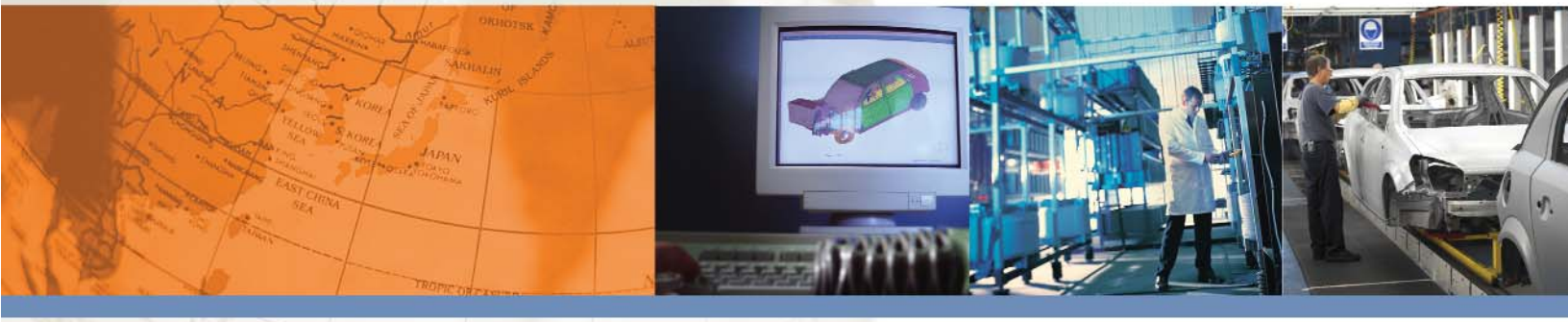
McKinsey Global Institute



Increasing Global Competition and Labor Productivity: Lessons from the US Automotive Industry

November 2005

McKinsey&Company

The McKinsey Global Institute (MGI) was established in 1990 as an independent think tank within McKinsey & Company, Inc., to conduct original research and reach a better understanding of the workings of the global economy. From time to time, MGI issues public reports. These reports are issued at the discretion of MGI's director, Diana Farrell, and its McKinsey Advisory Board when they conclude that MGI's international perspective and its ability to access McKinsey's knowledge of industry economics enable it to provide a valuable fact base to policy debates. The McKinsey Advisory Board is made up of McKinsey partners from Europe, Asia-Pacific, and the Americas.

MGI's staff members are drawn primarily from McKinsey's consultants. They serve 6- to 12-month assignments and then return to client work. MGI also commissions leading academics to participate in its research.

The McKinsey Global Institute is based in San Francisco and has a presence in Washington, DC, New York and Shanghai. MGI research fellows are based around the world as needed for individual research projects.

Increasing Global Competition and Labor Productivity: Lessons from the US Automotive Industry

Martin Neil Baily
Diana Farrell
Ezra Greenberg
Jan-Dirk Henrich
Naoko Jinjo
Maya Jolles
Jaana Remes

Preface

"Increased Global Competition and Productivity Growth in the US Auto Industry" is the result of ongoing research by the McKinsey Global Institute aimed at understanding the process of global economic integration and its implications. It examines in depth the response of US auto manufacturers to increased competition from overseas-based competitors in the fifteen years from 1987 to 2002. Building on MGI's many country and sector productivity studies, this research examines in detail how company-level actions translate increasing competitive intensity resulting from global market integration into accelerated growth in sector productivity.

Martin Baily, Senior Advisor to MGI and Senior Fellow at the Institute for International Economics, MGI Fellows Jaana Remes from McKinsey's San Francisco Office and Ezra Greenberg, from McKinsey's Washington DC Office, worked closely with me to provide leadership to this project. The project team also included MGI Fellows Jan-Dirk Henrich from McKinsey's Cologne Office, Naoko Jinjo from McKinsey's Tokyo Office, and Maya Jolles from McKinsey's Benelux Knowledge Center.

We have benefited enormously from the extensive input received from McKinsey's global network of industry and functional experts. We would like to extend a special thanks to Glenn Mercer, a Senior Expert with McKinsey's Global Automotive and Assembly Practice, who provided invaluable and active guidance throughout the project. We also benefited from conversations with McKinsey practitioners Tom Dohrmann, Matt Jauchius, Hiroshi Hayakawa, David Henderson, Hans-Werner Kaas, Stefan Knupfer, Stephan Kriesel, Guntram Nöth, Aurobind

Satpathy, Lothar Stein, and Andreas Zielke. In addition to our internal experts, we benefited from conversations with many external experts including Chris Benko, Lance Ealey, James Kondo, Sean McAlinden, and Michael Robinet.

