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Management innovation in supply chain: appreciating Chandler in the twenty-first century

Susan Helper* and Mari Sako**

Alfred Chandler attributed the rise of the vertically integrated corporation in the twentieth century to improvements in transportation and communication. In contrast, many have argued that further advances in transportation and communication have made vertical integration obsolete in recent years, replacing it with modularity, outsourcing, and networking. This article unpacks this apparent puzzle by regarding technological improvements in transportation and communication as theoretically neutral with respect to the degree of vertical integration. We argue that the key concepts and issues in supply chain management that Chandler highlighted remain highly relevant today. We integrate Chandler's detailed historical perspective on the evolution of the "visible hand" of managerial governance with more recent theories from organization economics and from engineering, yielding the following insights. First, aligning incentives of buyers and suppliers is important in achieving throughput and assured supply, but asset ownership is neither necessary nor sufficient for this. Second, vertical integration (and disintegration) decisions affect the internal operation of the firm and its future path. Third, firms need to design their value chains in such a way as to achieve coordination without information overload. The article demonstrates the continuing power of these insights in three phases over the last century. In the first phase (with the rise of mass production), Chandler himself noted a subtle array of make-*and*-buy decisions. In the second phase (with the rise of lean production), several varieties of non-integration (e.g. exit vs. voice) persisted because of the specific ways in which firms combined incentive alignment and information flow.

*Susan Helper, Weatherhead School of Management, Case Western Reserve University, Cleveland, OH 44106-7235, USA. e-mail: susan.helper@case.edu

**Mari Sako, Said Business School, University of Oxford, Park End Street, Oxford OX1 1HP, UK. e-mail: mari.sako@sbs.ox.ac.uk

In the third ("New Economy") phase, management of information and material flows through the supply chain remains an important source of competitive advantage. In particular, disintermediation as a form of vertical integration, and successful outsourcing require investment in technical expertise over a wide range of technological fields and coordination of knowledge to manage suppliers (see for example, Brusoni and Prencipe, 2001; Brusoni, 2003; Clark and Fujimoto, 1991). By noting that neither externalization through outsourcing nor flattening of managerial hierarchy is the same as decentralization, the article provides theoretical and empirical bases for the continuing importance of Chandler's principles in managing supply chains.

> The distinctive feature of the modern industrial enterprise is its vertical integration.
> (Alfred Chandler, 1977: 1)

1. Introduction

Alfred D. Chandler is known for celebrating the rise of the vertically-integrated, mass producing corporation. In a number of seminal works (Chandler 1962, 1977, 1990), he argued that productivity has increased dramatically since the 1880s because firms took advantage of advances in transportation and communication to create "economies of throughput"—cost reductions achieved by running a large volume of inputs through high fixed-cost machinery. To make this strategy work, he argued, a vertically integrated value chain was key. To keep the flow of inputs moving, firms needed sources of "assured supply" upstream, stable consumer markets downstream, and a large headquarters to coordinate the flow of inputs through the process. All of these developments, he said, were made possible by improvements in transportation and communication that allowed the headquarters to control developments across broad expanses of geography.

At first glance, it appears that Chandler's theories have little ability to help us understand present-day sources of economic success. Today, many argue that further advances in transportation (especially container shipping) and communication (especially the Internet) make vertical integration obsolete, replacing it with phenomena such as modularity, outsourcing, and networking (Piore and Sabel, 1984; Sanchez and Mahoney, 1996; Friedman, 2005). Rather than using the "visible hand" of specialized managerial hierarchies to coordinate supply chains, firms should focus on their core competencies, and rely on a constantly shifting network of financially independent collaborators who require little coordination, because their components fit into the standardized interfaces of modular products (see, e.g. Brynjolfsson and Hitt, 2000; Langlois, 2003; Gereffi and Sturgeon, 2004; Friedman, 2005). In such a world, what relevance could Chandler's work possibly retain?

We argue that the concepts that Chandler highlighted remain highly relevant today, and are ignored by businesspeople and policy makers at their peril. In particular, we argue that Chandler highlighted several key issues in supply chain management:

- the relation between technology and the optimal organization of supply chains (in particular the effects of technologies that facilitate disintermediation);
- the importance of aligning incentives to achieve throughput and assured supply;
- the impact of make-or-buy decisions on the internal operation of the firm and on its future path; and
- the problem of achieving a balance between the need for coordination and 'information overload.'

We analyze his contentions about supply chain management in light of more recent theoretical insights, and attempt to show how each can be strengthened in light of the other. In particular, we draw on the following.

- Theories from organization economics to argue that while Chandler rightly focused on the need to align incentives to achieve throughput and assured supply, asset ownership is neither necessary nor sufficient for this.
- The Design Structure Matrix from engineering to explore and extend Chandler's insight that make-or-buy decisions affect the internal operation of the firm.
- Both of the above theories to examine Chandler's views on achieving coordination across managerial tasks while avoiding "information overload."

Thus, our first contribution is to introduce theoretical rigor and updated empirical context to analyze alternatives to the mass production/vertically integrated production system so well described by Chandler. Chandler's arguments are much more nuanced than often realized; he was not an unquestioning proponent of vertical integration. Chandler's historically based methods add substantially to the fact base on which theories can draw, but sometimes the conceptual arguments that emerged from his work were a bit fuzzy. In contrast, theories from economics and engineering are logically rigorous, but their assumptions often fail to capture many features that are relevant in the real world. Our second contribution is to highlight these features as an area for future research. Chandler's work contains a number of insights that theory has not yet incorporated about the impact of vertical integration on the internal organization of the firm, and the ways in which a well-run managerial structure can align buyer-supplier incentives.

In the next section, we describe Chandler's views on the nature of innovations in supply-chain management that accompanied the rise of mass production. In this section we also analyze Chandler's arguments in light of recent work in economics and management. In Section 3 we look at the rise of supply-chain management innovations associated with lean production in light of Chandler's arguments and our theories from organizational economics and from engineering. In Section 4 we

examine recent trends toward modularity and offshoring in global value chains in a similar way. We conclude in Section 5.

2. Development of mass production and vertical integration

2.1 Chandler's argument

According to Chandler, 19th-century improvements in transportation and communication led to the rise of large corporations. In his view, the impact of these technological improvements on organization design is contingent on a number of mediating factors. In this section, we lay out each step in the link between improvements in transportation and communication and vertical integration, making explicit the mediating factors that Chandler appears to have had in mind, to explain the phenomenon in the period up to the early twentieth century. In contrast to economists such as Oliver Williamson (1985, 1990), Chandler as a historian focused on explaining the creation of new markets and new transactions, i.e. phenomena in disequilibrium. Vertical integration came about because existing organizations did not meet the needs of new mass markets (Chandler, 1977).

According to Chandler, the innovations of the nineteenth century reduced transportation and communication costs, facilitating the creation of mass markets from geographically dispersed locations.[1] This mass market created the potential for high fixed-cost investments in mass-production equipment to pay off. But new technology alone did not lead to this economic transformation; in Chandler's view, the firms that succeeded were those that married technology and managerial capabilities (Teece, 1993).

Firms needed new managerial capabilities to make use of the new technology profitably. For example, Coasian transaction costs (of determining prices for actions such as timely delivery, responsiveness when desired delivery times changed, and in describing and monitoring the specification of the good to be traded) rose because face-to-face trading became less common in geographically dispersed markets. They also rose because the cost of downtime rose with the high fixed costs of the mass production. In other words, firms saw increasing returns to having faster communication, and to having an assured supply of inputs and demand for outputs, because these kept expensive equipment running productively, thus achieving economies of throughput.

[1]Some historians challenge the idea that these innovations were necessary to create a mass market; they argue that the US Eastern Seaboard already had enough population density to make mass production profitable (John, 2008). However, the point that new organization was required to make it profitable to adopt the new mass production technology is still correct. Chandler (1977) also pointed out that these new mass-production technologies were not developed in every industry; where they were not, large firms did not arise. (See also Perrow, 2002; Sabel and Zeitlin, 1997).

