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**POWER DIFFUSION IN AUTOMOTIVE SUPPLY CHAINS**

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## Introduction

Forty years ago, John Kenneth Galbraith declared that the world had "solved the problems of production,"<sup>1</sup> and suggested that other problems were more deserving of attention. Although this claim proved to be premature at best, different business problems do tend to demand attention of industry leaders at different instants in time. In 1990, the "problems of production" were, in fact, on the front burner. That year, MIT's International Motor Vehicle Program (IMVP) published *The Machine that Changed the World*, a book that both provided an articulate and data-reinforced description of the Toyota-inspired lean production system and that predicted widespread adoption of this superior approach to integrated manufacturing and business management. In a very short time, the term "lean production" has entered the mainstream business lexicon and is indisputably important in the plans of a large fraction of the world's manufacturing base--automotive and otherwise. In fact, production was the problem of the time in 1990.

Seven years later the world has changed significantly. In the automotive industry, widespread adoption of lean production practices has reduced dramatically the competitive gaps among the world's key players. This narrowing of the gaps has spurred more rapid and diverse innovation efforts, as each player seeks some form of advantage in the marketplace. Simultaneously, all along the automotive value chain, from electronics suppliers to retailing outfits, innovative, aggressive companies are challenging the primacy of the automotive assembler--traditionally the supply-chain heavyweight in the industry. Additionally, industry growth is stagnant in the developed world, but skyrocketing in the developing world, bringing to the industry stage a raft of new players--not all of them traditional private-sector, profit-making ventures.

As always, the auto industry, the planet's *industry of industries*, seems to be a bellwether for the rest of the commercial world. Over twenty years ago, in more placid times, the U.S. auto industry, the undisputed industrial powerhouse of the world, experienced a double shock unparalleled in its history. As a result of the combination of the 1973 oil embargo and the invasion of high-quality Japanese cars into North America, the U.S. auto industry began a frantic period of seeking a new business model while hemorrhaging cash, market share, and jobs.

The history of the automotive industry since the double shock of the early 1970's has been a history of the diffusion of power--from a concentration in General Motors (the world's largest and richest corporation for a significant part of the 20th century) that was so high in the 1960's that its managers eschewed market share gains in order to avoid greater scrutiny from American antitrust investigations to a

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<sup>1</sup>Galbraith, John. *The Affluent Society*, 1955?

dispersion of power that is so great that governments with economies smaller than the auto industry dictate terms to once-omnipotent industrial titans.

The pinnacle of power concentration in the automotive world may have been reached with Henry Ford in the 1920's or more probably with Alfred P. Sloan in the 1950's. Indisputably, however, the diffusion of power since Sloan has accelerated and reinforces a unstoppable trend across the global industrial landscape. Not only have Ford and General Motors relinquished market power in the past few decades, but IBM, AT&T, Boeing, and many others have seen the center of the economic universe in their industries move away from the management of a small set of firms to a larger (more global) group of firms in their business, to a stronger set of players in their supply chains (both upstream and downstream), to a more demanding workforce, and to a more activist set of government entities.

For example, the United Auto Workers today has a say in a large set of business issues that range far beyond the factory floor. Perhaps most significant of these is the voice they have, at General Motors, on outsourcing, which severely influences management's ability to sculpt the corporation for the competitive challenges of the future. Looking up and down the supply chain, the same trend is evident: the large and growing first-tier suppliers have far more leverage in the system than they ever did and the explosion and splintering of distribution channels and retailing-relevant information moves the auto industry to a retailing model where the manufacturer calls far fewer of the shots.

On an international scope, we see competent automotive industry capabilities spreading to an increasing number of companies and countries with an acceleration of this trend on the horizon. Additionally, government entities--from California (emissions regulations) to Washington (CAFE, safety, emissions, etc.) to Bohn (recycling) to China (who gets to play)--influence almost every aspect of the design, manufacture, transport, sales, use, and disposal of automobiles. Even technology shifts have dispersed power, e.g., from steel producers and processors to steel plus aluminum plus composites producers, plus automotive electronics suppliers.

This diffusion of power is not limited to industry either. In the parliaments and palaces of government power, the same trend is evident. Neither the United States president, nor the U.S. government collectively, not NATO, not the U.N. security council, nor the Group of Seven economic powers can call the shots as they once could. Around the world, many more players have come of age and can demand a seat at the bargaining table. This course of events impacts not only the process of intra- and inter-governmental policy making, but also influences dramatically the policy options and outcomes for private firms.