Tim Beacom, MGI's dedicated Senior Analyst, Abhishek of McKinsey's North American Knowledge Center, and Julie Cook, Lutz Gläser, Tomoko Hibino, Tom Pepin, and Karen Victory of the Global Automotive and Assembly practice provided essential research support, and numerous helpful conversations. Susan Lund and Gina Campbell provided thoughtful input and editorial support. Moreover, Deadra Henderson, MGI's Practice Administrator, Terry Gatto, our Executive Assistant and Rebeca Robboy, MGI's External Relations Manager, supported the effort throughout.

As always, the findings and conclusions draw from the unique perspectives that our colleagues bring to bear on the sectors and countries researched here. These perspectives are a product of intensive client work with the world's leading firms. They are supplemented by in-depth analytical work and extensive interviews and dialogues with executives, government officials, and other leading thinkers.

Our aspiration is to provide a fact base to the public debate on the impact of global competition and productivity growth to enable policy makers and business leaders to make more informed and better decisions.

As with all MGI projects, this work is independent and has not been commissioned or sponsored in any way by any business, government, or other institution.

Diana Farrell
Director, McKinsey Global Institute

November, 2005

Contents

Executive Summary	9
Synthesis: How Competition Drives Innovation and Productivity Growth	23
How the Big Three Learned, Adopted and Diffused Lean Production	65
Product Differentiation as a Strategic Lever to Create Competitive Advantage	85
Technical Note	105
Bibliography	139

Executive Summary

Numerous studies by the McKinsey Global Institute (MGI) and others have shown that when new, more productive players enter a sector previously sheltered from global competition, the sector's overall level of productivity rises. Less well understood, however, is what companies actually do to link this cause and effect.

In increasingly global markets, it is important to understand how firms and policymakers can best respond to increasing competitive threats. To that end, we have studied the US automotive manufacturing sector between 1987 and 2002 as representative of an industry exposed to significant pressure from global competition. In particular, we have looked at the effects on company and sector productivity of decisions taken by the "Big Three"—Ford, Chrysler and GM—in response to competition from Japan-based Original Equipment Manufacturers (OEMs) and also competitors based in Germany and Korea.

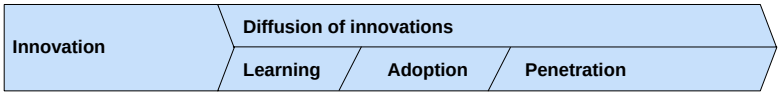
The Big Three's responses to these competitive threats were largely responsible for increases in sector labor productivity over this period. Rising by 3.3 percent a year, productivity performance in the US production of new vehicles was substantially faster than the 2.1 percent growth rate achieved by the non-farm business sector.[1] However, the three companies responded to the new competition at different rates and in different ways, depending on their perception of the seriousness of the threat, their understanding of the new players' sources of advantage, and the scale and speed at which they could introduce and emulate innovations.

1 Our sector definition includes the assembly and production of parts for new vehicles. Productivity is defined as real value added per hour.

Innovations are essential to pushing out the productivity frontier in every sector. Our study shows that the source of the innovation is often less important than companies' capabilities in recognizing the significance of other firms' frontier-shifting inventions, and understanding and adopting them. Furthermore, we show that far more important to overall sector productivity than the innovations themselves are companies' capabilities in rolling out process innovations company wide and product innovations into the market. It is the widespread diffusion of innovations that drives significant improvements in industry productivity rather than innovation by itself (Exhibit 1).

