

Internet-Driven Innovation and Economic Performance
in the American Automobile Industry

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1. Introduction

The automobile industry is among the largest industries in the American economy. It has been a font of innovation in production systems and marketing methods. Twice in the course of the twentieth century the industry led the world to a new paradigm for production, moving from craft to mass production in the teens and twenties and on to lean production in the 1970's and 80's. Automobile ownership is widespread among the households of the nation, and it is generally the second-most expensive durable good each owns (after only the home). No consumer product in history to date has had as profound an effect on lifestyles and on landscapes (both for better and for worse) and on the physical locus of work and residence. Except for the city-states of Hong Kong and Singapore, no major economy in the world today is considered to have established itself without a significant automotive sector. Furthermore, the automobile industry has been a lightning rod for regulatory activity. From the safety regulations inspired by Ralph Nader and the pollution and electric vehicle regulations inspired by Los Angeles smog, to the fuel economy regulations inspired by OPEC and the recycling initiatives inspired by German landfills, the auto industry has been every government's favorite target of regulatory opportunity. As industries go, it is naturally conspicuous.

There is even more beneath the surface. The industry also stands out for the complexity of the problems it poses for its managers. Its supply chains are broad and deep. Its technological challenges span a wide gamut across aerodynamics, fluid dynamics, mechanical engineering, electrical engineering, materials engineering, and civil engineering, among others. Its consumers are fussy about both performance and aesthetics. Design costs are large and sunk, driving chronic industry overcapacity and price competition in all but the hot-demand segments. The industry's relationships with growth-embracing but pollution-averse governments are many-dimensional. Furthermore the challenges in coordinating physical activities present extraordinary combinatoric challenges in the planning and control of production and distribution. Network technologies (e.g., internet, World Wide Web, etc.) promise major changes in the scope and cost of coordination through offering dramatic improvements in the ease and speed of communication. The industry is thus a natural subject for the project and a challenging environment for assessing the best use of these technologies.

Our paper proceeds in five steps. We first discuss briefly the historical evolution of the industry value chain and production processes. (We give a much more detailed account and critical account of this in a companion paper currently in preparation.) This exercise is motivated by the thought that present practices and possibilities are often partly determined and

highly constrained by past choices and historical events. This case may have lessons for other industries with similar histories as well as similar structural characteristics. Second, we discuss, in this context, recent web-related developments, future prospects, and implications. This discussion is qualitative but lays out an analytical structure. Some of the changes we site in that structure clearly represent relatively radical change in the present order. Third, we discuss what we consider to be the key question of the paper: whether the performance improvements triggered by new networking technologies will emerge as a one-shot boost or as a series of continuous improvements to be accumulated over years and decades. We interpret, in section two, the effect of Ford's moving assembly line as being in the first of these categories, but Taichi Ohno's lean production paradigm as being in the latter. Following this discussion, we turn to a systematic and, where possible, quantitative discussion of how the developments might affect practices in ways which could show up in the productivity statistics. Finally, we close with a discussion of the productivity statistics themselves and the industry's prospects.

2. Evolution of the American automobile industry value chain and production processes to the present

We find it helpful here to think the history of the industry's history as proceeding in five basic stages: the artisanal age (1890-1908), the age of Ford (1908-1930), the golden age of Mass Production (1930-1973), the age of Lean (1973-1990), the age of the Extended Enterprise (1990-2000). Post-2000, we expect the Internet to drive another transformation, the nature of which is the principal topic of this paper.

The artisanal age begins with the product concept still in the hands of workshop tinkerers and dreamers. It proceeds from prototypes through the earliest genuinely commercial offerings. The first major auto show was in New York in 1901. The first model which ever sold in volumes clearly unmanufacturable by hand methods went into production late in 1908.

In this earliest period, most output was manufactured by single-establishment enterprises which were vertically very unintegrated. Just like the pioneer innovators and the first entrepreneurs, these firms bought most of their parts from upstream firms which also supplied, at least initially, other industries. This supply industry was horizontally fragmented. Some of its output was made to buyers' specifications, some produced for the general trade.

The automobile firms did not disdain customized orders. Total volumes, even of the standard models, were low. The physical organization of production was along job-shop or, at best, batch production lines. The system exhibited tremendous inefficiencies in such simple features of the production process as the distances parts traveled in the course of individual stages of production. The grouping of machine tools and other equipment by process flow rather than by equipment type still lay in the future. For the most part, the manufacturers employed relatively highly skilled workforces who carried out their tasks with general-purpose equipment. These tasks were partly assembly and partly construction, but both often involved fitting and other fine work. The fitting was often necessary because of the irregular tolerances of the incoming parts. Firms began to do better than making each car one-at-a-time during this period,

but the old methods fell away slowly.

Firms had relatively modest product offerings; and both the trade journalism of the day and the surviving firm-level records suggest that they did not plan much in the modern sense of the word. Cost accounting was primitive (and not obviously widespread even at that). Systematic forecasting of demand scarcely existed. Instead, production runs were short and prices high. The demand side of the market was almost entirely confined—perhaps unsurprisingly--to the right-hand end of the income distribution.