It is this new world of dispersed economic and political power in which private corporations--large and small--must learn to thrive. The rules of the game have changed dramatically and will continue to change with each new power shift. We see in the explosion of economic opportunity and might in China the way that

new players may attempt to write new rules in their favor even as they struggle to cope and grow in a world of highly dispersed economic and political power.

The complexity of the world economy today is obviously far beyond the ready comprehension of any single model or analyst. In fact this statement is true for many individual sectors of the world economy such as the automotive industry. At MIT's International Motor Vehicle Program (IMVP), we have devoted continuous effort over almost two decades with a team of dozens of researchers around the world to collecting, analyzing, and synthesizing a large amount of information on the world's automotive industry. Although no industry could be considered as "typical" in a world whose industries span a spectrum that includes coal mining, semiconductor manufacturing, and multi-media entertainment, as examples, we have found that the label "industry of industries" is not altogether undeserved by the auto industry.

The auto industry has distinguished itself in the domains of production system innovation, economic development, consumer behavior, and regulatory initiatives, among others. Twice this century, the automotive industry has lead the world to a new paradigm for production--from craft to mass production in the 1920's and on to lean production in the 1970's and 80's. Except for the city-states of Hong Kong and Singapore, no major economy in the world today is considered to have "made it" without a significant automotive sector. And no consumer product in history has had as profound an effect on lifestyles and landscapes (for better *and* worse) as has the automobile. 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 is every government's favorite target of regulatory opportunity.

From our unique vantage point as students of this industry of industries, we attempt to make sense of the automotive world and the trends and patterns it responds to and creates, as well as to infer from our microscopic and macroscopic analyses what patterns are likely to spill over from the automotive milieu into the industrial world at large. In the course of our analyses, we have traced with care and watched with fascination the above-mentioned diffusion of power that has enveloped the industry. By studying these processes at the micro and the macro levels and by observing the details of the dynamics of action and reaction, attack and parry, integration and outsourcing, collaboration and competition, we have come to an understanding of the dynamics of this diffusion that may transcend the automotive industry into many other arenas. In this paper we focus particularly on diffusion of power into the supply chain.

## Supply Chain Design: Learning from the "Fruit Flies"

In analyzing the supply chain issues for the industry, we have relied on a framework developed by Fine (1996, 1998) which suggests examining fast-clockspeed or "fruit fly" industries to observe dynamic supply chain phenomena in rapidly-evolving industries as benchmarks for other industry situations. Geneticists study the rapidly-evolving fruit fly species in order to observe numerous data points in short periods of time to develop dynamic models of biological system evolution which are then tested for slower-evolving species such as humans. Similarly, we reference observations of dynamic processes in "fast clockspeed" industries to develop hypotheses about possible future changes in the automotive industry.

One of the fruit fly industries we have found to be particularly revealing the personal computer (PC) industry. In the early 1980's, IBM, which represented a significant majority of the worldwide computer industry had a technology supply chain decision to make as it entered the nascent PC industry. That is, IBM needed to concurrently design a product, a process, and a supply chain for that product. The technology supply chain they chose featured a relatively modular product architecture and reliance on Intel for microprocessors and Microsoft for operating systems.

Fifteen years and six product generations later (8086, 286, 386, 486, Pentium, Pentium-Pro) one can observe some fairly dramatic impacts of IBM's technology supply chain decision. IBM is still a large company by the standards of the computer industry, but, from the standpoint of their customers, one of the most critical features of their personal computer products is the logo on the machine denoting *Intel Inside*--a perhaps humiliating comedown from industry domination in the 1980s. Because of the widespread adoption of Intel and Microsoft technical standards, stimulated by IBM's decision to design these standards into their technology supply chain, relative power and leverage shifted along the supply chain--away from IBM onto its suppliers. IBM's choices about where to draw organizational boundaries for the extended organization and the supply chain resulted in the capture of less of the economic rents and industry power/leverage than they presumably hoped for. The lesson from this fruit fly: when designing your supply chain, beware of the possibilities of an *Intel Inside* situation.