Exhibit 1

DIFFUSION OF INNOVATION DRIVES TOTAL INDUSTRY PRODUCTIVITY GROWTH



General description	Development and introduction by innovator	Competitors acquire capabilities and introduce imitations	Innovations are widely implemented within companies and across industry
Product innovation	• New models • New and improved features and designs	• Transparent to industry • Can be easy to imitate • Hard to maintain competitive advantage	• Cost and regulation drive penetration within companies • Demand and regulation drive penetration within industry
Process innovation	• Labor saving • Capital saving • Input saving	• Lack of transparency • Harder to "re-engineer" • Opportunities to learn from innovators is critical • Potential source of sustained competitive advantage	• Competition creates incentives to drive down costs and spread innovations • Organizational capabilities determine penetration within companies
Impact on industry productivity growth	Low	Medium	High

Source: MGI

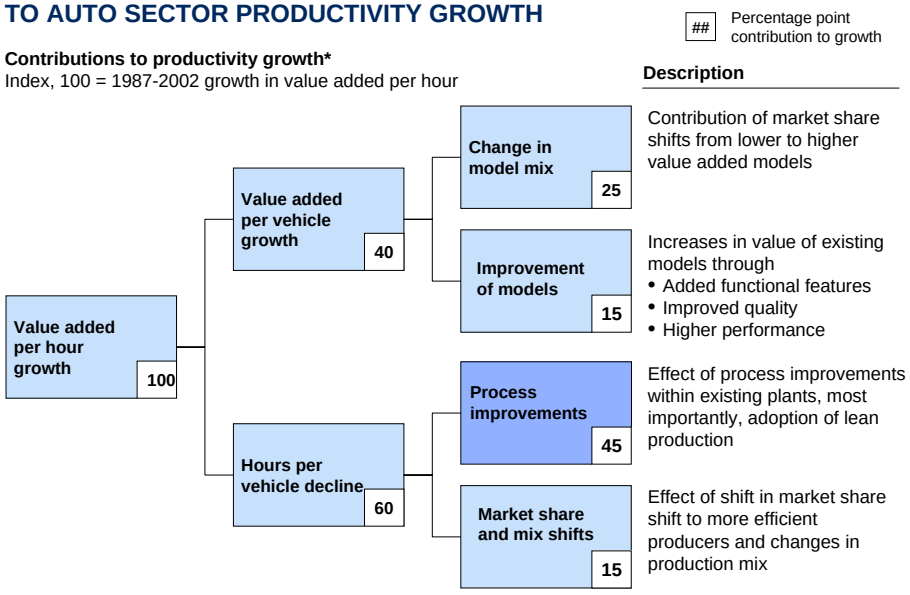
The diffusion of innovations in the US auto sector between 1987 and 2002 sheds light on some pressing questions facing players in increasingly global sectors: How does global competition change domestic sector dynamics and productivity growth? How quickly do these changes occur? What factors determine the speed of adjustment? What will be the impact on stakeholders? This summary outlines our key findings and conclusions from the study, presented in more detail in subsequent chapters of the report.

KEY FINDINGS

In the auto sector, labor productivity improves when it takes fewer hours to produce a vehicle because of process improvements, and when value-added per vehicle rises because of product innovations. The diffusion of process improvements made the greatest contribution to the increase in US auto manufacturing productivity between 1987 and 2002, accounting for 45 percent of the total increase. The introduction and popularity of higher value-added light trucks explains 25 percent of the increase, the second most important contributor. Improvements in existing models, shifts in market share to more efficient producers and changes in product mix accounted for the remaining 30 percent improvement (Exhibit 2).

Exhibit 2

PROCESS IMPROVEMENTS WERE LARGEST CONTRIBUTOR TO AUTO SECTOR PRODUCTIVITY GROWTH



* Contributions rounded to nearest five percentage points

Source: MGI

Process innovations contributed most to productivity growth

The leading Japan-based OEMs were clear leaders in hours per vehicle for the majority of the 1987 to 2002 period. The Big Three improved process efficiency largely by adopting the lean production techniques pioneered by the Japan-based OEMs, rather than developing wholly new process innovations of their own. The

impact of lean production in improving process efficiency is exemplified by GM, who was responsible for 60 percent of the total improvement in hours per vehicle over the period (Exhibit 3). However, catching up proved difficult: it took ten to fifteen years for the Big Three to learn, adopt, and implement lean production techniques and they succeeded at different rates (Exhibit 4).

