The Vanishing Hand: the Modular Revolution in American Business

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In a series of classic works, most notably *The Visible Hand* (1977) and *Scale and Scope* (1990), Alfred Chandler focused the spotlight on the large, vertically integrated modern corporation. He did this not merely to chronicle the rise of that institution but also to explain it and to give it a prominent place in American economic growth during the last century and a half. Put simply, Chandler's argument is this. In the late nineteenth century, the large vertically integrated corporation emerged in the United States to replace what had been a fragmented and localized structure of production and distribution. The driving force behind this transformation was increased population and higher per-capita income, combined with lowered transportation and communications costs made possible by the spread of the railroad, ocean shipping, and the telegraph.

Adam Smith (1976) had predicted an increasingly fine division of labor as the response to a growing extent of the market; and, although he was actually quite vague on the organizational consequences of the division of labor, Smith was clear in his insistence on the power of the invisible hand of markets to coordinate economic activity. Chandler's account appears to challenge this prediction: internal or managerial coordination became necessary to coordinate the "new economy" of the late nineteenth and early twentieth centuries. "Technological innovation, the rapid growth and spread of population, and expanding per capita income made the processes of production and distribution more complex and increased the speed and volume of the flow of materials through them. Existing market mechanisms were often no longer able to coordinate these flows effectively. The new technologies and expanding markets thus created for the first time a need for administrative coordination. To carry out this function entrepreneurs built multiunit business enterprises and hired the managers needed to administer them." (Chandler 1977, p. 484.) Thus the visible hand of managerial coordination replaced the invisible hand of the market.

Many would argue that the late twentieth (and now early twenty-first) centuries are witnessing a revolution at least as important as the one Chandler described. Population and income are again a driving force, but the railroad and telegraph have been replaced by the computer, telecommunications technology, and the Internet. In this epoch, Smithian forces may be outpacing Chandlerian ones. We are experiencing a structural revolution as profound as the one of the late nineteenth century. With the help of present-day digital technologies, production is becoming increasingly modular and increasingly coordination through arm's-length trading on thick markets. Management retains important functions, of course, including some of the same ones Chandler described. But as the central mechanism for coordinating high-throughput production, the visible hand — many would argue — is fading into a ghostly translucence.[1]

[1] The cover story of the April 30, 2001 issue of *Forbes* documents in considerable detail the trend in modern industry toward vertical disintegration and contract manufacturing (Dolan and Meredith 2001). Significantly, the piece is titled "Ghost Cars, Ghost Brands."

This paper is a preliminary attempt to explain why this is so — to provide some theoretical insight into the organizational structure of the new economy. The basic argument — the vanishing-hand hypothesis — is as follows. Driven by increases in population and income and by the reduction of technological and legal barriers to trade, the Smithian process of the division of labor tends to lead to finer specialization of function and increased coordination through markets — much as Allyn Young (1928) claimed long ago. But the components of that process — notably technology, organization, and institutions — change at different rates. The managerial revolution Chandler chronicles was the result of such an imbalance, in this case between the coordination needs of high-throughput technologies and the abilities of contemporary markets and contemporary technologies of coordination to meet those needs. With further growth in the extent of the market and improvements in the technology of coordination, the central management of vertically integrated production stages is increasingly succumbing to the forces of specialization.

Behind the managerial revolution.

Industrial structure is really about two interrelated but conceptually distinct systems: the technology of production and the organizational structure that directs production. These systems jointly must solve the problem of *value*: how to deliver the most utility to ultimate consumers at the lowest cost. Industrial structure is thus an evolutionary design problem. It is also a continually changing problem, one continually posed in new ways by factors like population, real income, and the changing technology of production and transaction.

It was one of the founding insights of transaction-cost economics that the technological system does not fully determine the organizational system (Williamson 1975). Organizations — *governance structures* — bring with them their own costs, which need to be taken into account. But technology clearly *affects* organization. This is Chandler's claim. The large-scale, high-throughput technology of the nineteenth century "required" vertical integration and conscious managerial attention. In order to understand this claim, then, we need trace out the interaction between transaction costs and technology in the nineteenth and early twentieth centuries. Only then can we begin to explain the more recent transition from the visible to the virtual.

Antebellum organization.

Along one dimension, the American system of production and distribution in the early years of the nineteenth century was indeed coordinated by the invisible hand of the market. The high cost of inland transportation created many isolated local markets, leading to a fragmented and decentralized system of production and distribution.[2] To the extent that it was possible to aggregate demands, it was the independent merchant or middleman who did so.

Looked at in another way, however, the antebellum value chain reflected a low level of specialization, just as one would expect in a thinly populated country with poorly integrated regional markets. The focus of the economy was not on manufacturing, which was still a matter of local crafts production, but rather on trade. And the central actors were the all-purpose generalist merchants. Rather than concentrating on a narrow range of commodities or on a single aspect of trade, the merchants diversified widely; and they acquired a wide range of skills necessary to trade.

> The merchants' strength rested not so much on their mastery of the ancillary techniques of shipping, insurance, finance, and the like, as on their ability to use them in support of the fundamental trading function, buying and selling at a profit. The merchants exercised this function over a range of goods as varied as the commercial techniques they employed. The histories of individual firms, as well as merchants' advertisements in colonial and early national period newspapers, demonstrate the merchants' willingness to sell anything that offered a profit. Coffee, sugar, iron, cloth — all were grist for the merchants' mills. (Porter and Livesay 1971, p. 17.)