In some cases, firms decided to assure supply by owning their sources of inputs. According to Chandler (1962: 228) the main reason for such backward integration was defensive: to provide the firm with "assured supply" of inputs in limited supply, and to prevent expensive downtime. For example, producer goods firms such as DuPont bought mines (Chandler, 1962: 88). Even if mass producers did not own their sources of inputs, they invested in managerial capability to manage flows of these inputs through their production processes. It appears from Chandler's examples that mass producers rarely used wholesalers for inputs that made up a large percentage of their costs. Instead, firms "disintermediated" (to use a modern term). That is, firms removed intermediaries such as wholesalers and distributors in order to deal directly with producers. To do this, they established purchasing departments that fulfilled the functions previously undertaken by wholesalers and distributors. For example, in the 1880s, in cigarettes: "By building its own buying, storing, and curing facilities, Duke's company was able to purchase directly from farmers, usually at auctions, and so reduce transaction costs and uncertainties" (Chandler, 1977:. 291). Around the same time, Procter & Gamble (P&G) also disintermediated its wholesalers, buying directly perishable raw materials such as animal and vegetable oils, fats, and soda ash which it used to make large volumes of Ivory Soap (Chandler, 1977: 291, 296).

In these cases achieving assured supply involved managing independently owned suppliers. Disintermediation puts the onus on the purchasing department (as opposed to an external wholesaler or retailer) to manage independent suppliers. As such, disintermediation is a form of vertical integration. Proponents of the "New Economy" (Langlois, 2003) often associate disintermediation with the dismantling of managerial coordination and the rise of markets and modularity. But Chandler's insight is that disintermediation often requires establishing and maintaining the capability to sustain managerial coordination.[2]

Make-or-buy was not always an all-or-nothing choice. Chandler (1977) discussed the case of make-*and*-buy in DuPont's attempt to establish assured supply of glycerine. In this case, DuPont made only a portion of its own needs of glycerine, enough to satisfy the amount demanded in the worst economic conditions. This strategy was advantageous in a world of fluctuating demand, because DuPont would not be stuck with excess capacity of glycerine in bad economic times, but would have enough to continue to operate when demand for glycerine was high.

So why did some firms integrate their input supply while others did not? Chandler focused on the need for assured supply and saw ownership as the key way of controlling supply when it was limited or uncertain. In effect, Chandler recognized only two ways of managing supply: control through ownership of inputs and arms-length

[2]See Section 4 for further discussion of this point.

purchase of inputs. He does not mention in-between modes, such as partnerships, long-term contracts, or relational contracts.[3]

Despite the subtleties mentioned above, Chandler generally assumes that ownership is necessary for administrative coordination of the supply chain. Here lies both the strength and weakness of Chandler's key argument. The strength lies in recognizing that firms need to align the incentives of their suppliers to achieve throughput and assured supply. The weakness lies in assuming that asset ownership is necessary and sufficient for incentive alignment.

2.2 Chandler's argument in light of more recent theories

In this section, we analyze Chandler's work using theories from organization economics and from engineering management. Our goal is to see what insights result from combining these different approaches.

Our first theory, by Baker, Gibbon, and Murphy (BGM) (2002), helps us understand more precisely how vertical integration changes incentives. In contrast to Chandler's implicit assumption that subordinates within a firm obey all orders, BGM assume that the ability to enforce directives is no greater within the firm than between firms. Instead, what changes with vertical integration in their model are the parties' incentives to follow through on their commitments.

In the BGM framework, the supplier can undertake two sorts of actions that increase the expected value of the supplier's product. One type of action increases the expected value of the product to the customer, while the other increases its value in an alternative use, which may not be directly beneficial for the given customer. Neither of these actions is contractible, meaning that the customer cannot pay the supplier based on the amount of the *action* taken. However, the customer can pay the supplier a bonus if the value of the product does indeed turn out to be high.

Vertical integration reduces the supplier's incentive to engage in the second type of action, whose only purpose is to increase the supplier's bargaining power. However, vertical integration also reduces the supplier's incentive to engage in non-contractible actions that do benefit the customer. The reason is that under integration, the supplier loses the ability to threaten to sell the product on the

[3]However, in his discussion of railroad organization, Chandler suggested that vertical integration was neither necessary nor sufficient for effective "administrative coordination." Initially, railroads managed traffic on their rails (avoiding collisions) by standards: for example, all traffic would head in one direction on certain days of the week. But this arrangement reduced utilization of the rails. Some railroads invested in administrative capacity to schedule when trains would meet, as well as managers who provided information on whether trains were running to schedule. While most railroads that did this were integrated (they owned all the track their trains ran on), some companies that did own long lengths of track were broken down into separate divisions with only loose coordination between them (e.g. NY Central before March 17, 1853), and other companies cooperated to run trains on each other's tracks. (Chandler, 1977: 137).

open market, thus increasing the customer's incentive to renege on its promise to pay a bonus if product quality turns out to be high. Therefore, a non-integrated firm can more credibly promise a larger bonus than can an integrated firm. The BGM model thus predicts that if the customer prefers a customer-specific product it will integrate (to avoid the supplier taking actions that enhance the alternative use value of the product). However, to the extent that there are non-contractible actions that increase the value of the product in both specific and general uses, the customer will NOT integrate, since it can credibly commit to pay a higher bonus to (i.e. can use higher-powered incentives with) an outside supplier.

A firm can deliver rewards in the form of promotion as well as in cash bonuses. A vertically integrated firm has more scope for promotion than one that does not own its suppliers. For example, Alfred P. Sloan and the Fisher brothers were promoted to top positions in General Motors after their firms were bought by the automaker (Helper *et al.*, 2000.) However, the logic of BGM's argument about bonuses still applies. Because a manager in an integrated firm loses the ability to threaten to sell her product to another customer, a firm can credibly promise a lower level of total reward to her than it could to the owner of a financially independent supplier.

It is important to note, as Chandler (1967) did, that exogenous factors sometimes outweigh internal incentive issues as a determinant of a firm's degree of integration. For example, in the Great Depression, less-integrated Chrysler gained market share from GM and Ford because it was able to choose among many suppliers desperate to sell their product; in contrast, its rivals bore the burden of the high fixed costs of their vertically integrated investments. In this case, it is the ease of achieving economies of scale rather than behavioral issues that determines vertical specialization.[4]

Another framework, this time from engineering management, is useful for analyzing the growth of the multidivisional structure from the perspective of information flow. The origin of this analysis may be traced back to Herbert Simon, who considered a product or an organization as a complex system that could be simplified by decomposing into a hierarchical structure (Simon, 1969). The design structure matrix (DSM) was originally a tool to assist engineers in effective product design and development (Ulrich and Eppinger, 1999; see also http://www.dsmweb.org). DSM requires the collection of data from the field (e.g. by talking to design engineers, studying design data and other documents) in order to construct different types of matrices: *component-based* DSM to get at the product architecture; *team-based* DSM to capture the underlying organization architecture; *activity-based* DSM to map out the sequence of, and interdependencies between, tasks to be carried out in a project; and *parameter-based* DSM to note the performance targets of each component or task.

[4]Thanks to Bill Lazonick for this point.