There was a tremendous amount of entry and exit of manufacturing firms. The entry was made easier by the facts that capital-intensive stages of production could be left to the supply industry and that it was often possible to contract for parts and components on 90-day trade credit. Many firms succeeded, at least for a time, in selling the cars before the bills for the parts came due. There was something of the air of a gold rush about all of this, and some of the exit was surely due to entrants proceeding without adequate managerial skills, financial resources, or strategic planning.

One pattern to the shake-out was geographical. The industry was initially been fairly dispersed, but by 1908 it was clearly concentrating in the Upper Midwest. In only a few years more, Detroit would be its unambiguous capital.

This period saw a tremendous amount of progress in the basic technology of the product. Early on, it was quite unclear if automobiles would be predominantly powered by steam, electricity, or internal combustion engines. By 1908, the answer to this was clear. Many other basic elements of mechanical systems and overall design were also taking shape by that point, though it was not for another twenty years that most were entirely in place.

The age of Ford really commenced in October, 1908. Its centerpiece was the Model T. The Ford company had been in business for some years previous, but only with the Model T did it begin to make its fortunes. The basic idea was simple: “The way to make automobiles is to make one automobile like another . . . , to make them all alike, to make them come through the factory just alike—just like one pin is like another pin when it comes from the pin factory and one match is like another match when it comes from the match factory.”¹ This sort of manufacturing could be done at a lower unit cost than more customized work. In effect, Ford then discovered (or, perhaps created,) the mass market. As the company did this, it became, by a very wide margin, the largest firm in the industry.

Once the company committed to the Model T, Ford production methods and human resources were optimized to the ideal of repetitive manufacturing. This included—crucially--the systematic deployment and exploitation of the so-called American System methods for producing truly interchangeable parts. (This had the feature, which Ford found attractive, of lowering, on average, the average employee’s skill requirements). None of this was, as a matter of implementation, simple. Ford machine design was highly innovative. The input tolerances

¹ Henry Ford quoted in Alfred D. Chandler, Jr., ed., *Giant Enterprise: Ford, General Motors, and the Automobile Industry* (New York: Harcourt, Brace, and World, 1964), p. 28.

required were unprecedented. The working conditions and demands were equally unusual in the industry of the day and the institutions Ford developed to respond to this became famous. The coordination tasks were equally challenging.

Mass output required inputs on a mass scale. Where was it to come from, particularly given the tolerance demands? Ford found the supply industry reluctant to invest in production capacity specific to his company; and for this reason as well as others, Ford's vertical integration was eventually substantial. It was, however, far from complete: many independent suppliers were still used. Ford forecasting of demand was crude and there is no evidence it was, once made for any period, commonly modified. The maintained buffer stocks appear from photographs to have been substantial. Scale and continuous flow of production were paramount.

The effects of these innovations on productivity were dramatic, not least because some of the changes (in particular, shop floor reorganization and moving assembly lines) were implemented quickly. Diffusion across the industry was not immediate, but the Ford company saw double-digit total factor productivity growth on an annual basis for extended period starting with the Model T specialization. With the development of the massive River Rouge manufacturing complex, however, current scholarship argues, productivity growth due to this innovation effectively stopped.¹ In effect, we think it reasonable to conclude that the Fordist production paradigm innovation was of an extreme type: it provided a one-shot (admittedly enormous) boost to economic performance, after which, performance improvements tended to come from other domains

Many elements of the initial approach to mass production persisted at Ford and elsewhere for many years. But starting in the mid-1920s, new developments took on increasing importance in the industry cross-section. The Ford Motor Company was essentially a single-product company, making a product that, famously, came in "any color the customer wants so long as it is black". In the early history of the industry, business combinations that did not follow this model tended to be small and not particularly prosperous. The General Motors Corporation was initially one such company. It grew significantly in size during the Model T era primarily by acquiring and (to a very limited extent) integrating many small players. But in this period, GM was never particularly profitable; and, in the years after World War I, it came close to financial crisis. Organizational innovations developed by Alfred Sloan in the aftermath of its troubles brought on close to half a century of superior performance. The innovations included a broad product line with planned, fashion-based, obsolescence, systematic investment in brand planning and advertising, multidivisional structures for governance and control, and sophisticated systems for financial accounting, market surveillance, and forecasting. Still, some elements of the way business was done changed little. Life on the assembly line continued to be pressured but passive. There had once been a vibrant and innovative supply industry, but GM and the other principal US car manufacturers brought and tended to keep in-house the assembly and product-development work for components and subsystems, typically outsourcing only the low-level production of individual parts according to detailed specifications. The automakers also worked to keep component prices down by demanding bidding competitions for each job.