A number of factors influenced their rates of catch-up:

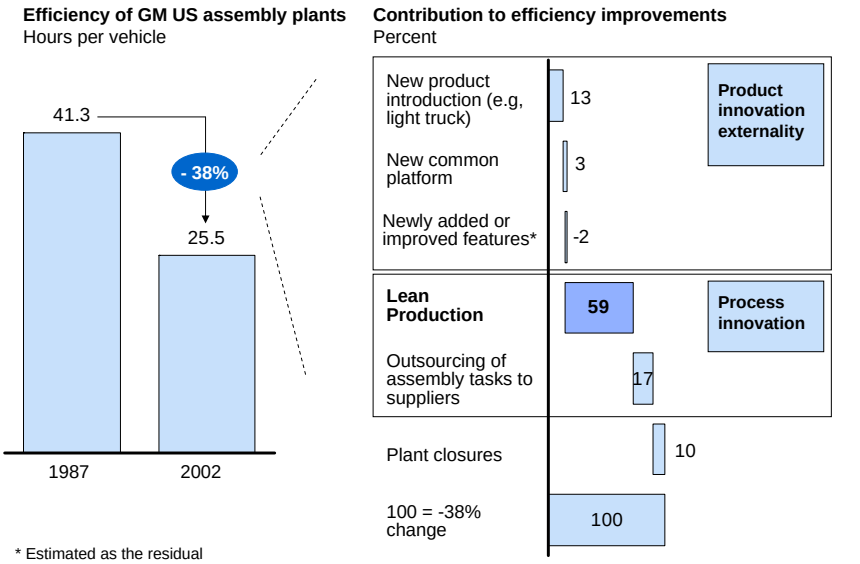
Perception of the threat. The weaker the company's financial position at the outset, the more keenly it felt the competitive threat, and the faster and more comprehensive its response. Ford's serious financial troubles after the 1981-82 recession had prompted it to focus on lean production before 1987, while the more financially comfortable GM did not see the need for process transformation until 1992, when the Gulf War recession hit its performance.

Understanding of new sources of competitive advantage. The effectiveness of each company's response depended on how well it understood the sources of the Japan-based OEMs' advantage. Ford realized early that lean production was a multi-functional system encompassing the entire value chain (including design,

Exhibit 3

LEAN PRODUCTION MADE LARGEST CONTRIBUTION TO GREATER OEM EFFICIENCY

GM EXAMPLE

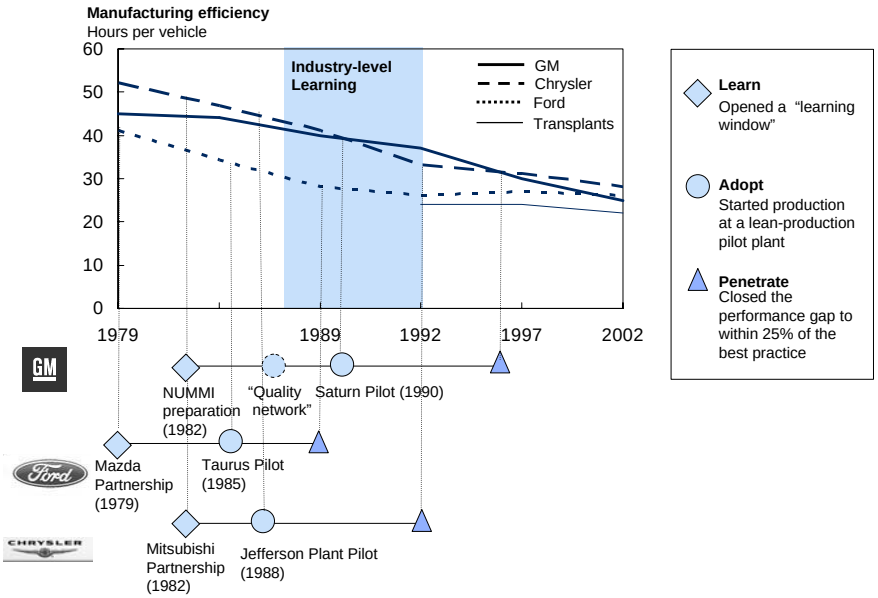


* Estimated as the residual
Source: Harbour Report, Literature Search, MGI Estimates

parts, assembly and organization), while Chrysler and GM initially had a narrower focus on assembly operations. They consequently lost time in catching up. Moreover, Ford knew from its practice of studying external benchmarks how far ahead the new competitors were on a range of fundamental performance measures.