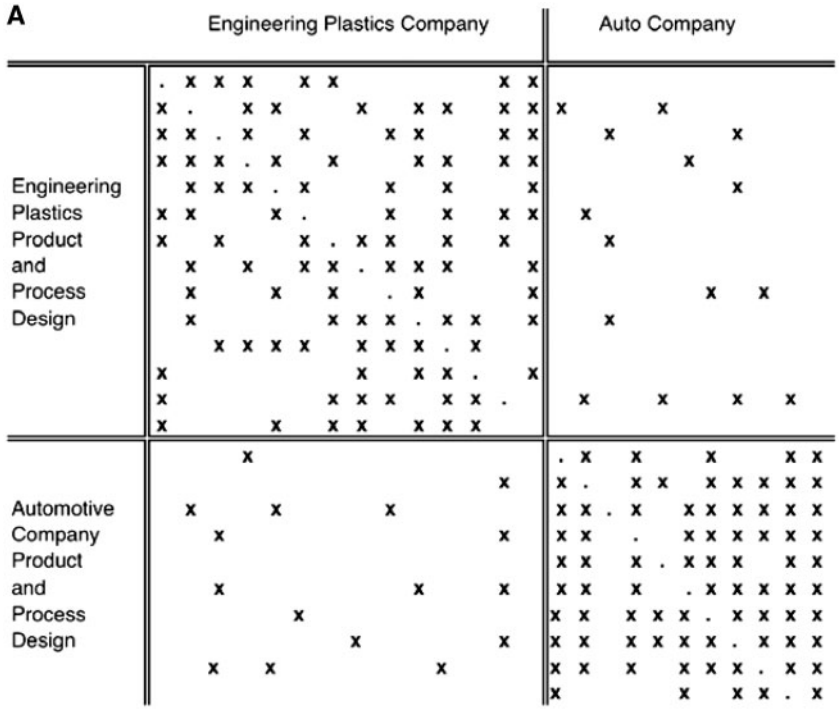

Figure 1 Task and transfer network for the plastic compound design process. Each out-of-block "x" represents a dependency to be resolved via consultations. (a) Initial design structure matrix. (b) Design structure matrix after tests developed.
Source: Baldwin and Clark (2006)

As shown in Figure 1, an 'X' is placed whenever there is information flow or other interaction between two components, persons, teams, tasks, or parameters. After all the Xs are mapped out, DSM becomes a tool to think about reducing interactions and feedbacks, using two methods. One method is *clustering*, applied to component-based and team-based DSMs where the time sequence of the items entered in the rows and columns does not matter. The other is *partitioning*, in which time sequence does matter, so that task A must be completed before task B can begin. Both clustering and partitioning are methods to enable complex systems to be grouped into smaller "chunks" or modules.

Information flows within a corporation may be mapped out in a DSM, and then rearranged via techniques such as clustering, so that "pinch points" (areas with few interactions, as in *panel* (b) of Figure 1) appear between organizational modules. Such clustering or partitioning may occur between the corporate headquarters and its operating divisions, or between a headquarters function and a divisional function. Much interdependent flow of information is likely to exist within each module.

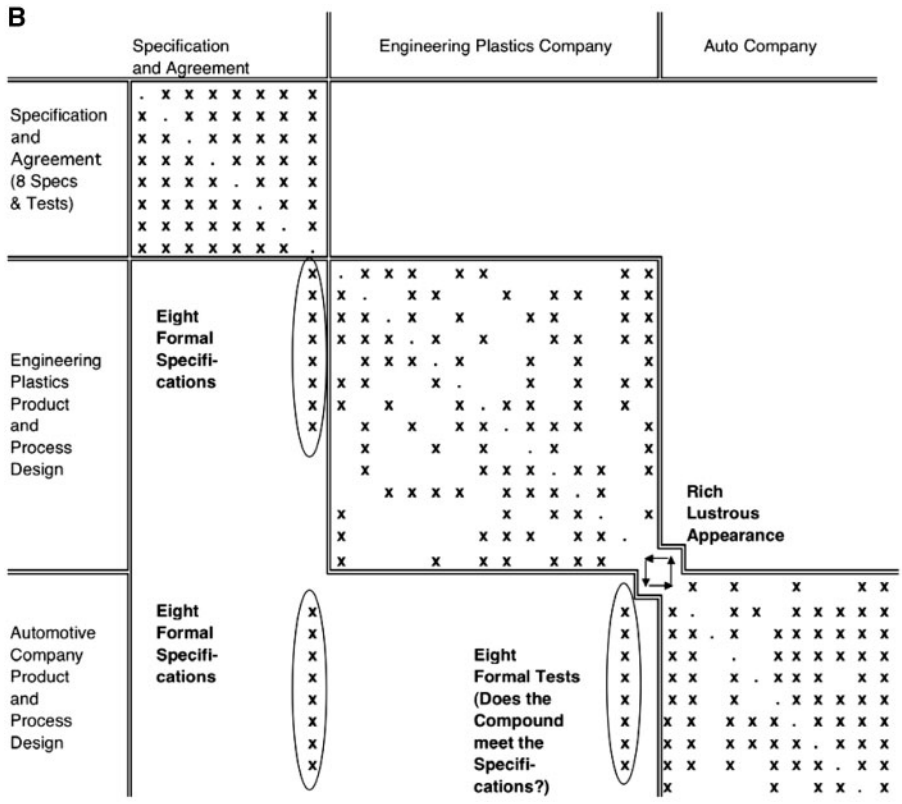

Figure 1 Continued

Baldwin and Clark (2006) provide an example of the use of DSM to improve information flow by reducing feedback loops. In 1994, an automaker sought to find a new plastic with high heat resistance for automobile interiors. Initially, there were a great number of interdependencies. The plastic supplier knew a lot about the properties of the plastic (how improving its heat resistance or shock absorption would affect its cost, for example), while the automaker knew how much heat the plastic would likely encounter in the automotive application. These interdependencies required several iterations of consultation; the plastics maker would develop a batch of plastics and send it to the automaker, who would ask for changes. But, eventually the two parties developed "design rules" (tests for heat resistance, e.g.) that allowed the two parties to work independently. To see this, compare Figure 1a and b, taken from Baldwin and Clark (2006).[5]

[5]Baldwin and Clark (2006) and Baldwin (2008) appear to assume that this process of writing design rules need happen only once (or very occasionally); they do not examine the case when managers

We argue in this article that organization economics (exemplified by BGM) and engineering management (exemplified by DSM) are complementary disciplines; each is enhanced by taking into account problems highlighted by the other. BGM assumes that incentives are the primary issue in information transfer: if two agents have proper incentives, then one agent will easily be able to transfer her information to another. In their framework, bounded rationality, tacit knowledge, and communication difficulties may lead to the non-contractibility of certain actions, but do not affect the final outcome if incentives are aligned. Conversely, DSM assumes that the primary issue is managing complex information flow in a world of bounded rationality. DSM highlights the problems caused by tacit knowledge and lack of information from preceding process steps; the theory does not include the possibility that divergent incentives (e.g. who gains from sharing knowledge) might also cause difficulty. Thus, the theory assumes that if two agents are near each other, they will make good-faith efforts to exchange the information necessary to do their jobs.

Chandler implicitly combines elements of both views. He mentions the importance of asset ownership in creating assured supply—an incentive argument—but does not explain how asset ownership creates the assured supply, or critically examine his own cases in which companies achieved high throughput and coordination without vertical integration.[6] His argument about the role of the head office and the importance of the separation of the strategic and operational roles is implicitly a DSM argument about which tasks benefit the most from proximity to each other, and about designing a corporate organization in which the head office can set broad policies ("design rules") for the divisions to follow while receiving structured feedback from them. The examples he gives of informational interdependencies required for coordinating high-volume throughput give content to the concept of "non-contractibility."

We now apply these theories to the case of the US auto industry, a case to which Chandler devoted significant attention (Chandler, 1964; Chandler and Salisbury, 1971). In particular, we wish to examine the logic behind Chandler's statement that:

> The new velocity of output flows [under mass production] encouraged integration of several units into a single enterprise. The managers of these new multi-unit enterprises were able to monitor the processes of

wish to revise the interfaces repeatedly. Thus Baldwin and Clark assume a static design in which interfaces are clearly defined prior to development. Yet in reality, compatible interfaces are created by a trial-and-error process during the development phase, especially in technologically complex industries. The development of complex interfaces requires constant changes and refinements. For an example of this process, see Ethiraj and Levinthal (2004) on Intel's Itanium chip and Ernst (2005) on the process of revising design rules for semiconductors more generally.