As a second example, consider Procter and Gamble (P&G), a company that sells Tide detergent, Ivory soap, and a many other consumer products for the home. Historically P&G products were distributed through was a large number of small retailers throughout the U.S. and the world. Even though P&G typically was not located in close proximity to the final consumers of their products (customers were much closer geographically to the retailers), P&G stayed "close" to their customers in many ways. P&G invested significantly in product development research and consumer behavior research on which they based decisions on advertising, pricing, promotion, and packaging, for example. Through these means, P&G held

significant control over the channel relationships and influenced how the retailers presented their product, for example.

Fast forward in time . . . The power shifted. P&G's control of the distribution channels did not stand unchallenged. Wal-Mart drove out of business a large number of P&G's small retailer-customers. Wal-Mart now consumes more than 15 percent of all P&G's output. Arguably, Wal-Mart is now closer to the final product consumer than P&G, at least in the following sense. Wal-Mart knows a great deal about customer behaviors and customer tastes. Wal-Mart makes their own decisions on pricing, promotion, advertising, packaging, and in-store presentation. To some degree, Wal-Mart can now tell P&G what products to develop and how they should be packaged, priced, promoted, and advertised. Wal-Mart the fruit fly has "disintermediated" Procter and Gamble from their customer base.<sup>2</sup>

Relatively speaking, the power in the chain has shifted away from P&G to Wal-Mart. Furthermore, Wal-Mart's leverage could enable them to create their own brands to compete directly with P&G brands, further challenging P&G's power. P&G and Wal-Mart do have a fairly positive, synergistic relationship today, but compared to the past, the power has shifted.

What can the automotive industry, traditionally a slower clockspeed industry than PC's or retailing, learn from these fruit flies? In the 1950's and 1960's, the core subsystem of the automobile was steel. The sheet metal body not only defined the styling which was critical to the market reception of the vehicle (witness the Edsel), but it also determined the structural integrity of the entire product, supporting all other subsystems designed into the vehicle. The electronics in the vehicle was virtually an afterthought and of minuscule consequence to design, manufacture, cost, or sales considerations.

In the 1990's, not only is the dollar value of the electronics in the vehicle overtaking the value of the steel body in many vehicles, but arguably electronics is more central to the entire design process. In most car companies today, the vehicle is designed with a customer profile in mind. Furthermore, virtually all of the features that will affect the perceptions of the vehicle by the owner are already or soon will be mediated by electronics--the acceleration, the braking, the steering, the handling, the seating, and the communication, information, and entertainment systems. Designing the future car for the customer means designing the electronics--almost first and foremost.

Now consider the situation of Toyota, the third largest automobile company in the world, and arguably the most formidable competitor in a no-longer-cozy oligopoly. Although Toyota has a seemingly unassailable set of competitive advantages relative to almost any car company one might name, they are far less vertically integrated in electronics than some of their competitors (e.g., Ford and GM), and

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<sup>2</sup>Jim Moore, *The Death of Competition*, Wiley, 1996.

fairly dependent on one company, Nippondenso, for electronic components and systems. If one accepts the argument made above that electronics system design will be increasingly central to automobile design and customer preference, then companies like Toyota may have to adjust their supply chain strategy in automotive electronics or risk the fate of IBM relative to Intel. Since the clockspeed of the auto industry is slower than that of personal computers, Toyota may have some time, but there may come a day when customers choose automobiles based on whether they say "Denso Inside" or "Bosch Inside" rather than by the name of the company that stamped and welded the sheet metal.

In contrast to Toyota, Ford and General Motors have two of the largest electronic companies in the United States inside their respective corporate structures. Ford has its "Electronics Division" (ELO) and GM has several electronics companies--Delco, Delphi, Packard Electric, and Hughes--all inside of GM's corporate structure. Interestingly, Ford and GM have taken very different strategies as to how they are going to treat their internal electronics suppliers.

The early Ford 2000 strategy chose decisively to move ELO inside of Ford Automotive Operations (FAO), in contrast to its earlier location "outside" in the Automotive Components Group (ACG). In apparent consonance with the analysis presented above, the clear message seems to be that electronics has been designated as integral to the organization and the Ford approach to designing vehicles.