Exhibit 4

BIG THREE TOOK 10-15 YEARS TO MATCH TRANPLANTS' EFFICIENCY



Source: Harbour Report, Literature search, MGI

Scale and speed of response. The quicker a company can learn and roll out process innovations, the faster it will catch up with competitors at the new productivity frontier. Ford's early success depended on implementing process improvements as part of a company-wide transformation program, and also on the good relationship between the autoworkers' union and management. It took four years for Ford to go from a pilot program to widespread adoption of lean production.

Chrysler moved more slowly at first but was able to speed the transformation once CEO Lee Iacocca realized its importance, because he wielded effective top-down control. On the other hand, GM's decentralized organizational structure impeded its ability to carry out process transformation, when it eventually realized the need.

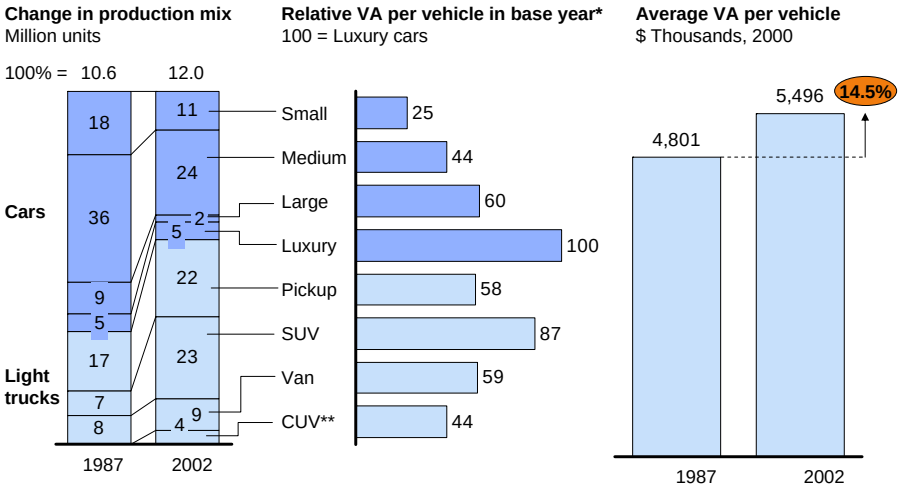
The shift to light trucks increased industry value added

Companies find it easier to research and copy new products than new processes, which are harder for outsiders to understand. Consequently, productivity advantages conferred by product innovations are far more difficult to sustain. The introduction of the Ford Explorer in 1991, kicked off the growth of the SUV market, but GM and Chrysler followed quickly with their own models leaving little competitive advantage to Ford. In contrast, Chrysler's investment in the minivan did pay off for the company, as competitors did not successfully field competitive models for some time.

The Big Three lost more than 10 percentage points of their overall light vehicle market share from 1987-2002, and their share of the car market plummeted by 21 percentage points. But these losses were to some extent offset in the late 1990s by their success in the light truck market with SUVs and minivans. These new products had higher value-added per vehicle, which helped to boost sector productivity (Exhibit 5). The explosive growth of the SUV market meant that SUVs played an important role in sector value added and productivity growth. Given the small size of the minivan market, this did not have as large an impact on the overall sector, although it was very important for Chrysler.

Exhibit 5

SHIFT TO LIGHT TRUCKS RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 15 PERCENT



* Relative magnitudes estimated based on 1999 reference year
** Cross-utility vehicle assumed to have VA per vehicle of a small SUV
Source: Ward's Automotive yearbook; Goldman Sachs; BEA; MGI Analysis

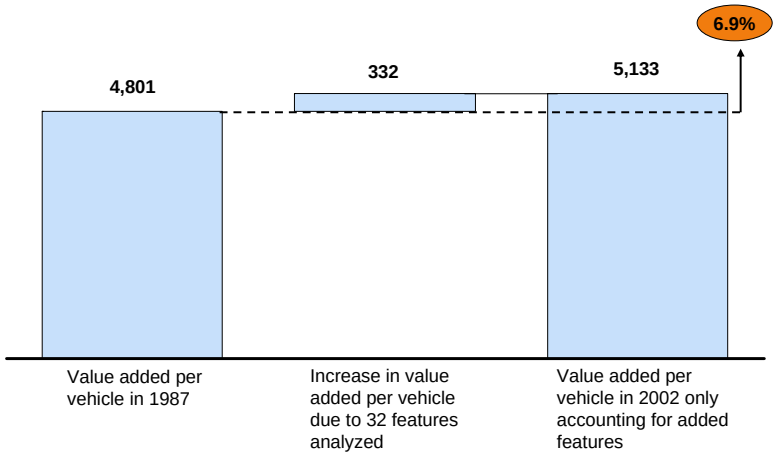
Combined with their gains in manufacturing efficiency, the Big Three's leadership in the SUV and minivan markets enabled them to reap substantial profits in the second half of the 1990s. But by 2000, the Japan and Germany-based OEMs were challenging their dominance in light trucks, materially eroding their profit margins.