[6]For example, Chandler (1997) describes the low vertical-integration of a number of computer companies, but doesn't look at how this decision affects their abilities to achieve high throughput.

> production and distribution and coordinate high speed high volume flows through them more efficiently than if the monitoring and the coordination had been left to the market mechanism. (1977: 208).

As the above quote indicates, mass production increased the payoff to suppliers with reliable delivery and fast problem solving. Similarly, the increased scale of auto assembly increased the volume of demand for parts, making mass production pay off in upstream production as well. Ford initially understood how to do mass production (investing a lot in jigs and fixtures that dramatically reduced variable costs) in a way that others did not (Langlois and Robertson, 1989; Helper, 1991). This new paradigm created feedback loops between assemblers and suppliers, a pattern of information flow that created a high payoff to proximity between Ford and its suppliers as predicted by DSM.[7] The payoff to these complementary investments was high, but achieving them required "planning" (i.e. agreements to invest simultaneously).

Chandler may also have had in mind an argument from Coase (1937) that administrative coordination is faster than markets because superiors can directly give orders without having to figure out a schedule of relative prices that would induce the subordinate to attend to the highest-priority activity at that moment. Given the expense of downtime in mass production, the ability to avoid the time and cost of setting prices would be an attractive argument for vertical integration.

However, Chandler shows that merely bringing units under the same corporate umbrella is not sufficient to achieve "economies of throughput." GM was transformed from "an agglomeration of many business units.. . . into a single, coordinated enterprise" only when Alfred P. Sloan created "a general office to coordinate, appraise, and set broad goals and policies for the numerous operating divisions." Lacking this structure, GM in 1921 almost went bankrupt because each division expanded, stockpiling components to protect itself against a recession. "These executives had full control of the funds in their divisions. They could borrow money as well as place orders for materials and equipment. No one checked to see how they spent the money they received or what materials they purchased and used" (Chandler, 1962: 128–130). Because of the need to set up a corporate structure to obtain the benefits of vertical integration, the make versus buy decision is not easily reversed—it affects the entire internal operation of the firm (Lazonick, 1991; Helper 1991).

General Motors's 1926 decision to buy 100% of Fisher Body can be explained using this framework. For a number of years, this incident was presented as the canonical story of hold-up: GM had to buy Fisher because Fisher refused to locate its plants near GM's assembly plants, fearing loss of ability to sell to other customers,

[7]As discussed below, another reason for vertical integration is so Ford could avoid having to share final-product market rents with suppliers that it collaborated with.

and because Fisher had negotiated a cost-plus contract for itself (Klein *et al.*, 1978; Hart, 1995).

Unfortunately, the above argument is completely false: Fisher and GM embarked on a campaign to build plants next to each other in the early 1920s, and around that time Fisher agreed that prices for its products would be set according to the same formula used by GM's divisions (Chandler and Salisbury, 1971: 575–578; Freeland, 2001; Helper *et al.*, 2000).

A better explanation for the merger was offered in Chandler and Salsbury (1971).[8] Rather than argue that GM bought Fisher because it could not trust the Fisher brothers, Chandler and Salisbury show that GM bought Fisher because GM management trusted them so much that they wanted the Fisher brothers to run all of GM: "Pierre [DuPont] and [Alfred P.] Sloan still needed experienced general executives to plan and carry out at the very top level the expanding production program. The Fishers, who had proved themselves exceedingly able, naturally tended to concentrate their efforts on Fisher Body rather than on General Motors" (Chandler and Salisbury, 1971: 576) before the merger was completed. In fact, GM gave the Fisher brothers effective control over its executive committee—something they would have been loath to do had they feared hold-up (Chandler and Salisbury, 1971: 587; Coase, 2000).

We can understand this development also in light of the two theories discussed above. The BGM model shows how asset integration was used to align incentives in the parties' relational contracts; because of the non-contractibility of the Fisher brothers' managerial tasks and GM's desire to induce the Fishers to focus on GM-specific management, an employment contract alone would not have been sufficient. The DSM framework suggests that one of the benefits of having the Fisher brothers involved in setting overall strategy at GM was that their knowledge of the potential of the closed steel body could be integrated upfront with complementary investments in paint shops, marketing, and overall product design, rather than having body production simply adapt to decisions made upstream.

3. Varieties of vertical non-integration

Even during the heyday of the Chandlerian corporation, some companies achieved high throughput without high vertical integration. In particular, Toyota followed a strategy that might be called "voice-based vertical non-integration." Toyota collaborated quite closely with its suppliers even though most suppliers remained financially independent. Toyota depended on suppliers for product design and for very timely deliveries (often several times per day); Toyota maintained almost no buffer stock in accordance with just-in-time principles. Problems between customer and supplier

[8]See also Helper *et al.* (2000) for an expanded version of the argument below.

were almost always resolved using "voice" (efforts to work out problems) rather than "exit" (finding another supplier) (Hirschman, 1970; Nishiguchi, 1994; Helper and Sako, 1995).

Despite the large amount of assets specific to buyer or supplier created by its production system, Toyota did not vertically integrate much into parts production or design (though it did make much of the equipment used by its assembly plants and suppliers). Why did Toyota not integrate? There are several reasons. First, unlike Ford and GM, Toyota initially was not profitable enough to finance expansion out of retained earnings and was not able to borrow large sums due to the lack of developed capital markets in Japan (Helper, 1990). Moreover, Toyota *wanted* its inputs to become more general because, until the 1970s, Toyota by itself did not generate enough demand to allow a supplier to operate at minimum efficient scale (Cusumano, 1985). And finally, in a path dependent manner, Toyota then developed (and borrowed) management innovations (described below) that allowed it to better observe suppliers' actions making these actions more contractible. Later, Toyota did gain market power and access to capital, but by that time the organizational investments in collaboration with outside suppliers were already in place (Smitka 1991; Sako, 2006). As we discuss below, vertically integrating its suppliers is not a marginal change—it requires a very different managerial structure—so Toyota's initial choices affected its future alternatives as well.

From the beginning, Toyota invested in the development of the purchasing department and an internal Operations Management Consulting Division (OMCD) to achieve assured supply, not through direct ownership, but through extensive monitoring of and collaboration with, financially independent suppliers (Sako, 2004). Toyota's focused product strategy was combined with the strengthening of managerial coordination beyond Toyota to its supplier networks. In this sense, Toyota "followed a 'Chandlerian' path to industry leadership" (Chandler, 2005: 136).[9]

Meanwhile General Motors allowed the exemplary managerial hierarchy developed under Alfred P. Sloan to atrophy. Ironically, while Fisher Body did not in fact hold up the automaker as an outside supplier in the 1920s, it became sufficiently powerful as an internal division to hold up the rest of the corporation (Freeland, 2001). In one notable case in the 1970s, Fisher informed GM purchasing, "If you'd like this car to have some doors, you'll do it our way" (Helper, 1991). GM also retained exit-based relations with many outside suppliers. By taking complex functions (such as product design and subassembly) in-house, GM created a market

[9]Interestingly, this brief comment on a symposium on his work is the only time that Chandler mentioned Toyota in print (according to a search of his work on Google Scholar). In this account, Toyota is counted as a "Chandlerian firm," though Chandler does argue that since the 1970s the functions of these firms (exemplified by Toyota and Dell) have changed; "these functions have shifted from focusing on the products firms sell to orchestrating networks of suppliers and customers." In this brief note, Chandler does not say why this shift occurred.

in which many suppliers vied for the ability to sell simple parts to the automaker. The resulting fragmentation of production and short-term focus on finding the cheapest supplier led to poor quality but this was not a problem given consumers' lack of alternatives—until the Japanese entered the market.