The merchants were generalists, of course, because the volume of trade was too small to support specialization. Only by aggregating demands for a variety of types of goods could they generate sufficient scale to employ their overhead

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2 The main constraint, of course, was the capacity of horse-drawn carriage and the sorry state of the network of dirt roads. Indeed, as late as the early twentieth century, "economists estimated that it cost more to haul a bushel of wheat along ten miles of American dirt road than it did to ship it across the ocean from New York to Liverpool" (Gladwell 2001, p. 13).

resources adequately. This meant in addition that marketing techniques, and in many cases the goods themselves, remained “generic” or nonspecialized in order to permit the necessary diversification.

Despite the recurrent features of trading in otherwise diverse goods, however, the thinness of antebellum markets confronted merchants with a wide variety of concrete circumstances and special problems to solve on a daily basis. To put it another way, the merchants faced considerable uncertainty and variation in their daily tasks. What enabled them to solve these complex information processing problems was the width of their sets of skills and their flexibility in matching skills to problems (Stinchcombe 1990, pp. 33-38).

Confronting environmental variation and uncertainty is a problem all systems of production and distribution must face; it is part of the environmental design problem alluded to earlier. As a result, all productive systems must have mechanisms to “buffer” uncertainty (Thompson 1967, pp. 19-24). One way to accomplish this is to use the cognitive abilities of skilled humans to interpret the data from a complex environment and to translate that data into the kinds of information the productive system can use. For example, in crafts production, neither parts nor finished products need be standardized because the artisan, who personally undertakes all or most stages of production, is able to buffer the variation in the parts and the variation in the tastes of consumers.[3] Wielding a wide repertoire of skills in a flexible way (Leijonhufvud 1986), the artisan can translate complex information about tastes and technology into a working finished product.[4] In the antebellum period, merchants were an important buffer in the system of production and distribution. They noticed profit opportunities and solved a myriad practical problems in a way that resulted in the more-or-less smooth delivery of goods and services. We might want to call this kind of buffering *management*.

In the years after 1815, population growth, geographical expansion, and international trade (especially in cotton) combined to increase the extent of the market in a classic Smithian way: by an increase in the volume of goods traded but without much change in the nature of those goods (Porter and Livesay 1971, p. 17). And, as one would predict, merchants began to specialize to a somewhat greater extent by commodity or function, almost always by means of specialized firms rather than through intra-firm specialization.

But merchants were far from completely specialized. Importantly, many merchants combined the middleman function with a financial function,

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3 For a more formal demonstration that a generalist strategy is useful in buffering environmental variation, see Langlois (1986).

4 Some other examples from Stinchcombe (1990): a professor translates the complex information on an essay exam into a letter grade that the Registrar's office can process; a physician translates the complex inputs from observation and medical instrumentation into a diagnosis, which results in a more-or-less unambiguous set of instructions for nurses, pharmacists, patients, etc.

something that was crucial for the development of American manufacturing before the Civil War (Porter and Livesay 1971, pp. 71ff.). As America began industrializing, the manufacturing sector was chronically undercapitalized, especially with respect to working capital. Investment is always a difficult business because of the problem of asymmetric information: the borrower typically has better information about his prospects than does the lender. In the absence of institutions designed to reduce these "agency costs," lenders will be reluctant to part with their money unless they have good information about the borrower and can cheaply monitor the use of the funds. Even putting aside its conservatism, the banking system was of little help to manufacturing, since its knowledge was concentrated in the agricultural sector it had grown up to serve. Many firms in the metals and mechanical trades were forced to rely on the private funds of the owner-manager or on retained earnings. Increasingly, however, merchants became an important source of financing. Since they dealt regularly with the manufacturers, they had knowledge of their operations and could observe the use of funds lent.[5] We can understand this as an instance of using human information processing as a "buffer" on the financial side: closely observing production, or even taking a hand in directing it, is a way of managing the uncertainty of capital provision.

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[5] For example, the merchant James Laughlin bankrolled the Jones and Lauth iron works, which prospered to become the Jones and Laughlin Steel Corporation (Porter and Livesay 1971, p. 67).

As Figure 1 suggests, then, the "value chain" in the U. S. in the early years of the nineteenth century was one dominated by merchants, who lowered

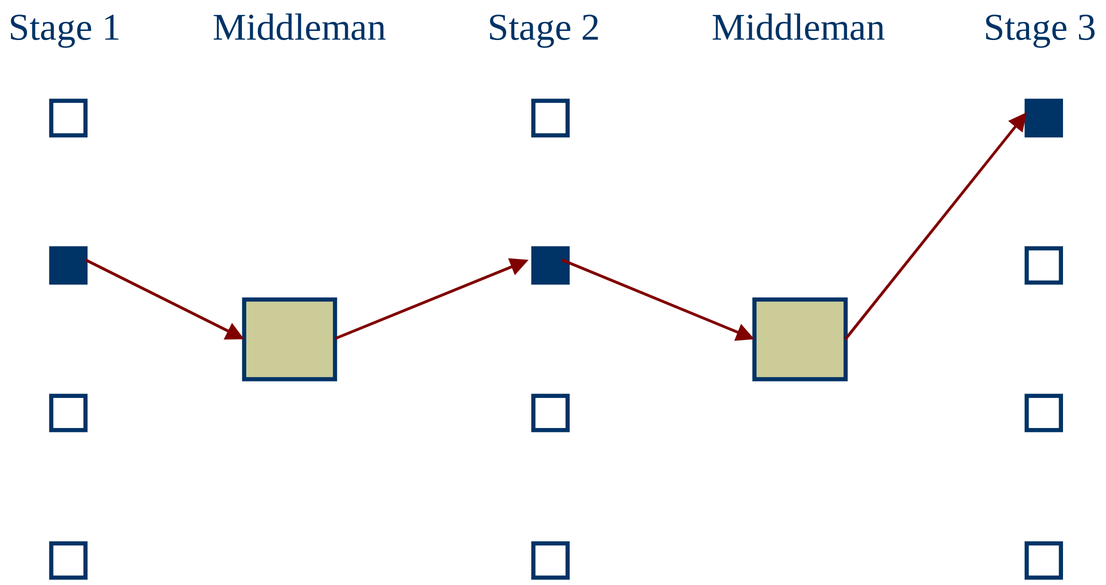

Figure 1: the antebellum value chain.

transaction and agency costs by aggregating outputs and demands from widely dispersed producers and consumers as well as providing capital for the growth of manufacturing.

