of Klein, Crawford, and Alchian (1978).

economies of scale arising from subdividing labor or mechanizing production lie in the sharing of overheads. That is, the *neoclassical* parts of explanations (1) and (2) boil down to explanation (3). This is not perhaps surprising, since, in the most formal of neoclassical theory, scale economies are always a matter of "nonconvexities," and that's essentially what an overhead is. Unfortunately, neoclassical theory is not very helpful in understanding how and why such nonconvexities arise, let alone how they fit in with the learning process attendant on increases in the extent of the market.

As for the learning curve, we might go so far as to say that this effect has two, and perhaps only two, underlying causes. One would come under the heading of increased "dexterity" — learning how to improve the efficiency of humans and machines, and perhaps also of how those humans and machines are hooked together. The other cause would involve the noticing of potential overheads that can be spread over more units. Fine tuning in the areas of "managerial functions, production scheduling, job layouts, material-flow control, on-the-job learning, and physical skills" (Alchian and Allen 1969, p. 231) would likely involve both improvements in dexterity and the discovery of overheads.[7]

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[7] von Hippel and Tyre (1995) see learning about production as involving primarily the identification and solution of problems. In a sense, the learning curve is about finding and eliminating bottlenecks as much as about discovering "antibottlenecks." It is also very much about the growth of knowledge, and it proceeds very much in the way science proceeds — that is, by the identification and solving of "puzzles" — a point that Loasby (1989) has made in various contexts. For von Hippel and Tyre, there are two reasons that learning takes place while doing rather than before: (1) problems cannot be identified beforehand because of the complexity of production and (2) users and others introduce new problem-related information after production begins.

The reuse of knowledge.

Having isolated what we might call the neoclassical core of the idea of economies of scale, namely, nonconvexities or sharable overheads, let me now suggest that even this core can in large measure be laid to the process of the growth of knowledge. One important class — perhaps the most important class — of nonconvexities arises because of standardization. And standards are reusable pieces of knowledge that emerge from the process of learning about production as output increases.

The production process is affected not only by the extent of the market but also by the *predictability* of the extent of the market. What permits a more extensive division of labor or a commitment to large-scale machinery is that, with increased predictability, production can be made more routine. A standardized product makes for more routine production. In crafts production, artisans adapt their activities to particular and differing circumstances: each object or service can be altered and tailored to the specifications of its buyer. This is particularly useful under conditions of uncertainty, when — as in the case of professional services (Stinchcombe 1990, chapter 2) — the craft must be adjusted interactively to a wide variety of concrete circumstances. But, with increased standardization, tasks become regularized, and they can be assigned to operatives who execute them repetitively — and, eventually, to machines.

Smith's division of labor is a way to gain economies from standardization without in principle changing either the artisans or the tools. But there is another effect of the increased standardization of production — an effect that, inspired by Alchian, I have called the *volume effect* (Langlois 1998). Unlike the pure division of labor, this effect gains economies by substituting more-capital intensive techniques.

The significant point here is that substituting a more capital-intensive technique for a more labor-intensive one is a way of *reusing knowledge.* Because of standardization (arising out of a larger and more predictable market) the same knowledge can be applied to more and more units of output. Consider the simple jig. With a reduction in uncertainty — permitting an increase in standardization — a particular sequence of activities can be hard-wired into a machine.[8]

> In drilling the plate A without the jig the skilled mechanic must expend *thought* as well as skill in properly locating the holes. The unskilled operator need expend no thought regarding the location of the holes. That part of the mental labor has been done once for all by the tool maker. It appears, therefore, that a "*transfer of thought*" or *intelligence* can also be made from a person to a machine. If the quantity of parts to be made is sufficiently large to justify the expenditure, it is possible to make machines to which all the required skill and thought have been transferred and the machine does not require even an attendant, except to make

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[8] Machines, of course, can deal with some kinds of uncertainty or variability. The prime example is the Jacquard loom, the ancestor of modern numerical-control techniques. But the effect of such "flexible specialization" is less to reduce the effect of economies of scale than to reduce the degree of standardization necessary to achieve economies of scale.

> adjustments. Such machines are known as *full automatic* machines. (Kimball 1929, p. 26, emphasis original.)