In response to competition from Toyota, GM in the 1990s evolved "exit-based vertical dis-integration," in which it closed or sold off many parts plants in an effort to raise cash and gain access to cheap non-union labour (Helper, 1991; Lamoreaux *et al.*, 2003: 423). To raise quality levels, GM began to involve suppliers more in product design and subassembly. But because of the legacy of mistrust and financial pressure faced by GM, it was tempted to renege on relational commitments. An uneasy "collaboration without trust" has evolved (MacDuffie and Helper, 2006). These divergent strategies for obtaining parts affected not just the purchasing department, but also the entire operations of the automakers. The key to maintaining GM's exit strategy with outside suppliers was maintaining a credible commitment to leave, which required the creation of a pool of potential suppliers whose price offers could be judged on an "apples-to-apples" basis. Maintaining this comparability required that most communication with suppliers be funnelled through purchasing. To the extent suppliers were able to talk directly with engineers, they might be able to encourage a change in the design of the component that would favor them and thus make price comparisons difficult. In contrast, the focus on problem solving at Toyota led to multiple points of contact between suppliers and automaker: in product design, with supplier engineers resident at Toyota facilities, and in production engineering with Toyota's OMCD engineers facilitating process improvements at supplier factories (Helper, 1991; Sako, 2004).[10]

We can use our two theories in organization economics and engineering to capture the reasons for the varieties of vertical dis-integration and non-integration identified above. First, the DSM framework may be used to contrast GM and Toyota in information flow: even with vertical integration, GM did not have much knowledge overlap with suppliers so that, to use the DSM language, its pinch point with suppliers was very narrow. With joint product development and problem solving, Toyota's pinch points with suppliers were broad and dispersed. This "knowledge overlap" (Nonaka, 1991; Takeishi, 2002) not only entailed redundancy in process steps, but also led to lower defect rates, lower inventories, and faster problem solving. Second, we can invoke organization economics à la BGM to contrast GM and Toyota in incentive structuring. In particular, GM wrote a detailed formal supply contract that attempted to minimize non-contractible elements, whilst Toyota relied more on "goodwill trust" (Sako, 1992) to execute relational contracts with its suppliers.

[10]Thus, in an interesting turnabout, Toyota started off wanting general parts and then moved to relationship-specific components, while GM became increasingly focused on standardization in order to compare "apples to apples" (Helper and Hochfelder, 1996).

In conclusion, the above evidence suggests that the Chandlerian focus on assured supply remains apt even as lean production (Womack *et al.,* 1990) supplants mass production. The two theories we discussed shed light on some of the mechanisms by which the managerial hierarchies so important to Chandler do their job. The DSM captures some conditions for efficient information flows (e.g. proximity of key decision-makers, avoidance of feedback loops), while BGM explains how asset ownership affects incentives to undertake hard-to-monitor actions. Voice-exit analysis looks at the combined effects of information transfer and incentives on performance. For example, we demonstrated that information between buying and supplying units would not flow freely unless parties feel enough commitment to invest in problem-solving mechanisms (Helper and Sako, 1995). The success of relational contracts at Toyota demonstrates that ownership is only one of several ways in which incentives can be aligned. As the BGM model and exit-voice analysis point out, the act of vertical integration (buying an upstream supplier), as at GM, does not guarantee incentive alignment. Much influenced by Talcott Parsons, Chandler's (1962: 8) own theorizing adopted the Weberian notion of legal-rational bureaucracy in which there is no incentive issue. However, his early discussion of these issues in the cases of railroads and GM suggests a more nuanced view.

Thus, the organization economics and engineering theories do not capture everything in Chandler. In particular, his historical analysis suggests a great deal of path dependence in a supplier-relations decision. A decision to move to mass production triggers heavy investments in supply chains, production, and distribution that are not easily reversed, even if marginal returns to make vs. buy change. This hysteresis is not well captured in either models of information exchange (DSM) or organizational economics (BGM or transaction costs).

There are also very important factors captured neither by these models nor by Chandler. In choosing to focus on the decisions made by large corporations, Chandler underplayed the role of other actors, particularly government and small business (Perrow, 2002; John, 2008). Thus, he missed some of the key forces that drove supplier relations decisions, and not always in a way that maximized efficiency.

In reacting against the historical tradition that preceded him, one that focused on the anti-social excesses of robber barons, Chandler overemphasized the efficiency impacts of the decisions made by the managers he studied. He overlooked, for example, the wide variety of levers used by US automakers, often in ways that increased their bargaining power at the expense of supplier and consumer welfare. For example, one reason that US automakers integrated into component design and subassembly was to protect their oligopoly profits from being held up by suppliers (Helper and Levine, 1992). Conversely, the deintegration of automakers in the 1980s was driven in large part not by efficiency but by huge wage differentials (often in the ratio of 3:1) that had opened up between employees of components divisions and of independent suppliers in the United States. A key source of this wage differential was management innovations in discouraging unionization while not running afoul of

US labor law (Herzenberg, 1991). Similarly, changes in US financial market regulations have increased the mobility of capital, leading to incentives to dismantle even productive managerial hierarchies (Lazonick, 2009). Even the "defensive" integration that Chandler argued assured supply for high-throughput production could also be interpreted as a move that created barriers to entry, thus also assuring monopoly profits (Lamoreaux, 1991). And large firms often preferred to retain a buffer of low-productivity, low-wage suppliers to protect their own profits (Harrison, 1994).

4. New economy dis-integration? Modularity and offshoring in global value chains

It has become a truism that reduced transportation and communication costs have led to vertical dis-integration and the replacement of dinosaur-like large companies with gazelle-like firms connected to each other in flexible and modular networks (Arora and Gambardella, 1994; Brynjolfsson and Hitt, 2000; Sturgeon, 2002; Langlois, 2003; Friedman, 2005). It is intriguing that the same factor (lower transportation and communication costs) that Chandler argued led to vertical integration in the twentieth century is now being held responsible for vertical dis-integration and geographic dispersion of production sites in the New Economy.

This section seeks answers to this puzzle by thinking through the various effects of improvements in transportation and communication, and by noting that they have the potential to enhance both central control *and* geographical dispersion of activities. In considering improvements in transportation, container shipping is the New Economy equivalent of railroads, enabling markets to extend from national to global scales. In considering improvements in communication, advances in information and communication technology (ICT) is the New Economy equivalent of telegraphs and telephones, again facilitating the creation of global markets in goods and services.

We begin this section with case studies of Dell (often argued to be the quintessential New Economy corporation) (Fine, 1998; Kraemer and Dedrick, 2002; Kenney and Florida, 2004; Fields, 2004), and of Procter & Gamble, an old-economy corporation that might be seen to be systematically dismantling its managerial hierarchy. We also look briefly at the offshoring phenomenon. We ask if Chandler's insights can help us understand these developments which seem antithetical to his arguments about how modern corporations both do and should operate.

4.1 Dell as a Chandlerian corporation

Dell's Direct model is often put forward as a New Economy business model. There is a strong element of truth in this as Dell saw the power of modular product architecture and ICT more clearly than perhaps any other competitor in the PC industry. The Dell model involves flexibility via vertical dis-integration (not owning its

production facilities and suppliers), responsiveness to customers via direct sales, and an online build-to-order system for mass customization. These features are enabled by the existence of competent contract manufacturers and specialist component suppliers as well as the Internet. Thus, Dell is often associated with the "vanishing hand" (i.e. the dismantling of managerial coordination and the rise of market-mediated transactions) (Langlois, 2003).