Postbellum organization.

Is change ultimately a gradual process or is it one that operates through discontinuous jumps or revolutions? This is one of the hoary questions of economic history — and, indeed, of social theory more generally. One's answer to the question is almost always a matter of perspective. From one viewpoint, for example, the coming of the railroad and telegraph by the time of the Civil

War was merely the continuation of a process of decreasing transportation costs already in motion. By 1857, one could travel about twice as far from New York in a day as had been possible in 1830. But the same could be said of the change between 1800 and 1830 (Paullin 1932, plate 138). From another viewpoint, however, the railroad and telegraph had a profound and discontinuous effect on the organization of production and distribution in the United States.

The important consequence of the lowering of transportation and communications costs, of course, was the collapse of geographical barriers and the increasing integration of the domestic market. In effect, technical change in the nineteenth century brought about an all-American version of "globalization," a topic to which we will return. Larger markets made it possible to adopt new technologies and techniques in many transformational and distributional stages in order to take advantage of economies of scale. With larger markets to serve, it became economical to reorganize some stages using a finer and more coordinated division of labor, what Leijonhufvud (1986) calls factory production. It also became economical to use larger and more durable machines that were often capable of integrating multiple stages of production.[6] In both cases, larger markets allowed a shift to higher-fixed-cost methods, which were capable of lowering unit costs — often dramatically — at high levels of output.

6 I distinguish these two results of the increasing extent of the market as the *division-of-labor effect* and the *volume effect* (Langlois 1999a, 1999b).

All of this altered the value chain in two ways. First, it reduced the number of establishments necessary at some transformation and distribution stages. When market size permits economies of scale, a few large plants can operate more cheaply — often far more cheaply — than a larger number of small plants. As Chandler tells the tale, consolidation often marched through characteristic stages. First came the cartel stage, in which previously insulated competitors, having suddenly found themselves competing in the same large market, attempted to manage the allocation of output. Predictably, this met with little success, which prompted the formation of a holding company. By pooling ownership in a single meta-company, in which each individual owner would take a share, the holding company transformed an incentive to cheat on the cartel into an incentive to maximize total capital value. The unintended consequence of this, however, was that the holding company took on a life of its own. Especially as the original owners died out or cashed out, the head office began managing production and investment in increasingly coherent ways. The culmination of this was the multidivisional (M-Form) corporation in the twentieth century, in which the old structure of many identical independent producers had been transmogrified into a unified structure with a wholly new functional division of administrative responsibility. Not all cases followed this model, of course. In fields with few incumbent producers, large unified firms grew up more-or-less directly.

The position of the middleman in the value chain also changed dramatically. As transformation and distribution stages grew in size and shrank in numbers, independent wholesalers were increasingly replaced by in-house purchasing and marketing units. In some cases, like petroleum, producers integrated all the way from raw materials to the final consumer. (See Figure 2.)

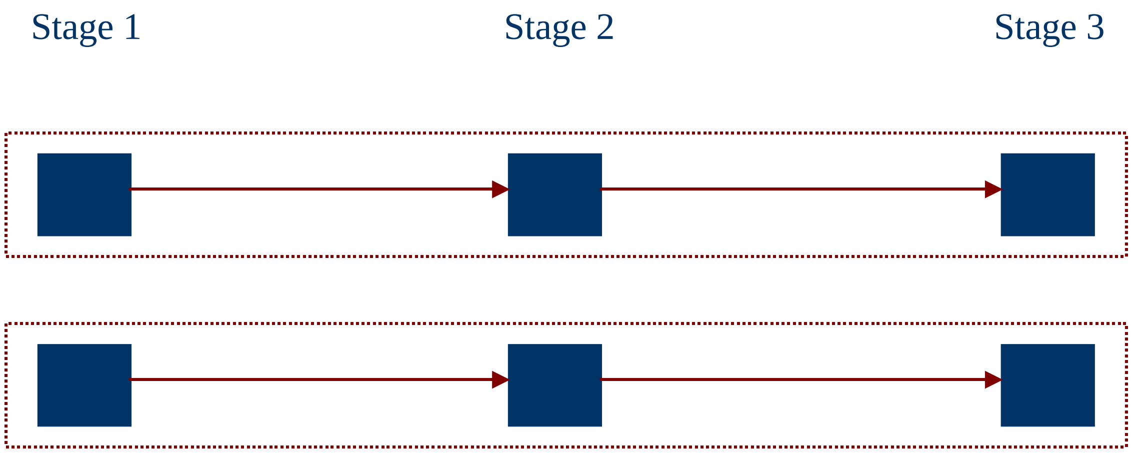

Figure 2: the Chandlerian value chain.

Chandler stresses the ways in which this process differed from what the Smithian division of labor would have predicted; that is, he focuses on the ways in which integration bypassed market relations among previously distinct stages. But it is important to notice that, however visible the hand of management had become, the process Chandler describes is at one level a fundamentally Smithian one. The rise of the modern corporation is very much about increased specialization of function. In an owner-managed firm, management is a craft engaged in by amateurs; in the modern corporation, management is a profession.[7] Moreover, the multidivisional structure or M-form that modern corporations came to adopt in the twentieth century reflects a decoupling of the strategic functions from the day-to-day functions of management in order to cope with the greater demands on managerial attention[8] (Williamson 1985, pp. 279-283).