Vehicles improved, and more efficient producers gained share

In additions to improvements in process efficiency and the popularity of higher value added light trucks, the features contained in new vehicles increased significantly between 1987 and 2002 (Exhibit 6). From leather seats and better audio equipment, to anti-lock brakes, four wheel-drive systems and airbags, many features were becoming standard equipment. There has also been a steady improvement in the overall quality and durability of vehicles (Exhibit 7). The main drivers of these improvements have been improved manufacturing of vehicle components and the more precise assembly of vehicles—a direct by-product of lean production. Both of these changes have raised value added per vehicle, and boosted industry productivity.

Exhibit 6

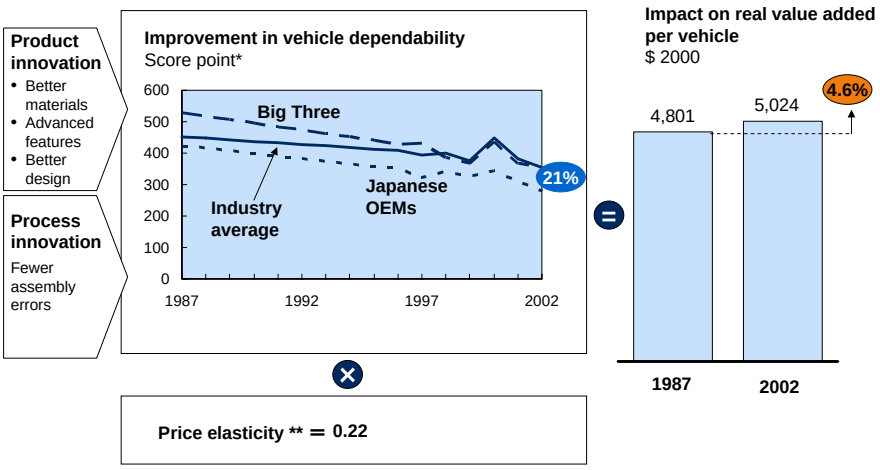
NEW FUNCTIONAL FEATURES RAISED AVERAGE VALUE ADDED PER VEHICLE BY 7 PERCENT
$ 2000



Source: Ward's Automotive yearbook; BEA; MGI

Exhibit 7

IMPROVED DEPENDABILITY RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 5 PERCENT



* Includes initial quality and durability. Scores before 1996 were estimated based on improvement ratio from 1997-2002
** Models considered for price elasticity estimation were: Upper small cars (Ford Taurus, GM Impala, GM Grand Prix, Toyota Camry) and middle SUV (Ford Explorer, Chrysler Jeep Grand Cherokee, GM Blazer, Toyota 4 Runner)
Source: JD Power, Ward Automotive Yearbook, MGI

The final factors boosting productivity were other changes which increased industry efficiency and reduced hours per vehicle. As the efficient transplants from the Japan-based and other non-US OEMs gained share between 1987-2002, average hours fell. Furthermore, the change in production mix to easier to produce light trucks also drove down average hours.

THE IMPACT ON STAKEHOLDERS

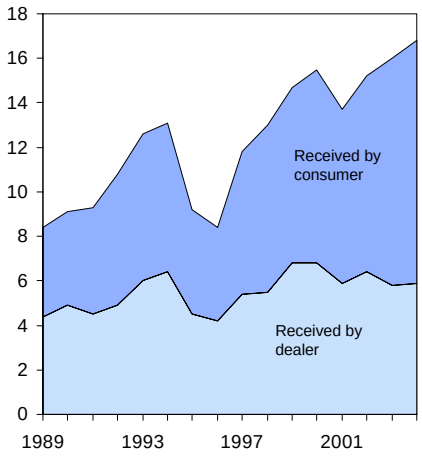
Consumers have been the largest beneficiaries of increased global competition. They have enjoyed falling inflation-adjusted prices for light vehicles, partly because the Big Three had to offer large incentives to make up for their quality shortfall against the new competitors (Exhibit 8). They have also benefited from the increase in features of new vehicles, and the overall improvement in the safety, quality, and durability of vehicles over our period of analysis.