¹ Karel Williams et al., *Cars: Analysis, History, Cases* (Providence: Berghahn Books, 1994)

For the period between 1930 and 1973, Ford, General Motors, and Chrysler (an entrant organized along GM-like lines) substantially dominated the American market. Unionization made no difference to this (though the 1948 settlement enhanced whatever bias there had been towards hard automation and an inflexible division of labor on the shop floor.) There was little effective competition from imports. In the wake of the 1973 oil price rise, however, this situation of product market hegemony changed sharply. Detroit was at the time producing powerful but heavy cars with low fuel economy, and the initial appeal of the Japanese producers was the fuel economy of their offerings. Toyota, Nissan, and Honda rapidly distinguished themselves, however, with their manufacturing excellence. The particular feature was across-the-board quality, which emerged from processes of continuous improvement and concurrent engineering. They also offered more variety, more conveniently attainable, than the Big Three did. All these played well with the consumers, and none proved easy to replicate rapidly.

The continuous improvement paradigm was a particular challenge for the Big Three. A key component of lean production, it originated at Toyota. Toyota had faced a very different market from Ford as the Japanese company launched its post-war development, and these best practices grew out of different approaches to shop floor culture and human resource management practices, different mechanisms for coordination with suppliers, and different use of inventories, i.e., as a tool for rooting out imperfection and inconsistency rather than as a means of preventing shortages and shutdowns. The American firms eventually made significant headway with this ongoing approach to productivity enhancement, but the system was so different from their own approach that the process took many years. In fact, we believe it appropriate to conclude that the lean production paradigm differs from that of Ford's innovations in a critical way: the lean paradigm, by its very nature, is one that demands incremental improvement over long time periods, in contrast to the "quick fix" provided by installation of the moving assembly line and Ford's set of innovations.¹

The most recent phase we see has Chrysler as its focal firm. By the 1980s, Chrysler had become cash-poor and nearly bankrupt. As the smallest and weakest of the Big Three, Chrysler typically stood third in line with suppliers, who were continuously at the beck and call of its much stronger and much larger cross-town rivals. At one of its darkest hours, Chrysler executives met with suppliers and, partly out of desperation, proposed a radical change in the way the company would deal with its value chain. They called (and trademarked) this the Extended Enterprise. Instead of the old system of dictating to suppliers and trying to pit them against one another—which the suppliers of course hated--Chrysler promised to commit to long-term relationships for developing entire subsystems and to share the benefits of any cost-saving ideas with suppliers. Long the norm in many Japanese companies, this mode of operation represented for Detroit a major departure from business as usual.

At the same time, Chrysler accelerated the outsourcing of its components-development and technology-development activities and, as a result, the corporate overhead associated with them. It came to design, assemble, and market vehicles to which it had contributed little of its

¹ Fine, Charles H. and Evan L. Porteus, "Dynamic Process Improvement," *Operations Research*, Vol. 37, No. 4, 580-591, discusses this feature of the system in detail and provides a number of references to support the characterization.

own innovative component technology. Instead, the company relied on mutually beneficial partnerships in which suppliers grace Chrysler's autos with the latest advances. The results of this restructuring were sweet: Chrysler vehicles became Detroit's most profitable, its styles the most envied, its unit costs the lowest, and its time-to-market the swiftest. Chrysler's market share and market valuation soared. Ultimately, the turnaround led to Chrysler's shareholders receiving a premium price when the company was acquired by Daimler Benz in 1998.

Chrysler's organizational innovation triggered important effects: Its suppliers were strengthened by the systems design and integration work opportunities, leading to a significant growth of these skills outside of the OEM's. This phenomenon, in turn, triggered in Ford and GM an impulse to increase outsourcing to the supply base and to divest their own components businesses to attain a cost structure more competitive with Chrysler's. The spin-offs of GM's and Ford's component-making arms, Delphi and Visteon, respectively, followed shortly thereafter.

Throughout this history, whatever the state of upstream organization, the downstream relationships were simple. In the earliest days, OEM's sold directly from the factory and through dealers who maintained showrooms, sales staff, and product inventory. As the industry consolidated, direct sales effectively ended. The main change for most of the second half of the century was legislation passed, primarily at the State level, which entrenched the property rights of the dealers in the exclusivity of their franchises. If a potential customer wanted to buy a car, he or she went to the local dealer. Virtually all purchases were made from existing stock since lead times on custom orders ranged from many weeks to several months, depending on the make and model. The inefficiencies of this system included the high cost of finished goods cached in dealer lots across the country, the frequent mismatch of individual customer desires with the locally available inventory options, and the frequent discounting required to clear the dealer lots of models with unwanted configurations.

Although many automobile dealers became wealthy in the post-war period, the system costs were high. Whereas the Big Three worked mightily during the age of Lean to get their factory and supply chain inventories down to a few day's worth, sixty or more days of inventory was typical in the distribution chain. The total cost of the distribution system was often estimated at up to 30% of the total vehicle price.

3. Recent web-related developments, possibilities, and implications

The question at hand is how widespread access to Internet and web-based communication might alter practice and productivity in the automotive industry. Before homing in on details of current industry practice, it may be worth examining some available models and influences.