The clearest and most significant way in which the rise of the modern corporation reflects specialization and division of labor, of course, is on the financial side. The corporation evolved in conjunction with developments in securities markets throughout the late nineteenth and early twentieth centuries (and, as we'll see, beyond). These developments encouraged the separation of ownership from control by creating alienable securities that could be traded on increasingly liquid markets. What made such markets possible was the development of social institutions like the limited liability corporation as well as standardized techniques for accounting and financial reporting. These latter

7 Take note that, although specialized to management, the manager was a generalist along another important direction: the manager was skilled in general techniques of management independent of any specific firm or industry. I return to this point below.

8 In Chandler's eyes, this progressive specialization and separation of function during the rise of the large corporation is indeed a large part of the secret of that system's success. He blames what he perceives to be Britain's lag behind the U. S. and Germany on precisely the British inability to specialize. "In most British enterprises senior executives worked closely in the same office building, located in or near the largest plant, having almost daily personal contact with, and thus directly supervising, middle and often lower-level managers. Such enterprises had no need for the detailed organization charts and manuals that had come into common use in large American and German firms before 1914. In these British companies, selection to senior positions and to the board depended as much on personal ties as on managerial competence. The founders and their heirs continued to have a significant influence on top-level decision-making even after their holdings in the enterprise were diminished." (Chandler 1990, p. 242.)

made it easier for investors to ascertain the value of securities without detailed knowledge of the business or geographic proximity to it, thus somewhat attenuating the costs of asymmetric information (Baskin 1988, pp. 227-230). By reducing the entry requirements to capital supply and by permitting unprecedented opportunities for risk diversification, the development of anonymous securities markets lowered the costs of capital for high-throughput projects and allowed managers to lay off some of the risks — that is, the financial risks — on anonymous markets (Jensen and Meckling 1976). In effect, then, the function of "buffering" financial uncertainties was transferred from human information processors — generalist managers — to external market institutions armed with such buffering mechanisms as portfolio diversification.

Nonetheless, as Chandler insists, along another dimension the rise of the large corporation reflected a process of *reduced* specialization. Whereas distinct sets of managers had once supervised each stage of production, with only the market standing above them, in the era of the large corporation a single set of managers came to supervise multiple stages of production. At the operational level, of course, the division of labor didn't necessarily decrease and may have increased. Each subunit of the large corporation had its specialized managers, the counterparts to the managers of the previously distinct stages. Integration of the management function took place at a "corporate" level higher than the day-to-day managers. The head office oversaw multiple stages of production in much the way a crafts artisan may have overseen multiple stages in the making of an artifact.

Why integration? I have long argued that one can't explain organizational structures without looking at the dynamic processes in which they are created (Langlois 1984). In my view, centralized organization often supplants more decentralized organization when technological and market opportunities call for a systemic reorganization of the structure of production and distribution.[9] This is so for the same reason that decision-making becomes more centralized during a war or other crisis. When many different pieces of the system must be changed simultaneously to create new value, centralized control can often help overcome the narrow visions of the local participants, and centralized ownership can more easily trump the vested interests of those participants. In short, vertical integration often occurs when it can overcome the *dynamic transaction costs* of systemic change (Langlois 1992b).

In many of the nineteenth-century industries Chandler chronicles, the possibilities of economies of scale at various transformation stages called for systemic reorganization in other complementary parts of the system. Consider the story of refrigerated meatpacking (Chandler 1977, p. 299 ff.; Porter and Livesay 1971, pp. 168-173). In the 1870s, the developing railroad network had permitted the shipment of western meat on the hoof to eastern markets, thus

9 Later I will want to associate the idea of redesign with the idea of *remodularization*.

taking advantage of economies of scale in western pasturing. But further economies of scale were possible, and Gustavus Swift realized that, if the system of meat packing, shipping, and distribution were completely redesigned, it would be possible to reduce transportation costs and to take advantage of the economies of a "disassembly line" in a high-throughput slaughterhouse. Claiming these economies required changing complementary assets and capabilities throughout the system, including the development and production of refrigerated rail cars and the establishment of a nation-wide network of properly equipped branch houses to store and merchandise the meat. Swift found it more economical to integrate into many of these complementary stages than to face the dynamic transaction costs of persuading the various asset owners to cooperate with him through the market. As Porter and Livesay (1971, p. 171) argue, the development of an integrated (non-independent) system of branch houses was "a response to the inadequacies of the existing jobber system."

But explaining the origins of vertical integration (or any other structure of organization) doesn't necessarily explain why that structure persists. If integration is temporarily necessary but otherwise grossly inefficient, we would expect the integration to be undone over time. And there are certainly examples of this.[10] But it is also possible that a structure of organization can persist

10 As Chandler (1992, pp. 88-89) notes: "integration … should be seen in terms of the enterprise's specific capabilities and needs at the time of the transaction. For example, Williamson (1985, p. 119) notes that: 'Manufacturers appear sometimes to have operated on the mistaken premise that more integration is always preferable to less.' He considers

because of "path dependence." A structure can be self-reinforcing in ways that make it difficult to switch to other structures. For example, the nature of learning within a vertically integrated structure may reinforce integration, since learning about how to make that structure work may be favored over learning about alternative structures.[11] A structure may also persist simply because the environment in which it operates is not rigorous enough to demand change. And organizations can sometimes influence their environments — by soliciting government regulation, for instance — in a way that reduces competitive rigors.