Shareholders in the Big Three have fared less well, with returns underperforming the market (Exhibit 9). This performance was not only because of the strength of the competition, but also because the Big Three face significant pension and health care liabilities that are much higher than their competitors'. Partly as a result, their productivity increases have not yet translated into sustained profitability improvements.

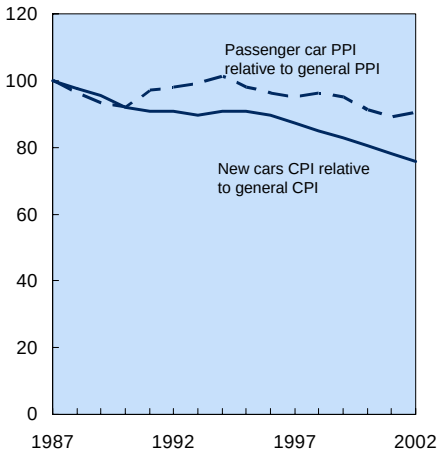
Exhibit 8

DISCOUNTS OFFERED BY BIG THREE CONTRIBUTED TO FALLING REAL PRICES

Average incentives for Big Three*
Percent of manufacturers suggested retail price



Real prices for passenger cars
Index, 1987=100



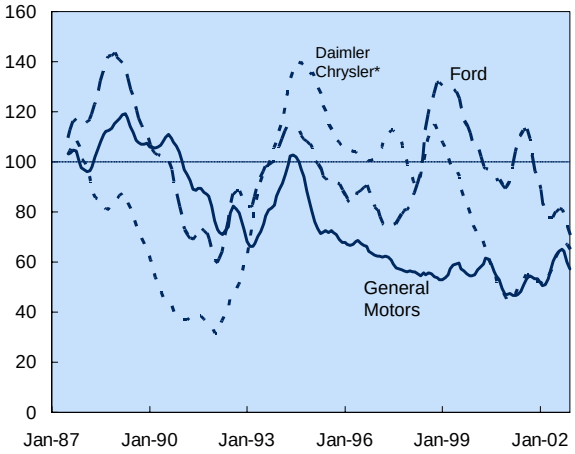
* Includes rebates, discounts or subvention finance rate incentives, lease incentives to customer, dealer discount

Source: CNW Marketing Research

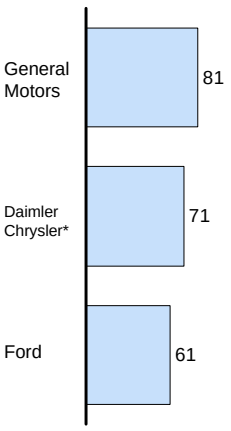
Exhibit 9

BIG THREE RETURNS GENERALLY UNDERPERFORMED S&P 500

TRS of Big Three relative to S&P 500
6-month moving average, S&P 500 =100
(Indexed January 1987)



Months TRS underperforms S&P 500**
Percent, 1987-2002



* Chrysler 1987-1996; DCX 1997-2002

** Based on actual TRS indexed in January 1987, not 6-month moving average

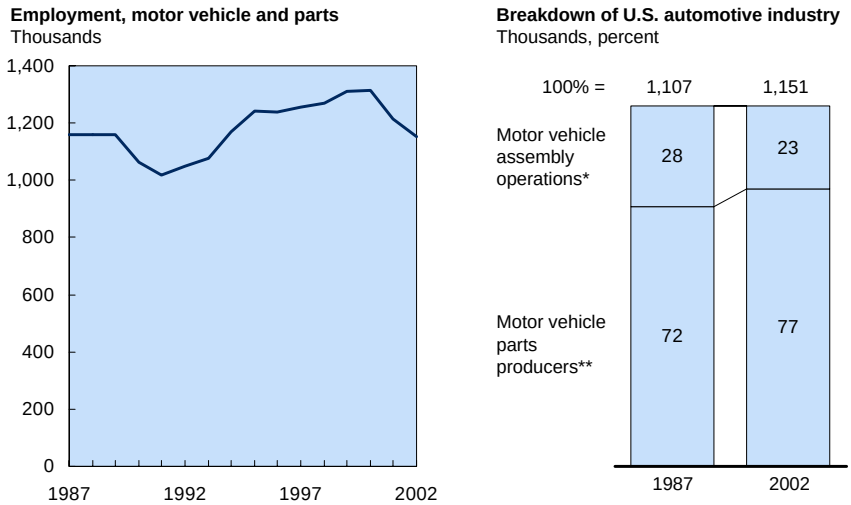
Source: Datastream as of 01/01/2003, MGI