As this quote from an old text on the organization of industry suggests, the transfer to a machine of "intelligence" often takes the form of a jig, pattern, or die. And, as Alchian (1959) points out, the "method of production is a function of the volume of output, especially when output is produced from basic dies — *and there are few, if any, methods of production that do not involve 'dies'*" (Alchian 1959 [1977, p 282], emphasis added). Why? Because, with increased volume, it pays to invest in *more durable* dies.

Consider the example of printing. If one is going to run off a few copies of a memo, a photocopy machine will do the trick. If one needs several hundred copies of documents on an ongoing basis, it might be worth investing in a small offset press. For even larger predictable production runs, it would pay to have a more serious printing press. As volume and predictability allow greater "durability of dies," unit costs decline. This is an effect of growth in the extent of the market distinct from the division of labor narrowly understood.

Again, the reason that costs decline as dies become more durable is that the same knowledge — created once — is spread over more and more units. This would seem to be a reflection of the familiar story about the production of knowledge long ago told by Arrow (1962) and well absorbed into neoclassical thinking: namely, that knowledge is a public good in that it has high fixed costs of creation but near-zero marginal costs of transmission to others. In a sense, this is exactly the story I'm telling, since I am claiming that it is the reusability of "dies" — or, more generally, of *template* knowledge — that creates an important class of nonconvexities in production. But to claim that (some kinds) of knowledge involve a nonconvexity is not the same thing as claiming that knowledge is a public good. The "publicness" of a good is a matter of its appropriability, which is in the end governed by the institutional regime (including the relevant structure of property rights), not by the inherent nature of the good (Demsetz 1969). What I am claiming is that reusable template knowledge has low marginal costs of transmission to *succeeding units of production*, not low marginal costs of transmission to other individuals or organizations.

Indeed, the theory of the production of knowledge underlying what I am suggesting here is in large measure fundamentally different from — even opposite to — what one finds in the neoclassical literature. Whether it be the older literature on research and development or the modern New Growth Theory, the mainstream account runs along the following lines.[9] Knowledge is produced privately using a sausage-machine called research and development that takes in inputs and gives off technological knowledge, which then immediately augments the production function for other goods. The only twist is that, in Arrovian fashion, the knowledge produced is (at least partly) a public

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[9] For an elaboration and critique, see Langlois and Robertson (1996), on which this paragraph draws.

good, so it spills over to other users. As the producer of the knowledge is not fully compensated for the external benefits created, that producer will generate less knowledge than is socially desirable. By contrast, the template knowledge I have in mind is not produced in a separate sausage machine but is generated in the process of producing other goods: in a sense, it is embedded in the production of those goods. Because of this embeddedness, moreover, the knowledge is not easily transferred to others and is thus mostly appropriable.

This is not to say that knowledge never spills over from its producer to others. Some knowledge is what Richard Nelson (1992) calls generic knowledge “that tends to be germane to a wide variety of users and users” (Nelson 1992, p. 61). But, although such knowledge easily escapes its creator, it is not received by others without cost. Potential beneficiaries must have already invested in the “absorptive capacity” (Cohen and Levinthal 1990) necessary to understand and use the information received, an investment that often takes the form of producing similar goods and services in similar ways. “Such knowledge is the stock-in-trade of professionals in the fields, and there tends to grow up a systematic way of describing and communicating such knowledge, so that when new generic knowledge is created anywhere it is relatively costless to communicate to other professionals” (Nelson 1992, *loc. cit.*). In other words, for knowledge to be understood, let alone be useful, it must fit in with existing templates (Langlois 1997).

One situation in which template knowledge is clearly a public good is in the case of public standards. Indeed, the creation of economies of scale is one benefit of such standards (Kindleberger 1983). Such economies arise from the increase in the extent of the market that results from reduced variety. For example, in the 1910s, the Society of Automotive Engineers set standards for automobile parts that winnowed the kinds of steel tubing in use from 1,600 to 210 and the types of lock-washers from 800 to 16 (Epstein 1928, pp. 41-43). Independent parts suppliers could then take advantage of longer production runs to reduce costs, which especially helped the smaller car companies who did not have high internal demands for parts. More recently, the emergence of the IBM architecture as a standard for personal computers regularized expectations about the future course of that industry and unleashed a spectacular array of economies of scale in compatible parts, software, and complementary products (Langlois 1992). By contrast, the Japanese personal computer industry has been hampered by a lack of a single standard, especially in software (Cottrell 1995).

Economies of scope.