In the end, however, structures that persist for significant amounts of time may indeed do so because they solve the design problem well — or at least well enough.[12] Surely this is Chandler's claim: the large vertically integrated managerial corporation persisted because it was the appropriate solution for the design problem of its day. Reading Chandler and his interpreters, we can discern the outlines of that solution.

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backward integration at Pabst Brewing, Singer Sewing Machine, McCormack [sic] Harvester, and Ford 'from a transaction cost point of view would appear to be mistakes.' But when those companies actually made this investment, the supply network was unable to provide the steady flow of a wide variety of new highly specialized goods essential to assure the cost advantages of scale. As their industries grew and especially as the demand for replacement parts and accessories expanded, so too did the number of suppliers who had acquired the necessary capabilities."

11 See Langlois and Robertson (1989) for an example from the early years of the Ford Motor Company.

12 Biologists understand that, to avoid a tautological theory, evolutionary explanation must mean showing how the biological structure in question would meet "an engineer's criterion of good design" (Gould 1977, p. 42).

Buffering and information processing.

At the price of high fixed costs, one could create low marginal and average costs — at least so long as one could reliably utilize the fixed assets to capacity.

> In the capital-intensive industries the throughput needed to maintain minimum efficient scale requires careful coordination not only of the flow through the processes of production but also of the flow of inputs from suppliers and the flow of outputs to intermediaries and final users.
>
> Such coordination did not, and indeed could not, happen automatically. It demanded the constant attention of a managerial team or hierarchy. The potential economies of scale and scope, as measured by rated capacity, are the physical characteristics of the production facilities. The actual economies of scale or of scope, as determined by throughput, are organizational. Such economies depend on knowledge, skill, experience, and teamwork -- on the organized human capabilities essential to exploit the potential of technological processes. (Chandler 1990, p. 24.)

In a world of decentralized production, most costs are variable costs; so, when, variations or interruptions in product flow interfere with output, costs decline more or less in line with revenues. But in a world of high-throughput production, fixed costs loom large, and variations and interruptions leave significant overheads uncovered. Chandler would say that uncontrolled variation in work flows lowers the effective economies of scale available. Integration and management are an attempt to control — to *buffer* — product-flow uncertainty.

In one sense, the scale economies of mass production are made possible by the elimination of uncertainty and variation. As we saw, artisinal production can easily accommodate variation in the quality and flow of parts as well as variation in the design of the final product. This is because the artisan buffers the variation by acting as a high-quality information-processing unit. But, at least as practiced in the era Chandler chronicled, mass production requires standardization of parts — the so-called American System (Hounshell 1984) — and the elimination of variation in the flow of inputs. It also works best when there is little variation in the final product. As Henry Ford famously remarked, you can have any color Model-T you want so long as it's black.

It is important to understand, however, that standardization and high throughput do not eliminate the need to buffer uncertainty; indeed, they make it all the more urgent — for any variation that finds its way into a high-throughput system can bring production to a crashing halt. What buffers uncertainty in Chandlerian managerial capitalism is exactly what buffers uncertainty in crafts production or non-specialized merchandising: the information-processing ability of human managers. Because of the new high-throughput structure of production, however, that buffering is no longer distributed to the individual stages of production — from which standardization has eliminated variation — but has effectively moved "up the hierarchy" to the managers who control the work flow.

Professional management is specialization in one sense: the manager is manager only and not in any important way a capitalist or anything else. But, like the merchant of yore, the manager is also a generalist: the manager is skilled in general techniques of management independent of any specific firm or industry. The nonspecific training of managers was abetted in the twentieth century by the rise of the business school, which, like other professional schools emerging at the same time, equipped its students with a standardized "toolkit" (Langlois and Savage 2000). This shouldn't be surprising. Chandlerian managers are generalists for the same reason that crafts artisans and merchants are generalists: because their function is to buffer uncertainty. They need a wide range of skills that could be applied flexibly in response to an unpredictable array of concrete circumstances.

The ability of humans to process information received from the environment — what Stinchcombe (1990, p. 5) call "the news" — depends, of course, on the available technology of information transmission and management. The early generalist merchants had at their disposal such tools as double-entry bookkeeping as well as an expanding system of mail service — which often literally delivered the news (John 2000). The nineteenth century developed a cornucopia of mechanical office equipment for information storage and retrieval (Yates 2000) along with the telegraph and telephone. These inventions had an important effect on the ability of organizations to buffer uncertainty. Consider meat packing again.

> Swift's branch houses presented complex problems because of the distance of these units from the controlling company and the resulting necessity for intimate contact between the producing plant and the field sales organization in order to control intelligently the flow of goods. Records had to be kept of the exact nature of the supply on hand in the branches and of the supply available (and potentially available) in the plants. A constant flow of communications was required in the form of reports, letters, telegrams, and (later) long-distance telephone contacts between the field organization and the packing plants. Some jobbers chose not to handle fresh beef because of the high costs of maintaining this flow … . The result was, of course, that they were replaced by full-time personnel in the field sales organizations of the large packing firms. (Porter and Livesay 1971, p. 171.)

The railroad itself offers a good example of the importance of the telegraph as an instrument of nineteenth-century product-flow management. Telegraphic communication among switching stations enabled trains to run in both directions on a single track without accident, thus saving the enormous cost of double tracking (Chandler 2000, p. 11-12).

The new economy.

Figure 3 displays the value chain of the new economy. In many respects, this structure looks more like that of the antebellum era than like that of the era of managerial capitalism. Production takes place in numerous distinct firms, whose outputs are coordinated through market exchange. It is in this sense that the visible hand of management is disappearing. Unlike the antebellum structure, however, the new economy is a high-throughput system, with flows of work even more closely coordinated than in a classic Chandlerian hierarchy.