Developments in the computer industry provide a very striking example of the possibility of moving away from a costly make-to-stock industrial tradition. Personal computer manufacturers once also worked in the auto industry's traditional way. The Dell Computer Corporation revolutionized that business with the superior performance and profitability of its

“Dell Direct” model. Dell’s approach eliminated links in the supply chain both upstream and downstream of the system OEM. Downstream, Dell eliminated retailers and distribution channel inventories by selling only direct to final customers over the internet on a make-to-order basis.

Upstream, Dell’s advantage arises from the end-to-end (E2E) integration of the supply chain with the distribution or demand chain. Using parts ordered from catalogs, Michael Dell began assembling and selling computers from his dormitory room at the University of Texas in the mid-1980’s. The basic process has changed little since that time. Dell Computer takes orders for customized PCs and workstations over the telephone and on its Internet site, begins building the machines almost immediately after the orders are complete, and ships the completed products as soon as they are built, often within 24 hours. The company carries no finished goods inventories, nor does it employ any distributors or retailers who carry inventory. It ships all products directly from its factory to the final customer. Furthermore, Dell carries almost no materials inventories: Every part the company buys goes immediately into a machine that is then built and sold.

How does Dell know what it will sell? To understand the answer, it helps to frame the question the other way around: Dell sells whatever it has purchased. The only variable is price¹.

Dell’s sales organization is responsible for forecasts and decisions on what components to purchase. Because commissions are based on Dell’s profit margins, salespeople must sell whatever they order, including components for which buyers misjudged customer demand. If demand falls or customers no longer want a component, the sales organization must lower the price so that the product sells no matter what.

How does the company avoid getting burned? First, it gets good prices from suppliers because it buys in volume. Second -- and this is the real key -- if in doubt about likely customer preferences, buyers always opt for ordering components of latest technology because those have the longest shelf life. Because the company carries no inventories and has no resellers, it can be the lowest-cost producer. In addition, because high-end users usually purchase the latest components, the Dell model is to service this select group to keep its profit margins healthy.

In a set up like this, the faster the clockspeed of the computer industry, the greater the advantage Dell wields over its competitors. How does this work? Every other major PC maker builds to stock and sells through resellers who carry inventory. This is an industry in which inventory does not age gracefully.² In fact, aged inventory in the computer market is downright ugly. What could be worse than holding a large inventory of PCs with built-in 28K modems when the new 56K modems hit the market? Who would have wanted to have on hand several thousand Pentium processors when Intel introduced the Pentium II and prices of the old Pentiums dropped through the floor?

¹ Stuart Smith, “Capitalizing on Clockspeed in the Direct Business Model,” paper presented at “Creating and Managing Corporate Technology Supply Chains: Value Chain Design in the Age of Temporary Advantage,” symposium at the Massachusetts Institute of Technology, Cambridge, Mass., May 12-13, 1998.

² Ibid.

In the lightning-speed PC industry, such obsolescence is practically an everyday occurrence. The more inventory in the chain, the higher the obsolescence costs. And the faster the clockspeed, the higher the obsolescence costs. So, whoever has the leanest chain wins -- and the faster the clockspeed, the larger the margin of victory. As we understand it, this is how the Dell system exploits its end-to-end integration.

In summary, Dell reaped a number of advantages from this structure. It tied up much less working capital in raw materials inventory and work-in-process. It tied up dramatically less working capital in speculating on which particular configurations customers would want to buy (since it now only made what they asked for). It was paid promptly--indeed, often before it had to pay for its own inputs. Its channels required much less management (though its supply chain probably required significantly more).

The possible advantages could be even more powerful in a less commoditized business. It might be that consumers place a high value on having very particular configurations of equipment and have a correspondingly high willingness-to-pay for them. If—unlike in Dell’s business—these configurations are hard for other vendors to imitate—perhaps because brands matter—than the ability to give the customer precisely what he or she wants may be very profitable.

For better or worse, companies like Dell and the ubiquitous Amazon.com have created customer expectations that are beginning to affect the auto industry. Consumers are increasingly also Internet consumers, and Internet consumers have come to expect that the norm in retail commerce is at least converging on custom-ordering products one day and expecting home delivery the next. The appeal of this model for automobiles is high for both customers and manufacturers, but achieving dramatic reduction in lead times with a build-to-order capability is far beyond the present-day capabilities for most auto manufacturers. Automotive supply chains are far broader and deeper than those of personal computers and incomparably more so than those of books. The ineradicable lead times in auto manufacturing are just much longer. These differences reflect the much greater complexity of an automobile and the much greater physical product variety in the marketplace.

Build-to-order capabilities in the PC industry are also enhanced significantly by the modular structure of the dominant product platform. By the mid-1980’s, a personal computer comprised such highly-standardized modules that a college student like Dell could indeed launch a PC design-production-sales business by ordering standard components from a catalog and assembling these into a computer in a garage or a dormitory room. The automobile of the late twentieth century exhibits a highly-integral product architecture, whereby each product takes many man-years to design and significant capital investments to assemble at efficient scale.

In addition, franchised dealers with extensive legal rights to exclusivity play a major role in car distribution. Existing automotive manufacturers are effectively prohibited from disintermediating their dealers and the costs of distribution in the current system are often estimated as being as high as 30% of total vehicle price. Such legal protections have never been present in consumer electronics markets, so that Internet retailing was easily implemented by

firms such as Dell and Amazon.