General Motors, however, has chosen to place all internal corporate electronics at "arm's length" from the North American Operations (NAO) organization, which owns responsibility for core product design and development. These internal suppliers are treated like external suppliers with market-like intermediated transactions. Seemingly, GM does not share the view that electronics design is as integral to vehicle design as was argued above. Furthermore, GM's approach must implant duplicate expertise into the customer and supplier within the corporation. For example, if when NAO goes to write the technical specification for a certain subsystem, the braking system, for example, it needs a certain sophistication in its knowledge of brake systems. Delphi, GM's internal brake system supplier needs to have some of this same knowledge to be a systems supplier. If GM were to choose to only locate this type of knowledge in Delphi, counting on the supplier divisions expertise to support new vehicle subsystems specification, then NAO would be in the position of needing to request technical help from Delphi to be used to outsource brakes, a request not likely to be treated expeditiously, given the incentives of Delphi to win GM business, rather than to help NAO outsource to an external supplier.

Seemingly Toyota is investing more in electronics capability, perhaps to forestall a possible future scenario of *Denso Inside*.<sup>3</sup> The power of the clockspeed analysis for

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<sup>3</sup>Based upon interviews with Toyota in June 1994 by Nitin Joglekar and Sharon Novak. See also New York Times, 8/14/96.



industry cross-benchmarking is to study the fruit flies (e.g., IBM-Intel-Microsoft in personal computers), model the underlying forces in the supply chain dynamics for the fruitfly industry, and then apply the resulting model to slower-moving industries for use as a forecasting tool. The first lesson, relevant for many industries beyond computers: When designing your supply chains, beware of the *Intel Inside* phenomenon

**Fruit Fly Evolution: Dynamic Instability of Core Competencies and Industry Structure**

Now, consider the model of the computer industry over the past two decades articulated by Intel's CEO, Andrew Grove. From the early 1970s through the early 1980s, the industry had a strong vertical structure with each competitor offering products with fairly integral architectures. Figure 1 illustrates a sketch of the industry structure during this period when IBM was the clearly dominant firm.<sup>4</sup> Each company in this era provided all the key subsystems of a computer system, maintained internally broad technological competencies across these subsystems, and offered systems that had very little "mix and match" capability.

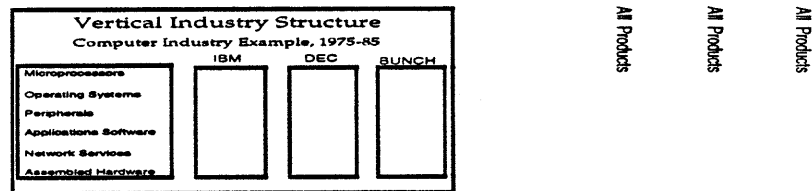


Figure 1. From the early 1970's to the early-to-mid 1980's, the computer industry was dominated by vertically-integrated systems suppliers. IBM strongly dominated virtually every aspect of the industry in this period. Its growth rates were sometime jokingly measured in "DECs per year."

<sup>4</sup>The vertical vs. horizontal models of the computer industry captured by Figures 1 and 2 are due to Andrew Grove of Intel. We have also been stimulated by the model of [Farrell, Hunter, and Saloner] which addresses systems competition versus component competition and also builds on Grove's model. We believe our contributions here are a fuller articulation of the dynamics between horizontal and vertical structures and the connections to sourcing strategies and core competencies.

Although this structure survived for some time, IBM was constantly under attack. Since it had to maintain competencies over a broad array of technologies, it was vulnerable to focused attacks on each of the many subsystems that made up the system. To maintain its position, IBM needed to keep a relatively closed architecture and offer the best "systems package" so that customers wouldn't leave them for a competitor that offered much better performance on a subset of the necessary subsystems. In the language of Farrell, Hunter, and Saloner, the systems supplier has to be at least a "jack of all trades," if not the best in one or more subsystems. However, the precariousness of the situation for a systems supplier should be clear.

Against the backdrop of the industry structure of Figure 1, in the late 1970's IBM faced a technology supply chain decision (i.e., a simultaneous design of product and supply chain) for the launch of a product to compete with the upstart Apple II. IBM's personal computer group chose to break with tradition and use a modular architecture with the microprocessor outsourced from Intel and the operating system outsourced from Microsoft. This set of decisions catalyzed a dramatic change in the industry to a "horizontal" structure, with highly modular architectures for the dominant product ("IBM-compatible" personal computers). The modular (mix and match) architecture created significant competition in each of the "rows" of the industry illustrated in Figure 2.