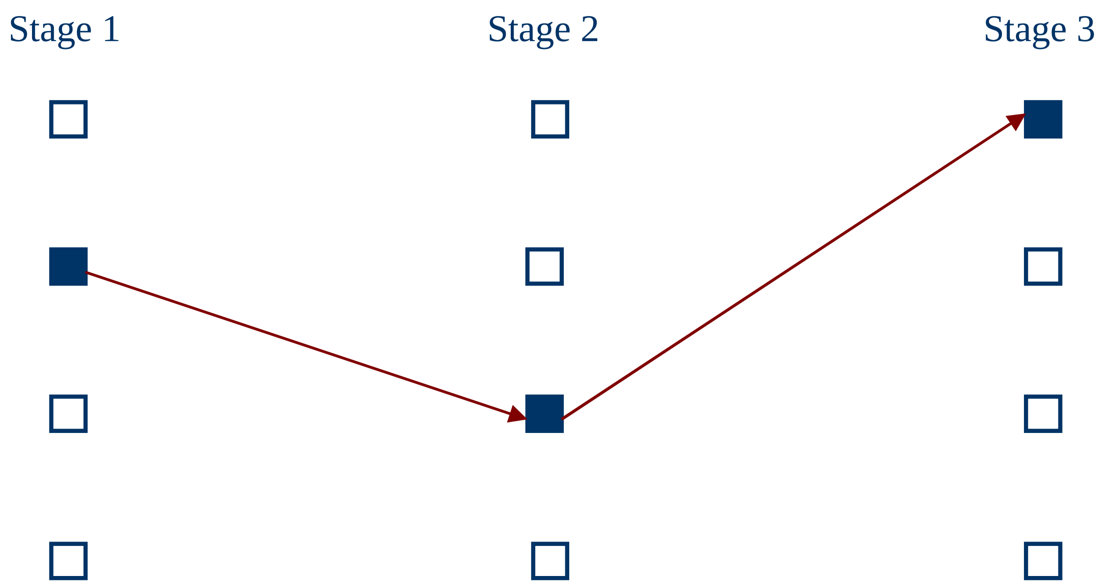

Figure 3: the New Economy value chain.

How then can we explain (what I claim to be) the increasingly spectral quality of multi-stage management? One part of the story is technical change. In an argument akin to the vanishing-hand thesis offered here, Malone and

Laubacher (1998, p. 147) point to changing information technology. "The coordination technologies of the industrial era — the train and the telegraph, the automobile and the telephone, the mainframe computer — made internal transactions not only possible but advantageous." But the development of even more powerful coordination technology — personal computers and broadband communication networks — has had precisely the opposite effect. "Because information can be shared instantly and inexpensively among many people in many locations, the value of centralized decision making and expensive bureaucracies decreases" (p. 147).

This is certainly part of the story. But the hypothesis I offer here is a bit more subtle — or at least a bit more complicated — and perhaps a bit more general. In my view, the phenomenon of the vanishing hand is a further continuation of the Smithian process of the division of labor on which (as I argued) Chandler's managerial revolution was a way station. Thus the vanishing hand is driven not just by changes in coordination technology but also by changes in the extent of markets — by increasing population and income, but also by the globalization of markets. Reductions of political barriers to trade around the world are having an effect analogous to the reduction of technological barriers to trade in the America of the nineteenth century. Is this a revolution or the continuation of a long-standing trend? Again, the answer depends on one's perspective. My argument is that, just as the American "globalization" after the Civil War was revolutionary in its systemic reorganization of production toward standardization and volume, the new era is revolutionary in its systematic reorganization toward modular systems in response both to changes in coordination technology and to plain-old increases in the thickness of markets.

When we think of markets becoming "thicker," we think of more traders for existing commodities. But liquidity is also a matter of having markets in the first place. To put it another way, the development of markets is often and importantly about the creation of new tradable units. Sometimes these are "new products" in a conventional sense: the hula hoop or beanie babies. But often the new products around which markets develop are pieces of some larger system that become standardized and get broken off for arms'-length trade. For example, markets for spare parts blossomed in the 1920s as the aging of the automobile fleet encouraged a multitude of third-party manufacturers (Langlois and Robertson 1989, p. 369). At a deeper level, what made this possible was the standardization of the automobile into a "dominant design," thereby reducing qualitative variation in the list of parts. Even though designs and parts change from year to year, cars are effectively modular systems, many of whose modules are standard enough to trade on markets.

Just as do high-throughput technologies, modular systems require and arise out of standardization. But unlike high-throughput technologies, which standardize the products or processes themselves, modular systems standardize something more abstract: the rules of the game, or what Baldwin and Clark (1997) call *visible design rules*. These rules consist of three parts.

- An *architecture* specifies what modules will be part of the system and what their functions will be.
- *Interfaces* describe in detail how the modules will interact, including how they fit together and communicate.
- And *standards* test a module's conformity to design rules and measure the module's performance relative to other modules.

It is these visible pieces of information that are often widely shared and communicated (and thus standardized). By contrast, *hidden design parameters* are encapsulated within the modules, and they need not (indeed, should not) be communicated beyond the boundaries of the module. These principles of modular partitioning are what enables decentralization and the use of local knowledge while retaining the coherent functioning of the whole (Langlois 2002).