The pressures to reduce cycles times in the present-day automobile industry are nonetheless immense. One reason for this relates to the product itself. As the capabilities of small computers and chips steadily grow, the vehicle itself is becoming less mechanical and more electronic in its functioning. (It is becoming less a machine and more an information-intensive mode of transportation.) Many auto firms hope to exploit the promise of telematics (telecommunication capabilities in vehicles) to effectively use the vehicle as a portal to a wide range of new services that can be sold to the customer/driver. These services might include offerings in the domains of enhanced safety, navigation, concierge services, email/web/telecom-based personal productivity, and entertainment. There might be whole new revenue streams here as well as new gadgets, since the driver is a relatively captive audience. However, the development cycles in the auto industry are slow (4-6 years) relative to those in the handheld device market (e.g., 6-12 months for palm-sized computers and mobile phones). As a result, the automotive OEM's may be relegated to merely offering the driver a place to rest his/her handheld device for mobile services, rather than innovation in this arena, unless key players can find ways to dramatically increase the clockspeed of the conception and delivery of their product and services.

In short, it is apparent even before any detailed examination of the process of making automobiles that networking technologies provide an array of opportunities and challenges for the processes of designing, manufacturing, and selling cars as well as for the bundle of services delivered by the product itself. In the former case, the challenges for traditional carmakers are to re-engineer their business processes from their supplier's supplier to their customer's customer and do so before a new entrant leapfrogs the existing dominant firms. In product space, the challenge is to enhance the vehicle with services offered through new networked technologies before other firms (e.g., mobile phone providers) beat them to the punch.

4. The significance of these developments for costs and the generation of consumer surplus

This section is the analytical and evidentiary core of the paper. It reports current estimates of the significance of it for costs and the generation of consumer surplus. Our procedure for presenting these estimates begins with informed but essentially conceptual analysis. We considered the whole of the value chain involved in automobile design, manufacturing, and distribution and identified the steps at which networked communications might conceivably have an impact. These are laid out and explained below.

We then summarize the literature attributing numbers to the potential impact for as some of these. The estimates derive from the suite of analyst reports currently in circulation (from Goldman Sachs, J.P. Morgan, Deutsche Bank-Alex Brown, and others) addressing specific issues that come up in our analysis. The reports are ultimately based on conversations with company experts, so they move our conceptual analysis in the direction of hard data. But they have two weaknesses as sources which we should clarify before we start.

The first weakness is structural. One might have hoped that the reports would all have the same conceptual organization and focus but different sources and therefore represent, in effect, independent observations of common random variables. But this hope is naive. Analysts are paid in part for being well-known authorities, and product differentiation is a far easier road to this status than head-to-head conflict. (It is also generally faster, and there can be no doubt that the institutional clients who are the principal audience for the reports wanted to hear something sooner rather than later.) In the event, few do address the whole range of questions we have identified and there is indeed little overlap, particularly among the quantitative estimates. Collectively, however, they do offer numbers to fill in many of the cells.

The second weakness might be called procedural. Analysts are generally both intelligent and hard-working, and the best are very well-informed and highly perceptive students of the firms and industry they cover. But the environment in which they work offers complex incentives. The analysts' firms sell brokerage services. One observes that critical analyst reports in advance of unambiguous bad news are infrequent, as are downgrading of ratings. On a matter such as the significance of technical change for long-run growth—in which results are likely to emerge unambiguously only long after portfolio reallocation decisions will be made, and possible even after analysts have retired to cultivate their gardens—one might reasonably fear a blue-sky bias. We can at this point offer no remedy beyond a cautious attitude.

We also note that it is easy to fall into the habit of thinking of this industry as pure manufacturing. Those activities are not themselves simple. But, as we noted above, they are very far indeed from the whole of the system and thus from the whole of the potential realm of economic impact. In that larger realm, we see four broad sets of activities worth detailed analysis, each with many subcategories. These broad categories are product development, procurement and supply, manufacturing systems, and the vehicle order-to-delivery cycle. We turn to such anatomizing next.

4.1 Conceptual Apparatus for assessing the economic impact of network technologies

To assess the potential economic impact of network technologies on the automobile industry requires a framework with which to categorize the effects. Figure 1 below presents the framework we propose for this purpose.