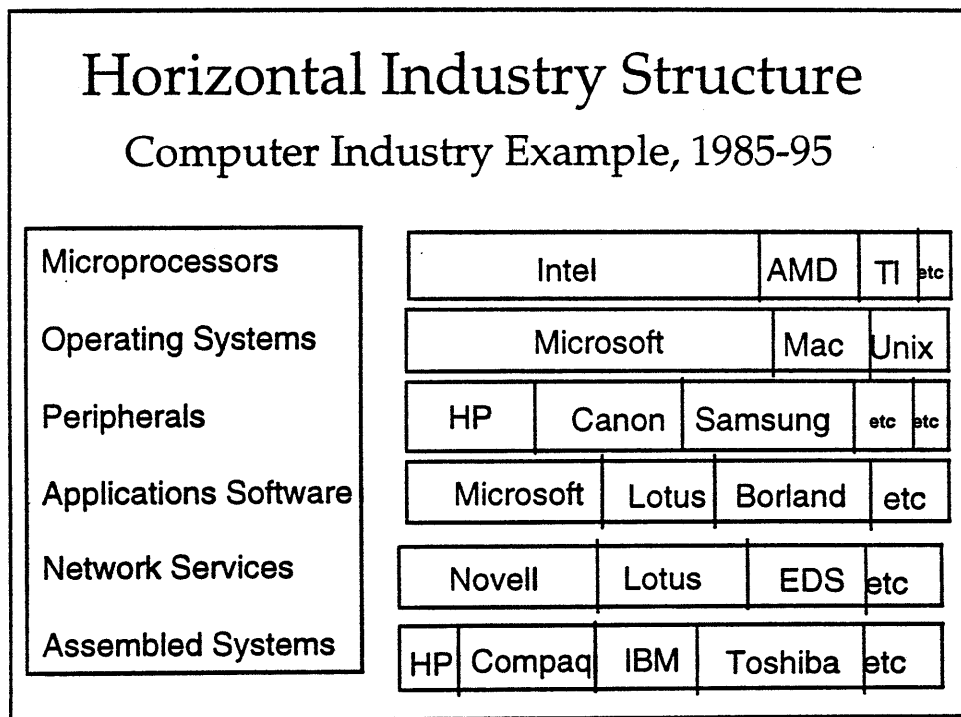


Figure 2. Since the mid 1980's, the computer industry has been dominated by highly modular systems. With such an industry structure, competitive rivalry takes place primarily within the rows.

Competition has been quite vigorous in many of the "rows" of Figure 2. However, this structure may also prove to be quite unstable. In particular, once a firm comes to dominate its row it tends to look to how it can exploit its market power by expanding vertically. Both Microsoft and Intel, each of which came to dominate its row have exhibited this behavior. In the case of Intel, it has forward integrated into the design and assembly of "mother boards," making deep inroads into the value added typically controlled by the systems assemblers. In addition, with each new microprocessor generation, Intel has added more functions on the chip that traditionally were offered by applications software suppliers. In the case of Microsoft, dominance in operating systems has been followed by entry into compatible applications software and network services. In both these cases, the vertical integration is accompanied by a product that is moving in the direction of offering a proprietary system rather than a modular component.

Alternately, a member of a highly competitive row may find itself with low profit margins because it provides merely a commodity module in an architecture designed by someone else. This circumstance, too, can drive a firm to increase its vertical integration.

Figure 3 attempts to represent this dynamic instability by illustrating the forces that drive the cycles from vertical industry structures with integral-architecture products to horizontal industry structures with modular-architecture products and then back to vertical again.