By taking standardization to a more abstract level, modularity reduces the need for management and integration to buffer uncertainty. One way in which it does this is simply by reducing the amount of product standardization necessary to achieve high throughput. This is the much remarked upon phenomenon of mass customization (Cox and Alm 1998). Consider the personal computer, for example. As I have discussed at length elsewhere (Langlois 1992a), the PC developed during the 1970s and 1980s as a largely open modular system. This made it possible for Michael Dell and others to begin selling PCs to order by assembling them like Legos® from a set of standardized components. In so doing, PC makers could blanket more fully what economists call the product space (Langlois and Robertson 1992) — that is, they could fine tune products more closely to the needs of individual users — and thus buffer uncertainty through flexibility. Flexible specialization didn't originate with the Internet economy, of course. General Motors pioneered an analogous strategy in the early automobile industry when they offered a wide variety of slightly differentiated variant models based on a common set of underlying mass-produced parts (Raff 1991) — a classic American idea that Marshall (1920, I.viii.2, p. 141) called "multiform" standardization. But the Internet has clearly accelerated the movement to mass customization by lowering the costs of acquiring information about the tastes of consumers.

Beyond this, of course, modularity makes it possible to buffer product flow uncertainty in much the same way that modular financial instruments make it possible to buffer financial uncertainty — by laying the uncertainty off on markets. Again, commodities markets have long existed to provide this function; but the so-called business-to-business (B2B) marketplace on the Internet has expanded the possibilities immensely. Kaplan and Sawhney (2000) distinguish two kinds of B2B hubs catering to manufacturing inputs:[13] *catalog hubs* and *exchanges*. The former are market-thickening mechanisms *par excellence*. By bringing together a very large number of specialized items, often through the creation of meta-catalogs or catalogs of catalogs, these sites can lower the transaction costs of search for both buyers and sellers. (Amazon is an example of this on the consumer side.) By contrast, exchanges bring together sophisticated buyers and sellers of relatively homogeneous commodities like electricity, natural gas, or even digital bandwidth. Hubs of this kind extend the function of traditional commodities markets, and are an important way to buffer product-flow uncertainty by creating liquidity.

Indeed, it is perhaps in the area of commodities that the visible hand is fading most dramatically. Because commodities are standardized virtually by definition, high-volume throughput is essential, bringing with it the need to buffer product-flow uncertainty. In oil, for example, an oligopolistic industry of highly integrated petroleum majors proved a stable structure for many decades after the days of Rockefeller's Standard Oil (McLean and Haigh 1954). The integrated structure permitted the buffering of the various uncertain elements of the production process (notably exploration) while maintaining high throughput, especially at the refining stage. In other energy industries, the problems of

[13] They make a similar distinction for what they call "operating inputs," more generalized inputs like office supplies needed by most businesses. Since these are general-purpose inputs, they already benefit from relatively thick markets, even if the Internet has succeeded in thickening the markets further.

buffering were so severe that firms sought and received government regulation as “natural” monopolies or as common carriers. A similar story can be told in the telecommunications sector and elsewhere. By the last quarter of the twentieth century, however, changes in relative prices, reductions in technological economies of scale, and lowered transaction costs had begun to create profit opportunities for those who could successfully “unbundle” some of the vertical stages of production.[14] In effect, this is a continuation of the organizational revolution of the nineteenth century — a further subdivision of function within the economy. But it is one that enlisted markets not management to solve the problem of buffering product-flow uncertainty.

The case of Enron illustrates how markets — eventually including electronic exchange markets — came to solve the buffering problem. Enron was formed in 1985 by the merger of two established natural gas pipeline firms. By the end of the 1980s, the company began responding to the deregulation of natural gas markets by inventing “products” that could be traded on liquid markets. In effect, Enron did this by creating novel financial contracts complementary to the company’s physical assets.

> In 1989 negotiations broke down with a Louisiana aluminum producer who sought to obtain fixed-price gas from Enron. Enron’s costs to physically transport the gas made the transaction unattractive. Just as everyone was getting tip from the negotiating

[14] For a discussion of the economic sources of institutional change in electricity, see Kench (2000, chapter 2).

> table, the negotiating team suggested that the aluminum firm continue to buy its gas locally — at floating prices, but transportation costs. Enron could then write a financial contract in which the aluminum producer would effectively pay Enron fixed payments while Enron paid the producer's floating prices. The aluminum producer could minimize its costs of physically obtaining gas, while using a financial contract to tailor the form of its payments. Though the Enron team did not realize it at the time, they had executed what in hindsight was one of the first natural gas swaps. … From 1990 through 1993, Enron spent $60 million to develop its Financial Trading System, staffed by a mix of gas experts and Wall Street traders, to develop an information and trading system that permitted the organization to function as the trading desk of an investment bank. (Bhatnagar and Tufano 1995, p. 5.)

On the supply side, Enron revived a turn-of-the century contract, now called a Volumetric Production Payment (VPP), to securitize ownership rights to gas reserves in an alienable way. The company then applied the idea of modular tradable rights to other areas such as electricity, and it now maintains major electronic exchanges trading a wide variety of commodities, including bandwidth, over the Internet.[15]

In effect, the executives at Enron were doing exactly what entrepreneurs in Chandler's world were doing: actively remodularizing production to take advantage of the profit opportunities afforded them by the nature of markets and the transaction technology of the day. Like Chandler's managers, these executives had to invest resources to create new production technologies; they

[15] "Enron's e-commerce site, which handled some 550m transactions with a notional value of $345 billion in 2000, its first full year of operation, is the most successful Internet effort of any firm in any business." (*The Economist*, February 10, 2001.)

had to overcome the dynamic transaction costs of change by systemically reorganizing production and distribution.[16] But rather than orienting management around high-throughput physical assets, the company oriented management around what Stinchcombe (1990) refers to as a "fiduciary" function: the business of transforming high-risk inputs into predictable, low-risk products.[17] As Enron executives think of it, the post-Chandlerian revolution of the late twentieth and early twenty-first centuries is about "the transition from hard assets to soft assets."

Conclusion.