(Figure 1 about here)

1. Product Development
a. Ease of Engineering Changes
i. Costs of Making Changes
ii. Threshold for Quality Improvement
b. Lower direct cost of communication
c. Lower cost of n-way coordination
d. Product Development Cycle Speed

3. Manufacturing System
a. Improved Manufacturability
i. Faster setups
aa. Smaller lot sizes, reduced inventory
bb. Higher capacity utilization
ii. Easier assembly
b. More outsourcing

2. Procurement and Supply
a. Reduced transaction costs in purchasing
i. Speed existing processes
ii. Redesign Processes
b. Consequences of Aggregating Orders
i. Bulk buying at firm's n-th tier
ii. Bulk buy across OEM's
iii. Bulk Shipping
c. Consequences of Price Competition
i. Margin reduction
ii. Cost Reduction
d. Logistics
i. Reduced "rush" orders due to better information

4. Vehicle Order-to-Delivery
a. Reduced Order-to-Delivery Cycle Times
i. Lower inventory levels in pipeline
ii. Better matching of Supply to Demand
aa. Higher prices for higher customer satisfaction
bb. Less discounting of undesired stock
b. Retail Channel costs
i. Lower sales commissions
ii. Fewer dealers and lower total overhead
iii. Lower shipping costs to fewer stock points

Figure 1: An Economic Framework to assess economic effects of network technologies

4.11 Opportunities in product development

Product development in this industry is extremely expensive, with many projects costing in the range of \$1-3 billion and extending over 2-4 years, in the course of this consuming in excess of a million engineering man-hours.¹ Cars are complex objects, and particular resolutions for many design problems have implications for the ways other problems can be resolved—the interaction effects are potentially quite intricate. This is the more so as the product becomes more technologically sophisticated (e.g. with the increasing integration of electronic control systems) and as consumers increasingly notice the degree to which general design problems have been resolved in optimized ways (observing this either directly or through quality and durability records). Traditional methods for taking care of this were slow. Yet both the technological possibilities and consumer tastes seem to be evolving rapidly. Thus fast new product development is increasingly seen as an important element of competitive advantage. The development process being information-intensive, it is a natural target for network-based innovation.

Typical development processes have in fact changed significantly over the past decade. The days of Mercedes' twelve-year product cycles, for example, are past. Four areas of product development as it is currently organized and carried out offer significant network-based opportunities for productivity enhancement.

The first of these concerns the ease of actually making engineering changes. Networked communication lowers the direct cost of implementing changes. Variant designs, created on CAD-CAM systems, can be circulated widely both rapidly and cheaply. Modification is also rapid and cheap. Even just taking the menu of changes to be made as given, the costs of making them declines.

There is more to the impact on making engineering changes than this, however, since this menu of changes is not to be taken as fixed. (In economists' language, there is a general equilibrium effect to the factor price change as well as the partial equilibrium change.) As change becomes cheaper, the threshold level of quality improvement large enough for change to appear worthwhile will fall. More of that which is possible will actually seem financially feasible: thus, more changes will actually take place.

As designs grow more complex and design interdependency increase, there is increasingly more to the costs of making design changes than multi-input revisions of CAD-CAM calculations. Recall the costs of new product development. These are principally the cost of human resources rather than of materials or equipment. Thousands of individuals and hundreds of specialties are involved. Direct and opportunity costs of communication decline as networked communications permit e-mail to replace face-to-face meetings and telephone calls. Increasing numbers of people become involved in making the decisions, but the decision-making takes less time collectively and no longer requires getting groups together into a common room

¹ See, e.g., Kim Clark and Takahiro Fujimoto, *Product Development Performance* (Boston: Harvard Business School Press, 1991).

at a specific time. “Meetings” have become cheaper and perhaps even asynchronous.

The most important element, however, is likely to be a general equilibrium effect not yet touched on. With communication and coordination cheaper and implementation easier and more frequently done, the fixed cost of new product development is lower and the whole product development cycle can easily go faster and more frequently. This enables the manufacturers to get designs to market in a more timely fashion and to do this in an affordable fashion, permitting a better matching of products being offered with customer desires.

4.12 Opportunities in procurement and supply

A second important element of the value chain is procurement and supply. The significance General Motors placed on the services of the Spaniard Ignacio Lopez, as well as the ferocity with which it fought his being poached by VW in the mid-1990s, gives a crude measure of the importance the company saw in getting this optimized. Similarly, the rise of Thomas Stallkamp, to president of Chrysler and then to president and vice-chairman of DaimlerChrysler, illustrates how highly valued his Extended Enterprise™ model was to corporate success.

As suggested by the enormous interest in on-line business-to-business marketplaces, networked communications will significantly affect the economic structure of supply networks as well as the costs of the underlying activities. This has a number of components.

Transactions costs of purchasing will undoubtedly fall. Clerical work will become automated, and go on both faster and more reliably. Processes—needs identification, vendor selection, review and approval--will work very much faster and more efficiently.

The new communications technologies also offer opportunities for aggregating orders that seem likely to have large consequences for costs. These have three main elements. All derive from the fact that web-based procurement makes advertisement of requirements and terms cheap and enhances the likelihood of receiving comparable bids. This is of the first importance in an industry with a typical cost-share of materials of nearly 50% for many companies and products.

Orders can be consolidated and placed strategically at the nth tier of the supply chain. That is, the OEM can use the technology to gather and keep current information about supplier capabilities and performance and to use this to concentrate orders at the most efficient suppliers. If information about the whole supply chain is available in a transparent fashion, the OEM can use the fact of the scale of its overall orders to obtain advantages for its suppliers at all n tiers (for example, if multiple Tier n suppliers are using common Tier n+1 suppliers) as well as extending the use of advanced scheduling software and the like.