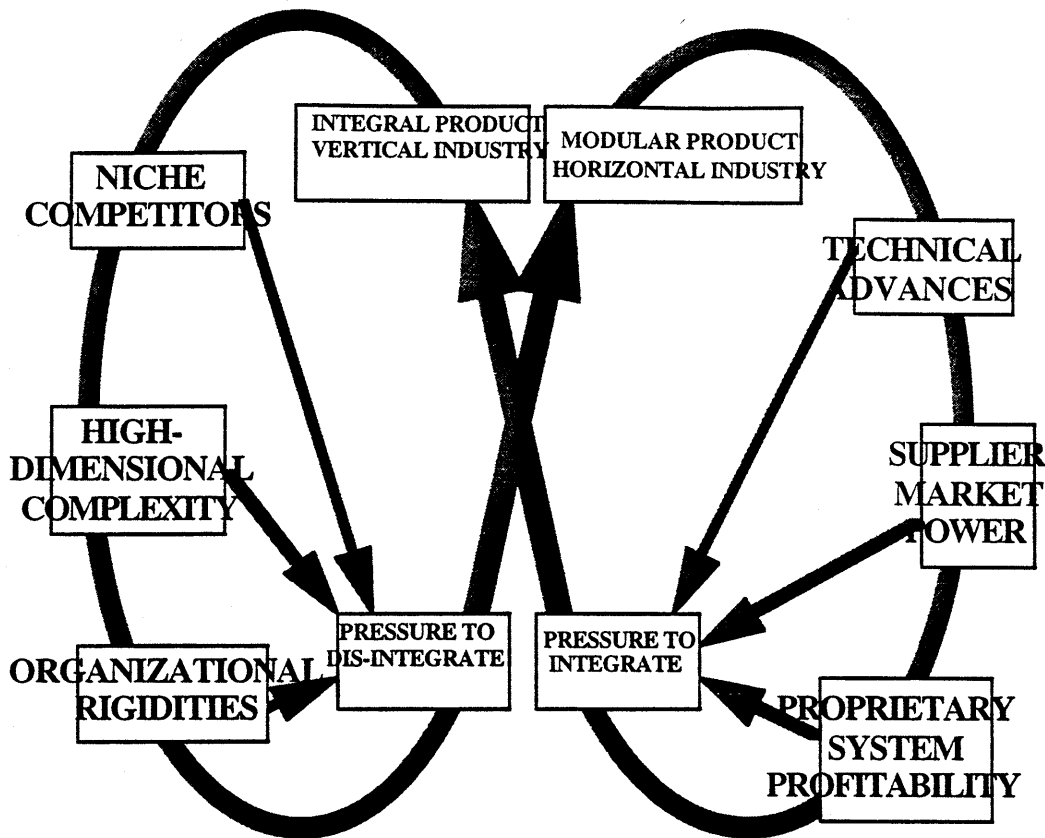


Figure 3. In an industry exhibiting a vertical structure with an integral product architecture, a number of forces (niche competitors, the complexity of the task of staying ahead technically with a very complex product, and the organizational rigidities that can set in once a firm has an established market position) push toward a loss of the established position and possible disintegration of the product architecture and industry structure. On the other hand, with a modular product and horizontal industry structure, numerous forces (technical advances, market power in one or more module suppliers, potential profitability from integrating into a proprietary system offering) push toward the integration of product architecture and industry structure. (ref: adapted from Fine & Whitney, "Is the Make/Buy Decision Process a Core Competency?" MIT working paper, 1996, available at <http://web.mit.edu/ctpid/www/people/Fine.html>)

Consider the plight of Apple computer in the backdrop of this story. In the mid to late 1980's the Macintosh was clearly the technically superior product in the PC industry. However, Apple failed to realize that its only advantage was in its operating system, not the vertical bundle of hardware and software it was offering. As a result, Apple tied its superior operating system in a vertical bundle to inferior hardware while the IBM-compatible PC industry raced ahead, subsystem by

subsystem, propelled by intense competition in each subsystem segment. In the end, the Macintosh system, shackled to an anchor, could not match the overall rate of improvement in the modular and highly competitive PC market. Had Apple understood the dynamics of product architecture and industry structure described above, they might have uncoupled their product and controlled the catbird seat now held by Microsoft.

Although IBM's PC sourcing decision paved the way for their loss of power to Intel and Microsoft, it was Compaq the PC maker that utilized Intel and Microsoft to first weaken IBM's hold on the computer industry. Continuing the earlier analogy, Chrysler is the Compaq of the auto industry. The brilliant insight of Compaq's founders was that the company could buy the chips and software from Intel and Microsoft, bundle them into an equivalent personal computer, and dramatically undercut IBM in price. This is Chrysler's strategy today. Its managers have shucked most of their corporate overhead and R&D, and rely on suppliers for technology. Chrysler designs, assembles, and markets vehicles to which it contributes little of its own innovative technology. Instead, it relies on partnerships and gain-sharing to encourage suppliers to grace Chrysler's autos with the latest advances. This reduction in Chrysler's scope of activities has freed its managers to focus on capabilities-chain development and management. The goal: integrating Chrysler's capabilities chain with its product development process and speeding new products to market.

To date, its strategy is a smashing success. Chrysler has the low-cost cost structure of the Big Three and Ford and GM are scrambling to distance their automotive operations from their components operations to follow the Chrysler model. The risk: Now that Chrysler's capabilities chain is developed and accessible to all, another company may well venture to play Dell Computer to Chrysler's Compaq. The usurper will develop the capabilities chain for the next level -- and create a more enticing final product.