Figure 4 summarizes the vanishing-hand thesis in visual form. I have called the independent variable "thickness of markets," which is driven by exogenous factors like population, income, and the height of technological and political trade barriers. The vertical axis is called "urgency of buffering," by which I mean to capture the degree to which the technology of production is complex, sequential, and high-throughput. Producing cotton cloth under the putting out system would have a low degree of urgency of buffering; producing electricity for the state of California would have a high degree of urgency of buffering. The straight line moving northeast from the vertical axis represents the boundary

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[16] For example, it took eighteen months and millions of dollars to craft the VPP contract (Bhatnagar and Tufano 1995, p. 7).

[17] Perhaps surprisingly, Stinchcombe's example of fiduciary management is the research university, which transforms risky investments in the uncertain research programs of its faculty into the relatively standardized and liquid output of a university degree.

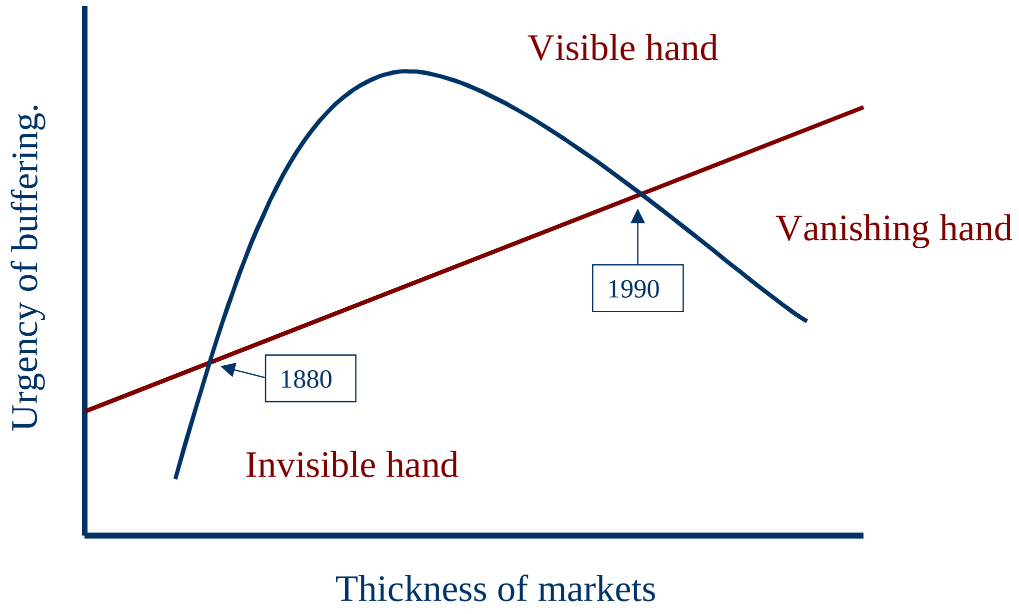

Figure 4: the vanishing-hand hypothesis.

between firm and market. Above the line, buffering through integration and management is less costly; below the line, buffering through markets (of a thickness given on the horizontal axis) is preferable. That the line slopes upward simply reflects the increased ability of markets to buffer product-flow uncertainty as they thicken.

The more-or-less parabolic curve superimposed on this space represents the vanishing-hand hypothesis. Think of it as a path in time, rather like the plot of an explorer's progress on a map.[18] The possibilities for high-throughput technologies and mass production made possible in the late nineteenth century generated a rapid and sudden increase in the urgency of buffering. This is reflected in the initially steep slope of the curve: markets were insufficiently thick to buffer product-flow uncertainty, just as they were initially too underdeveloped to handle financial risk. Over time, two things happen: (a) markets get thicker and (b) the urgency of buffering levels off and then begins to decline. In part, urgency of buffering declines because technological change begins to lower the minimum efficient scale of production.[19] But it also declines because improvements in coordination technology — whether applied within a firm or across firms — lower the cost (and therefore the urgency) of buffering.[20]

More or less arbitrarily, I have labeled as 1880 the point at which the path crosses the firm-market boundary. This is the start of the Chandlerian

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18 The technically inclined may want to view it as the projection onto two dimensions of a curve in three-dimensional space, with the third (*z*) dimension being time.

19 There is certainly reason to suspect that scale has been declining on average in modern industry. We need only think of steel minimills, gas-turbine electric generators, and microprocessors, all of which replaced larger-scale predecessors. But the effect of technological change on scale is sometimes subtle, in that scale reduction in one part of the system can lead to increased scale elsewhere. The advent of the small electric motor (eventually) led to the demise of highly centralized steam power in factories (David 1990); but it also increased the extent of the market for electric power and (initially at least) helped increase the scale of its generation. Indeed, in some cases, the Internet and FedEx® have clearly had the same scale-increasing effect as the telegraph and the railroad: think of online bookstores. See also Gladwell (2001) for a fascinating account of the (internal) management of high-speed product flow at Land's End,® an arrangement that has not been greatly affected by the coming of the personal computer and the Internet.

20 Notice that, unlike Malone and Laubacher (1998), I do not assume that coordination technology was first biased in favor of internal organization and then biased in favor of the market, even though there may be considerable merit to that assumption. As I suggested earlier, one manifestation of "path dependence" is that an organizational structure is more likely to adopt innovations that fit in with, and therefore reinforce, that structure than they are to adopt innovations that would creatively destroy it. But there are also often unintended consequences of innovation, so that a technology developed for use in an integrated structure may find an even more ready application across markets — and vice-versa.

revolution. Equally arbitrarily, I label as 1990 the point at which the path crosses back. This is the vanishing hand. Far from being a general historical trend, the managerial revolution — in this interpretation — is a temporary episode that arose in a particular era as the result of uneven development in the Smithian process of the division of labor.

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