However, the evolution of Dell from a business run out of a dorm room to a $12 billion global corporation in 13 years is remarkably Chandlerian. Chandler (1997) noted Dell's fast growth based on "marketing, not technological innovations" (p. 89) such as telephone-based ordering and advice. This story is reminiscent of the replacement of "jobbers" by direct sales discussed in Chandler (1977). Michael Dell disintermediated dealers in order to obtain better control over the distribution network and invested in establishing a department with specialist salespersons experienced in dealing with large corporations as clients (Dell and Fredman, 1999: 23; Fields, 2004: 180). Dell went for "scaleable" business with governments and large corporations (they constituted 90% of Dell's sales) where it could exploit scale economies (Magretta, 1998: 121). As Dell's product diversity grew, the company also moved away from U-form (functional structure) and developed an M-form (multidivisional) structure, initially segmenting client markets and then developing autonomous business units with their own sales, service, finance, IT, technical support, and manufacturing commissioning arms (Dell and Fredman, 1999: 73). In order to effect the necessary managerial coordination within Dell, the company went from 627 employees in 1987 to a peak of 90,500 in 2007. Thus, Dell has established a managerial hierarchy, notably in marketing and purchasing, in order to coordinate activities on a global scale.

For Chandler, the essence of "the visible hand" was coordination within the managerial hierarchy, not vertical integration *per se* (Chandler *et al.,* 1997). What Dell calls "virtual integration" involves tight coordination with independently owned suppliers with whom order information and production plans are shared in real time. ICT boosts the value of information sharing, reducing time-to-market, thus creating the same sort of value that high throughput time and assured supply did for Chandler's corporations. Thus Dell relies on information assets (created by its Internet-based system of balancing demand and supply) rather than the acquisition of physical assets to manage its high-volume build-to-order delivery (Dell and Fredman, 1999: 220). Information sharing makes the DSM involving Dell and its suppliers dense and not partitioned. The mutual gains from this intensive information sharing provide suppliers with incentives to collaborate with Dell as though they are part of Dell (Magretta, 1998: 116). Dell, however, also uses considerable market power and administrative control to make suppliers comply with its innovative system of order fullfilment and logistics (Fields, 2004: 228).

To summarize, Dell may be a quintessential New Economy firm with vertical disintegration and disintermediation, but it is nevertheless also a Chandlerian

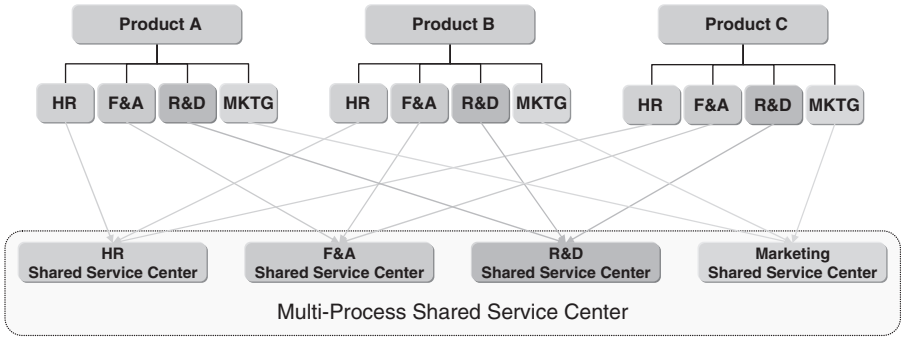

Figure 2 Unbundling and rebundling of corporate functions. HR = human resources; F&A = finance and accounting.

corporation which uses command and discussion (rather than prices) to coordinate activities within the managerial hierarchy and with external suppliers.

4.2 P&G as modular corporation and the offshoring of business services[11]

P&G is an Old Economy firm, discussed in some detail in Chandler (1962, 1977). By the late nineteenth century, this family-owned soap manufacturer was fast becoming a modern managerially controlled business, and it diversified into food-related business during the interwar years. The post-war expansion of P&G was marked by product diversification through acquisitions and organic growth. P&G managed this growth by developing a multidivisional structure in the United States, with a more loosely coordinated national company structure overseas. In the mid-1990s, P&G began to reduce the number of product divisions, consolidated brand management, and introduced greater control over national companies. A more global structure emerged as a result of a drastic corporate restructuring drive called "Organization 2005" (O2005), which began in 1999.

O2005 at P&G involved the consolidation of product divisions into just two Global Business Units (GBUs), one for household goods and another for personal care products. It also involved the creation of an organization unit called Global Business Services (GBS) which took responsibility to consolidate and manage shared administrative services such as finance and accounting and human resource management on a global company-wide basis (see Figure 2 for a schematic representation of this corporate restructuring). This unit was eventually outsourced and offshored to third-party service providers. Because of this externalization, business service outsourcing/offshoring is often associated with the dismantling of managerial

[11]This section draws on Gospel and Sako (in press).

hierarchy. It seems, indeed, to undo the Chandlerian process of the development of a professional managerial hierarchy.

However, P&G's corporate restructuring to create and outsource a shared services center involved major investments requiring central managerial coordination and negotiation. Chandler recognized that some staff functions would be carried out at the corporate head office level and some at the divisional level. The creation of GBS, therefore, may be interpreted as a reallocation of administrative tasks, away from product divisions to the head office. This move toward central control was enabled in part by ICT technology, which was employed by the company to address Chandler's concern for achieving coordination across managerial tasks while avoiding 'information overload.'

GBS took responsibility for consolidating administrative services in procurement, accounting, facilities management, and HR into three regional centees in Costa Rica, northeast England, and the Philippines. These locations were chosen for their relatively low costs. This consolidation meant that these corporate functions were taken away from product divisions and centralized at the global HQ level, reducing autonomy of divisional and country managers. As noted in Section 2, the M-form is a decomposable hierarchy (Simon, 1969), which enabled the partitioning and modularization of management information. However, with the deployment of an SAP enterprise resource planning system, P&G challenged the old way of decomposing the hierarchy. Within each divisional corporate function (e.g. human resources) at P&G, processes that are rule based and partitionable from other processes are consolidated and standardized globally. The firm created a captive, fully owned Shared Services Center to optimize their processes internally first before outsourcing. In the language of Design Structure Matrix, P&G applied partitioning to tasks within each corporate function, and in this way helped to decompose knowledge and information flows wherever possible.

Once partitioned chunks of processes were reasonably well established, P&G moved to outsource each chunk to business service providers such as IBM, Jones Lang LaSalle, and HP. For example, IBM signed a $400 million contract over a period of 10 years to manage employee services (e.g. payroll and benefits administration, expatriate relocation) for 100,000 P&G employees in over 80 countries. Under the contract, IBM acquired P&G's operations in three locations (in Costa Rica, England, and the Philippines) and inherited over 2000 P&G employees working in those locations. The logic of this arrangement can be understood in terms of Chandler's (1990: 388) argument that the party that makes the big investments in coordinating the flow of materials is the one whose technology holds the potential of large economies of scale and scope. In some industries, it was production that offered this potential; in others it was distribution. IBM's hope in the case of business services is that its expertise in computing and consulting will allow it to achieve economies of scale and scope by aggregating business services for many clients, enabled by the use of digital technology.

Under what circumstances will this plan succeed? According to BGM, to the extent that the supplier's product is general, the customer is able to credibly promise higher-powered incentives for good performance to outside suppliers than to captive units. Indeed, IBM stood to make much more money if (and only if) it performed well compared to the internal supplier it replaced. However, making the products general (standardizing them) requires changing the design structure matrix to reduce the amount of interaction necessary across the boundary between service provider and user. This was not always desirable. For example, P&G country managers requested so many exceptions to the expatriate relocation policy that IBM asked P&G to take this aspect of HR back in-house.