## **Summary & Conclusions**

Automotive supply chains are evolving very rapidly. Although no one can tell the future, this paper introduces the idea that benchmarking rapidly-evolving "fruit fly industries," such as the personal computer industry, can yield some insights as to the opportunities and pitfalls that may await the automotive industry.

In trying to develop a better understanding of the forces that will affect the future evolution of automotive supply chains, we should also note the following observations about the industry, some of which are somewhat speculative:

1. The automotive business is played out on a worldwide stage. Supply chains are long and complex and there are many important players both upstream and downstream of the major assemblers. Further, very long supply chains exist within

the majors as well. Consequently, competition can be thought of as occurring *between* supply chains, e.g., Nissan's vs. Ford's, with the added complexity that these chains may share common elements (e.g., component suppliers, dealerships, or even jointly developed products, for example), as well as *within* supply chains, e.g., an assembler and component supplier each may want to add significant and unique value to the vehicle's electronics capabilities. Speed and flexibility (*agility*) in detecting shifts in market opportunities and reconfiguring these supply chains to respond to those opportunities will be the important rent-earning assets.

2. Although private sector companies dominate many aspects of the industry in the developed world, governments have historically and may be expected to continue to play major roles in shaping the industry. The U.S. government has influenced significantly the emissions, economy, and safety features in cars. The government of China will likely decide which companies will even be allowed to participate in China's automotive industry development as well as the rules under which that development will take place.

3. Although the auto industry is often referred to as a "mature" industry, dramatic changes in product and market leadership, technology, and even the geography of production have occurred in the past two decades. In the year 2015, perhaps Samsung will be the world's largest carmaker, with most of its factories in China assembling a product that more resembles a computer on wheels than an oil-burning steel vehicle.

4. Sales volume is likely to continue its exponential growth path in developing countries, whereas flat demand will continue in the developed world. As a result, much of the new investment and perhaps many product innovations will occur in the developing world. Therefore, production volumes, real wages, and working conditions are likely to improve significantly in the developing world and come under continued pressure in the developed world. Developing countries such as Korea hope to become significant exporters, above and beyond filling their burgeoning domestic markets.

5. In the developed world, severe competition (and over capacity) is likely in every segment of the supply chain, driving innovation in business models as well as continued turbulence in different players' standings. Global sourcing is not likely to disappear, however, it will be tested as to when it is optimal for the entire marketing to delivery product realization process. In some cases, tight links with longtime partners may give better overall performance than use of lowest-cost global suppliers.

6. Especially in the developed world, public sector pressures to make vehicles even safer and more environment-friendly are unlikely to abate. These pressures will drive research and innovation in powertrains, fuels, electric vehicles, and lightweight materials. Given the twin pressures of government regulation and product competition, car companies that can develop and implement innovations

in their supply chains are likely to benefit significantly in finding low cost ways to meet requirements and put customer-desired features on the vehicles.

7. Cost competition is likely to continue the pressure to use "world car" concepts in order to amortize development efforts over more production units. Government regulations that are not harmonized across borders will continue to limit (at least to some degree) the attainable gains from this strategy, assuring that companies will find ample reason to aggressively lobby governments for improved regulatory coordination.

8. Predicting industry concentration trends is very difficult. For every argument for consolidation, one can find another to support the contention that new competitors are likely to happen upon the scene. The economics of development and manufacturing support concentration, but the splintering of the distribution chain, the geographic dispersion of market demand, and the possible radical shifts in technology deployed (e.g., non-ferrous electric vehicles) encourages disaggregation.

9. The industry is likely to continue its path as a knowledge-intensive industry as opposed to just cutting, forming, and joining metal. Consequently, human intellectual asset development--in manufacturing, marketing, engineering, etc.--will only increase as a key competence for all firms. Strategies that emphasize the jettisoning of intellectual capital as a response to cost pressures are likely to lead to ruin in the longer term. Firms should continue to experience significant returns to improved human relations throughout the organization and throughout the supply chain.

10. As in many other industries, electronics is likely to continue its inexorable march into the product. Designers have a myriad of ideas for increased electronic control of the vehicle and consumers seem to like the features that can be developed. The continued shrinkage in cost and size of electronics also makes its use attractive. More broadly, electronics use is likely to only increase for control of the entire transit system, not only on board the vehicle.

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