The process of consolidation need not stop there. OEM's have joined together to create Covisint to pool their purchasing power and to develop technology platforms to exploit networked technologies in many arenas, including procurement and engineering. The recent decision by the Federal Trade Commission suggests that this venture will actually go forward.

Consolidating orders could enable consolidating shipping. Effectively, larger orders with more lead time and certainty might allow the assets of transportation providers to be used more effectively.

Such consolidations should yield savings primarily through economies of scale in production and distribution. In addition, network technologies should also lead to greater price competition in the supply chain. This would have beneficial effects for the OEM's through two distinct channels, both of which would show up in the productivity statistics as currently calculated. The first is that supplier margins would decline given the basic structure of costs: there would be more direct competition for orders. The second is that suppliers would be motivated—if not forced—to invest more in cost-reducing innovation: in the long run, costs would go down too.

There is a final element of supply cost that would be affected, and this because of the lower cost of obtaining and using up-to-date information about demand. With more current information, there would be greater forecast accuracy and a clearer understanding upstream about what demands were coming. This would lead to fewer rush orders. Rush orders are almost always filled and shipped in high-cost ways.

4.13 Opportunities in manufacturing

The manufacturing system itself may well change in highly significant ways. Here, there are two main possibilities. First, networked communications may lead to improved manufacturability within the set of activities the OEM's continue to carry out. Such improvements may result as an added benefit of networked product development activities in enhancing design for manufacturability. In turn, improved manufacturability may reduce scrap and setup/changeover times as well as reducing assembly times and complexity, all resulting from the reduced amount of real-time process engineering required by factory personnel who often must find ways to compensate for difficult-to-manufacture designs.

In addition, due to reduced transaction and search costs, an environment of fast and flexible communication across the automotive supply chain may lead to a greater use of common modules across automotive manufacturers and first-tier suppliers. This modularity, in turn, can encourage firms to outsource greater portions of the manufacturing enterprise as firms begin to specialize in certain kinds of modules.¹

4.14 Opportunities in the order-to-delivery cycle

Dramatic changes seem likely to occur in the vehicle order-to-delivery cycle. There are two broad categories. The first concerns cycle times per se, the second channel costs.

As mentioned earlier, Internet penetration into households seems to have stimulated a demand for more goods available as configurable over a World Wide Web interface and

¹ See, for example, Charles Fine, *Clockspeed*, Perseus Books, 1998.

delivered by a rapid service delivery provider. In response, on the supply side, we believe that networked communications has the potential to reduce order-to-delivery cycle times, although probably not at the level of delivery times and inventories achieved by Dell. Network technology will make it possible for suppliers to “see” customer orders as soon as they are placed, reducing the historically significant delays in transmitting this information along the supply chain. Conversely, order takers should have much better visibility into the capacity and inventory available in the chain so that prices can be proactively adjusted to steer demand toward product configurations that can be delivered within shorter time windows. Better information about demand even without full make-to-order will lead to smaller efficient levels of finished goods inventory. The amount of money tied up in such inventories now is very large, with 40-80 days’ worth of distribution-chain inventory being typical for many models.

The effect of better information will also turn up in the revenue line. Desired stock (that is, stock made to order) should bring higher prices because it will be precisely what is desired by a given customer. The magnitude of severe discounting of difficult-to-sell configurations as well as the reduction of all promotional expenditure of overstock should be reduced.

The costs of operating the retail channel should also decline, perhaps dramatically. Sales commissions should fall since the information-conveying role of the sales force seems likely to melt away. (From a more sour perspective, customers will know so much that competition will force commissions down.) Indeed, with consumers seeking out information over the web, manufacturers may become very much better informed about consumer tastes. This would be valuable information throughout the value chain.

For the same reason that fewer salesmen are required, fewer dealerships may be in order (and thus total value-chain overhead may decline). With fewer dealers, there will be fewer stock points and lower industry shipping costs. (Some scale economies may be lost getting cars to customers, but there will be very much less backhauling.)

4.2 Current estimates of the size of these opportunities

The most thorough study to date of these matters is the Goldman study.¹ The numbers given below are theirs unless otherwise stated. We note that these are not all of their components (we do not discuss about twenty percent of the savings they identify) and that we sometimes aggregate the primitive components rather differently than they do.

The overall estimates are given as possible cost reductions relative to present average costs (which they put at \$26,000). We will explore in Section 5 the extent to which these represent productivity improvements in the sense the phrase is usually used. But they are a start towards understanding the industry’s present situation; and they are thought-provoking because the magnitudes they suggest are not small.

Under the heading of product development, all analysts see some prospects for improvement. But there is so little consensus as to suggest a lack of detailed analysis. Goldman

¹ Gary Lapidus, *Gentlemen, Start Your Search Engines* (New York: Goldman, Sachs, 2000).

puts the potential cost reductions at this stage at \$388, Deutsche Bank Alex Brown at more than two-and-a-half times that sum. Neither seems to have considered the process itself analytically: the numbers represent savings from superior designs as reflected, for example, in lower warranty and other expenses due to improved quality. On the basis of our description of the process and its expense above, we certainly think there are unconsidered elements here. For a \$2 billion vehicle development project that yields one million production units over its lifetime, \$388 would represent a savings of 19%, which is optimistic, but not impossible, in our opinion.