In summary, the ICT revolution led to a repartitioning of tasks in corporate functions. Through a reexamination of the Design Structure Matrix in the managerial hierarchy, corporations such as P&G have modified the M-Form by reducing autonomy of product divisions through the creation of shared services in corporate functions. Chandler's insight concerning the need for optimal coordination to cope with "information overload" still holds. P&G's decision to outsource business services does not fully reverse what Chandler described in the building up of the administrative hierarchy with professional managers. This is because even after outsourcing, P&G continues to have Global Business Services (GBS), which in effect acts as the purchasing department to manage business services providers. Thus, as Chandler would note, successful outsourcing also requires investment. That is, outsourcing and offshoring required investment into (and not dismantling of) a new organizational unit to manage suppliers. Thus, vertical disintegration (and integration) decisions have consequences for the internal organization of the firm. Our arguments are therefore consistent with Chandler's emphasis on managerial coordination. But there is a caveat: Chandler himself had not thought about why a firm might outsource services that pertain to the internal administrative operation of its business.

4.3 Services offshoring[12]

One case where new technology has clearly had an effect is in enabling offshoring of services as well as production. Use of advanced ICT has the potential to enable back-office work such as data entry or software updating to be done in a low-wage nation, then sent almost instantaneously around the globe to be united with customer-facing, and/or higher skilled process steps done in a rich country.[13]

[12]This section draws on Helper and Khambete (2008).

[13]Based on the US Bureau of Labor Statistics' Dictionary of Occupational Titles (Bardhan and Kroll, 2003; Blinder, 2006) or on data on geographic clustering within the United States (Jensen and Kletzer, 2005), scholars argue that potentially 12–40 million of 75 million US service jobs could be sent offshore, and that even if not so many jobs actually move, the increased supply of this labor means wages will fall significantly.

In this section, we look at the offshoring of engineering design in the automotive industry as an example of this trend. Although estimates are hard to come by, it seems that several hundred million dollars of engineering is performed in India for US automakers every year, a number that is growing. Functions performed include finite element analysis and updating drawings with computer-aided design (CAD) programs (or digital draftmanship).

Helper and Khambete interviewed a firm that provided engineers on a temporary basis to auto suppliers in Detroit. Many of these engineers were of Indian origin, so the firm found it attractive to experiment with leaving them in India where they could be paid an Indian wage rather than a US wage. The first project the firm tried failed—the product was late, of poor quality, and over budget. The second project was more successful—the work was done as well as it would have been in the United States and saved money. The difference between these scenarios was that in the second case the firm invested in developing managerial capabilities to monitor far-flung workers: the firm introduced product development software in which each person was to document their work (and enforced this software's use), set up a weekly conference call to catch any issues not flagged otherwise, brought the Indian engineer to the United States for 3 months to learn tacit aspects of the job, and most importantly, maintained a liaison in the United States who was in daily phone and email contact with the Indian engineer.

"Design rules" were important in allowing the United States and Indian engineers to work independently. These rules worked well when the Indian engineer was doing drafting for automotive windows, allowing the Indian designer to work independently of his US counterparts. However, the US-based designer ended up making all the changes to the windshield design himself, rather than delegating it to India, because of the sheer number of interfaces involving the windshield. As he noted, "The windshield is affected by the design of the roof, the headliner, the locator pin, the bead that seals the windshield, the body side—and then if the windshield changes they have to change the wiper assembly. There can be a change a day! One time the lace section [a black line to hide the headliner from view] changed four times in 2 days. The sheet metal people would ask me to do something, I'd do it, it would go back to the studio, they don't like it strictly on appearance. . ."

Services offshoring, like the rise of mass production, is an organizational innovation that results from innovations in transportation and communication (in particular, the diffusion of Internet access). As in the earlier case, taking advantage of this improvement required an increase in managerial coordination.[14] That is, because of the loss of visual control available with proximity, informal mechanisms for coordinating task and tracking the progress of work were no longer sufficient.

[14]Such reorganization and codification of tasks has also been observed in other types of offshoring, such as legal services (Sako, 2009).

To be viable, offshoring required the introduction of product life-cycle management software (and incentives for its use).[15]

This section has reexamined the debate over the role that Chandlerian firms play in the New Economy. Some argue that as a central tendency, the buffering and coordination functions of management are devolving to the mechanisms of modularity and the market—informational decomposition, flexibility, and risk spreading (Langlois, 2003: 377). In contrast, in Chandler's world, "Increased specialisation must, almost by definition, call for more carefully planned coordination if the volume of output demanded by the mass market is to be achieved" (Chandler, 1977: 490). The disagreement lies in different assumptions made. Langlois assumes that thickness of the market is exogenously given or that it is already established, while Chandler assumes that the mass market is something that has to be developed.

Chandler's view seems more correct here. Modularity is not a panacea. In practice, problems arise that were not considered when the standard was drawn up. Or, someone comes up with an innovation that requires re-drawing module boundaries. Thus, some overlapping expertise between adjacent modules, or between design and production, has a big payoff in reduced lead time, defects, etc. (Clark and Fujimoto, 1991; MacDuffie and Helper, 1997; Ernst and Kim, 2002; Sabel and Zeitlin, 2004). In our cases above, both P&G's outsourcing of business services and the offshoring of automotive engineering faltered to the extent that standardized interfaces led to reduced performance. Firms' efforts to reduce the number of interdependencies in decision-making have costs when increased discussion leads to improved problem-solving. For example, these highly "pinched" interfaces saved money in ordinary situations by reducing redundancy, but were unable to cope with "integral" changes due to a lack of knowledge overlap.

How can we account for the seeming effect of ICT in increasing integration in one period, while reducing it in another? Clearly, the ability to have information zipping around the world at a fast pace is key to visions of a new, "flat," decentralized, disintermediated, and outsourced world (Friedman, 2005). However, this view conflates a number of concepts that our cases help to separate. We advance four propositions below.

First, outsourcing does not necessarily mean decentralization (Gospel and Sako, in press). In the case of Dell, whilst Dell does not own suppliers' physical assets, it maintains tight administrative control over suppliers which comply with its system of order fulfillment and logistics. Similarly, P&G's outsourcing of business services was enabled by a corporate-wide centralization and standardization of these services using SAP's enterprise resource planning system.

Second, similarly, flattening (a reduced number of layers in the organizational hierarchy) is consistent with *more* centralization, not less. In the case of P&G, the

[15]Although it is a short-term success, it is not clear that the offshoring experiment represents a global optimum for the US auto industry (Helper and Khambete, 2008).

outsourcing of its internal shared services centers went hand in hand with reduced managerial autonomy for divisional and country managers over policies concerning HR, finance, procurement, and other functions. For example, P&G country managers used to have the ability to modify the formulation of products such as hair conditioner to match their perception of local tastes. Now (in part because of fast communication made possible by the Internet) these decisions are all made centrally.[16]

Third, disintermediation is quite consistent with vertical integration. Dell cut out the middleman, just as Duke did in tobacco and Proctor & Gamble did with animal fats over a century ago. Use of ICT makes the cost of this stage much cheaper than before, so the ratio of purchased parts to sales is very high. But running this retail operation—now extended to owning retail chains—is key to Dell's success, and depends on immediate access to constantly changing consumer preferences. Since these preferences are constantly changing, they are not subject to "design rules;" it is necessary to have management decide how to respond to these changes. Indeed, in *The Visible Hand*, Chandler stresses the integration of production and distribution much more than he stresses the vertical integration of the supply chain.

Finally, successful offshoring requires more than just an Internet connection. Technology alone is not sufficient to make offshoring work; offshoring may well require increased Chandlerian managerial capabilities to manage distant flows of materials and information. As the engineering service offshoring case shows, the promise of lower wages makes firms willing to incur higher coordination costs than they would face with purely domestic production.[17]

5. Conclusion

We conclude by summarizing three themes that emerge from our discussion of supply chain management in three eras marked respectively by the rise of mass, lean, and modular production. The three themes are first, the neutrality of the impact of transportation and communication improvements on vertical integration, second, the importance of non-technological reasons in explaining the recent

[16]Some authors argue that decentralization is occurring (e.g. Brynjolfsson and Hitt, 2000; Bloom *et al,* 2008; Guadalupe and Wulf, 2008); they find a reduced number of levels in the corporation and increased autonomy as measured by the ability to independently carry out decisions interpreting given policies. However, we argue they are not measuring decentralization correctly: they don't ask what has happened to managers' ability to design their own policies (e.g. compensation system, type of equipment used). We argue instead that reduced communication costs make it possible to more closely direct and monitor activity from a central location with fewer intervening layers of management.