For simplicity, I have so far concentrated on economies of scale. But the basic ideas hold true for related concept of economies of scope. Here too the neoclassical "core" is the presence of a nonconvexity or shared overhead. Beef and hides — a favorite example — always partake of economies of scope in the sense that the act of cutting off the hide is shared between the production of meat and that of leather. A better example might be bees and apples: the two products are produced more cheaply in geographic proximity because the apple blossoms improve the honey and the pollination by the bees improves the apples.[10] And, here too, standardization and the reuse of knowledge are important sources of economies of scope. In Cusumano's (1991) example, producers of software can "remember" and reuse pieces of software code that are common to several applications. For example, a single input-output routine could be written once and used for (and therefore shared between) two different applications programs.

Notice how the idea of knowledge reuse blurs the distinction between economies of scale and economies of scope. In the former case, a body of knowledge is shared over a large number of identical units. In the latter case, a body of knowledge is shared among several slightly different products.[11] Indeed, the idea of sharing existing knowledge over different products is at the base of an important modern theory of diversification. Edith Penrose (1959) argued that firms diversify into related areas because they possess "resources"

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[10] There is, however, great confusion about the organizational implications of such economies of scope, confusions not confined to textbooks. In fact, the presence of economies of scope in the production function has no organizational implications whatever. As David Teece (1980) argues, technologically separate activities can be carried out in a separate firm even in the presence of scope economies, since, in the absence of transaction costs, the parties involved can easily write contracts to share out the joint rents. In fact, beekeepers and orchardists do this all the time. This is a more general point: it is transaction costs, not production or costs functions, that determine the boundaries of firms.

[11] Indeed, it is often a matter of the definition of the product that decides if it is economies of scale or economies of scope that are at work. In the Cusumano case, the reuse of code could be seen as producing "more software" at lower unit costs or "different applications" more cheaply together than apart.

that are in excess capacity. Perhaps the most important kind of resource is managerial capacity, which, if in excess capacity, can be applied to new but related areas of business. In G. B. Richardson's (1972, p. 888) related account, firms can be expected to diversify into similar activities because the existing "knowledge, experience, and skills" of the organization can be applied in a related area. Ronald Coase once asked "why General Motors was not a dominant factor in the coal industry, and why A&P did not manufacture airplanes" (Coase 1972, p. 67). The answer lies in the ability (or, in this case, the inability) to reuse knowledge.

Knowledge, overheads, and geometry.

Even though the discovery of such economies of scale and scope is necessarily part of the process of the growth of knowledge — and therefore in some sense a "result" of knowledge — I am not trying to claim that all such economies arise out of the reuse of knowledge *strictu senso.*

If we consider those economies of scale that arise out of shared overheads, one could, with a little stretching, make the claim that these are typically (always?) economies in the reuse of knowledge. Consider the example of the modern movie theater in the United States (McEachern 1997, p. 462). Such theaters typically have several screens (small by the standards of the past) each showing a different film. But the screens all share a common lobby, common ticket-takers, common concessions stand, common rest rooms, etc. These common resources are shared overheads that make it cheaper to house all the screens together than separately. Are these common elements are not knowledge reused? It would seem not. But suppose instead we used the example of a printing press that serves both a morning and an afternoon newspaper. The press (not just the offset plates that contain the text and pictures) is arguably a durable die that replicates a particular configuration of knowledge for many units of output. With a little stretch, could we not say that the shared elements in the movie theater (the routines of the ticket-takers and candy-vendors, for example) are being reused in much the same way as the knowledge embedded in the press?

Even if one buys this argument, there remains a stumbling block: the parable of geometry, that fourth explanation for economies of scale that I have so far neglected. And here I am prepared to concede that what's at stake may not be the reuse of knowledge in any meaningful sense. Clearly, building a bigger warehouse or using a bigger pipe are aspects of the process of substituting more durable dies in production. But the economies that come from geometry are arguably distinct from those that come from greater "durability"; that is, there could be economies of scale from increased durability even if there were *diseconomies* of geometry, as very likely there must sometimes be.[12] But, far from

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[12] And even if there are no diseconomies of increasing geometry, there are often learning diseconomies: scaling up from a small to a large version of any product or process is a notoriously costly enterprise, as Loasby's (1976, pp. 86-87) account of an actual move from a smaller to a larger warehouse — that of W. H. Smith & Sons — makes clear.

being the paradigm of economies of scale, economies of geometry are an interesting, if odd, special case.

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