Under procurement and supply, Goldman sees a slightly larger but basically similar-sized opportunity. They see \$160 in reduced transaction costs (others' estimates come to roughly comparable dollar sums). They also see \$70 in firm-based bulk buying and another \$47 from inter-OEM coordination. Declines in supplier margins would contribute another \$94, they say, for a total of \$331. They do not consider web-enabled economies in shipping expenses, nor do they seem to think that web-procurement will lead to significant cost-reducing innovation from suppliers. The whole issue of rush-order-related costs is not recognized. This too suggests underestimate.

Goldman sees manufacturing as the same size opportunity. Their analysis suggests total of \$302 of savings from improved manufacturability. They do not seem to see important advantages coming from a change in outsourcing behavior in itself, despite the different cost structures OEM's and supplier firms typically have.

The order-to-delivery cycle is, in their view, where the big money is. They see \$575 in savings due to lower inventory in the channels (though others' estimates of this run as low as \$150) and \$832 in savings due to better matching of supply and demand. In retail, they predict \$381 for lower sales commissions, \$387 for the reduced burden of fewer dealerships, and \$50 for lower overall shipping costs, for a sub-total of \$818. Altogether, the total for this stage (in our categories) is \$2225.

All in all, then, Goldman sees (on our terms) potential reductions of \$3446 i.e. in excess of 13 percent. And there are reasons to believe that important potential savings have still to be incorporated into this. So even if one imagined their figures to be biased high for the reasons described above, the true figure appears likely to be very substantial.

In a subsequent publication more focused on European manufacturers, Goldman offered a focused but more detailed financial analysis (based on one disguised actual manufacturer). They place some weight on the possibility that revenue will actually rise but do not factor this into the computations. The gist of their results are as follows. Reductions they think perfectly feasible in channel inventories would boost the return on capital by about 11 percent by the second year out. These reductions plus what they take to be a feasible decline in sales incentives on 40 percent of the cars sold (which they take to be a feasible target) would push the return up an incremental 18 percent. Pushing the percentage to 100 percent (complete build to order) adds another 29 percent. We take these calculations to be merely illustrative but to make clearly the point that there is a great deal of money and time tied up in the order-to-delivery cycle and a great deal of lost opportunity tied up in selling cars with specifications different from the ones the customer

would actually prefer.

5. Relationship between these changes and sources of ongoing improvements in productivity

Traditional measures of total factor productivity and productivity per head (i.e. the average product of labor) measure output in value terms rather than in physical units. Any factors which affect sale prices will thus affect measured productivity. This is a good feature of an index if improved quality--not measured by the statistician but recognized by the consumer—enhances, say, product operating life in ways for which consumers recognize and are willing to pay: The index goes up as economic reality says it ought to. But there are circumstances—increased competition, for example--in which such an index might go down with true productivity either not changing or actually rising. So such measures should be interpreted cautiously.

The statistical productivity indices available for this industry possess these vulnerabilities and more besides. Most importantly, they are available only through 1994. This may well not be enough history to show important patterns. The general pattern they do show is noisy trend growth in multifactor productivity through the early 1970s, a steep drop-off and recovery in levels over the next rough fifteen years, and a distinctly sharper trend emerging roughly as the real diffusion of lean production got under way. This is, of course, consistent with the continuous improvement emphasis of lean production. Suppose that is what it is.

The question the discussion of Section 4 raises in this context is as follows. Do the changes networked communications seem likely to bring to automobile industry's value chain and the structure of its costs seem likely to affect true productivity in the same sort of ongoing way as lean production? Or are they likely to be merely transitional, essentially one-shot changes (however long the new equilibrium may take to establish itself) where they affect productivity at all, predominantly representing a transfer of surplus from one stage of the value-chain-plus consumers to another (or at least putting them up for grabs in competition between firms)? The discussion of Section 4 suggests that there will ultimately be some of each, but that the predominant effect of networked communications will to rescue the industry from what was once a great advance—make-to-stock-oriented mass production—which has become outdated as living standards have risen and alternatives have grown more rich. The predominant effect thus seems likely to be to wring inefficiency out of a value chain through what is basically a one-shot improvement in forecasting, communication, and coordination. The automobile sector of the manufacturing economy is large and this could well have a discernible effect on productivity growth while it is happening; but it does not seem likely to be ongoing.

A transition of the manufacturing system and supply chain to one focused on this might difficult to bring about and impossible in any short timeframe. So it would be difficult to predict with any confidence what numbers to expect and over what time period even if we knew the possibilities with certainty. And we certainly do not know this. But this much is clear. Even if the potential cost-savings discussed above were twice or three times too high, the true numbers would still be large. They might not attract so much attention from stock analysts and

journalists, but they would still command the attention of firm decision-makers. That something will happen seems thus beyond doubting. To whom it will matter, and for how long, still seems up for grabs.