[17]The coordination costs involved in offshoring are lower than they would have been before the Internet, however.

phenomenon of vertical disintegration, and third, the enduring relevance of Chandlerian insights.

First, we revisit the paradox with which we opened the article: that improvements in transportation and communication are associated with increased integration at the turn of the twentieth century, but with reduced integration at the turn of the current century. We argue that technological improvement in transportation and communication are theoretically neutral with respect to the degree of vertical integration—it can facilitate tighter communication between integrated units (as in the case of P&G), or it can reinforce exit-based relations (as in the case of GM's offshoring).[18]

However, even in a modular world, we still need managerial coordination, not least when interfaces change and when new markets emerge. Chandler and Langlois each see other's model of the state of markets as transitional (Lamoreaux *et al.,* 2004). Looking specifically at the case of vertical integration, Chandler (1997) argues that the key firms in the computer industry (e.g. Intel, Microsoft) fit with his model. All firms started small, but where there were opportunities to exploit economies of scale and scope, the successful firms invested in managerial hierarchies and distribution mechanisms that enabled them to achieve high throughput and create a mass market. In contrast, Langlois argues that vertical integration is important at the beginning of an industry. But, once the industry learns how to manage and define interfaces, a modular industry structure will (and should) take over. In contrast, Teece's (2002) idea of systemic innovation suggests a cycle (though one fraught with potential market failures and roadblocks). During the period Chandler examines in *Scale and Scope*, "the leading industries of that era—chemicals, steel, and railroads—were all transformed by systemic innovation. The winners were the companies that made major investments to shape the markets, and did not simply rely upon outsourcing strategies for key inputs. Today we see leading companies like Intel, Lucent, Microsoft, and Cisco making extensive investments to enhance their current capabilities and spur the creation of new ones" (Teece, 2002: 66). Our evidence from the three periods suggests that the rise and fall of vertical integration may best be interpreted as responding to disequilibria created by the needs of the company and what is available in the supply market.

[18]Malone *et al.* (1987) and Brynjolfsson (1994) start from this premise of neutrality as well, but then conclude that information technology is indeed pushing firms to become less integrated. Malone *et al.* argue that IT reduces coordination costs for both in-house and outsourced production; they appear to assume that the reduction is equal on a percentage basis, because they go on to argue that this equal reduction disproportionately tips the scales toward outsourcing, since coordination costs are higher there. Brynjolfsson *et al.* (1994) find support for this proposition empirically, in that establishments that invest in IT are smaller than otherwise similar establishments that invest less. However, his data is for establishments, not firms—so we don't really know from his study what is happening to financial integration. It could be that firms are splitting themselves into smaller units that remain centrally owned. In fact, Dosi *et al.* (2008) find almost no reduction in firm size as the Internet age advanced.

So what does tip the scale? Why do improvements in transportation and communication lead to greater vertical integration in one era, and less in another? The answer lies in our second theme, the importance of non-technological factors. As noted above, Chandler paid little attention to the role of the government in affecting the relative advantages of make and buy. The same holds true of many of Chandler's new economy counterparts, many of whom argue uni-causally that ICT advances have led to the fall of the vertically integrated corporation (Sturgeon 2002; Langlois, 2003).

In contrast, Lazonick (2009) analyzed the role of financial and labor market deregulation. This deregulation combined with the rise of the view that corporations exist to maximize shareholder value led to increased interest in maximizing return on assets by reducing assets, in part by dismantling managerial hierarchies. Similarly, Friedman (2005) argued that financial market deregulation enabled the "electronic herd" to move capital in and out of countries quickly based on economic and political 'openness' (Friedman, 2005). Whilst we agree that ICT speeds up communication and reduces monitoring costs, these advantages may be exploited *within* firms as much as between firms. Thus, what tips the scale from vertical integration to disintegration is not ICT *per se*, but the use of ICT to pursue the changed managerial goals derived from deregulation. In a semi-globalized world, with a different mix of contending regulatory, institutional, and cultural forces at play in different locations, we envisage a wide range of possibilities in the way ICT influences vertical integration and supply chain management[19].

Last but not least, our analysis suggests that there are a number of Chandlerian principles that apply to supply chain management in all three eras. First, incentive alignment remains important. So successful companies do not use arm's-length

[19]As this article was going to press, we read Bloom, *et al.* (2009), which argues that communication technology and information technology have distinct effects on firm organization. Communication technology (like a corporate intranet) reduces communication costs, making it easier for the boss to communicate his desires while IT (like CAD/CAM or the internet) reduces information acquisition costs, making it easier for workers to find information on their own, facilitating decentralization. This distinction suggests an explanation for our paradox: In Chandler's time, the big innovations were the telephone and telegraph, which reduced communication costs, and were used to transmit orders from headquarters to plants. In recent decades the internet gave workers (and suppliers) the power to find out themselves the information needed to complete their tasks, so they could act without direct orders from the boss. However, these innovations were not always used in a manner consistent with the authors' arguments. For example, one might argue that later, telephones on each workers' desk facilitated horizontal communication as well as vertical communication, while mainframe computers were initially under central control. The issue of who controls CAD/CAM and its predecessor technology, NC (i.e. whether a few engineers in an office or many blue-collar machinists sitting at machines write and modify the programs that control the equipment) has been much studied (Noble 1978, 1984; Shaiken, 1985). So while we find the distinction between communication costs and information acquisition costs quite useful, we believe the balance of these effects from any given technology is importantly influenced by managerial goals and institutions.

markets where fast, interdependent decision-making allows the achievement of economies of scale and scope. Instead of relying on prices alone to coordinate action, they build managerial structures that make decisions based on hierarchical commands and also on discussion among peers. Second, make-or-buy decisions affect the internal organization of the firm. So the outsourcing of some functions changes the way the remaining functions operate and thus also affect future paths and switching costs. Third, management continues to face the issue of organizing information flow in a way that allows for streamlined decision-making in normal times, yet allowing revision of interfaces when necessary. Managers ignore these principles at their peril, and social scientists risk impoverishing their theoretical lens without these principles.

The epigraph from Chandler with which we began this article asserted that vertical integration is the key to the modern corporation. However, what his analysis really shows is that it is managerial coordination, not vertical integration *per se,* which has been important for unleashing productivity growth in the modern era. Vertical integration was often associated with the adoption of high-throughput technology but in fact was neither necessary nor sufficient for it. For example, both Toyota and GM capitalized upon product modularity to outsource production, but only Toyota integrated the knowledge and organizational structure of its upstream suppliers, thus demonstrating a Chandlerian integration. GM's failure to manage supplier knowledge placed it at a significant disadvantage. Thus, we would amend Chandler's statement to read, the distinctive feature of the modern industrial enterprise is its managerial coordination.

Recent decades have seen a dramatic altering of the economic landscape through processes such as outsourcing, offshoring, and disintermediation. However, as the cases of Dell and P&G show, these trends may be associated with *more* centralization and managerial coordination, not less. Outsourcing means that more and more production requires managerial coordination across firms. Thus, the death of the managerial practices in supply chain associated with the rise of mass production has been greatly exaggerated. Nevertheless, in the twenty-first century, customer firms increasingly rely on their suppliers' specialized skills, but have less private incentive to invest in improving those skills, since suppliers are shared with their rivals. A challenge for the future is whether nations can develop institutions to help business firms in the twenty-first century reap as much of their productive potential as they did in the heyday of the mass production era.

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