Workers, however, have on average benefited—perhaps contrary to expectations. Levels of employment in the industry have remained relatively stable (Exhibit 10). Even so, there have been large shifts in employment between companies, displacing workers. Big Three employment in assembly operations fell by about 190,000 while parts employment increased. Transplants nearly doubled their employment from 15,000 to 29,000 workers albeit largely in locations different from where the Big Three plants were located.

In addition, workers' purchasing power has also remained stable (Exhibit 11). Although an average of only 38 percent of workers in the sector belonged to the autoworkers' union between 1987 and 2002, the non-unionized transplants have paid wages comparable to those commanded by union members. Toyota matched union wages in 2004. Only non-union parts suppliers pay substantially lower wages.

Exhibit 10

TOTAL EMPLOYMENT REMAINED FLAT, WITH SHIFT FROM ASSEMBLY TO PARTS MANUFACTURING



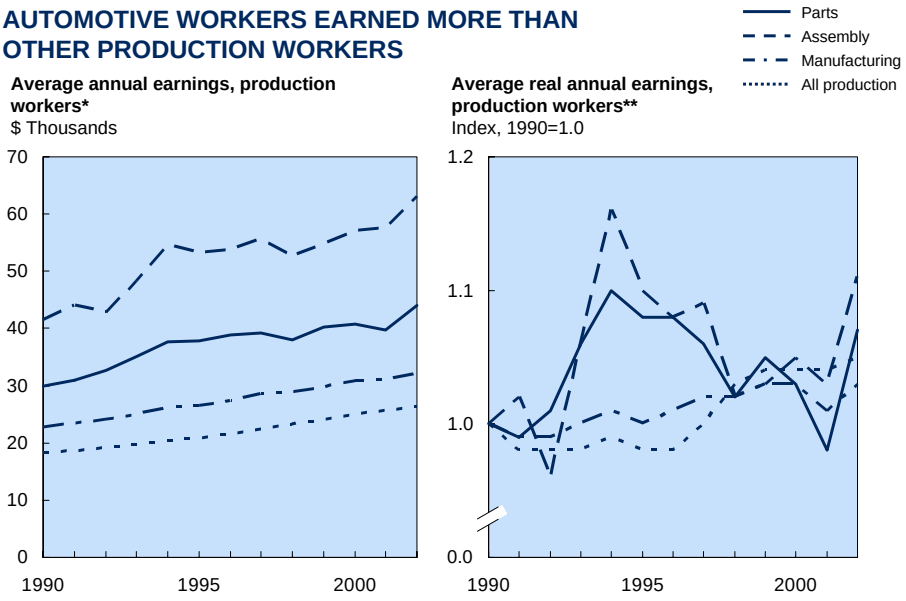
* Parts employment for the Big Three and other assembly operators (e.g., Delphi and Visteon in 1987) are classified by the BLS as parts employment

** Include companies that manufacture part, motor vehicle bodies and trailers

Source: BLS

Exhibit 11

AUTOMOTIVE WORKERS EARNED MORE THAN OTHER PRODUCTION WORKERS



* Based on average weekly earnings
** Deflated using CPI, all urban consumers

Source: BLS

IMPLICATIONS FOR POLICY MAKERS

The rapid diffusion of innovations within companies and across markets drives productivity upward. It is also likely to involve significant changes in market shares among companies and an associated migration of jobs. So while economies will as a whole benefit from policies promoting diffusion, there is also a case for policies to help stakeholders adversely affected by the resulting adjustments.

Expose domestic companies to competition from global best practice players. The evidence from the US auto sector and numerous other case studies confirms that opening markets to external competitors is a powerful way to introduce innovations, initiate the diffusion process, and raise productivity growth. Although the automotive industry in the US is strongly affected by regulation for safety, fuel economy and emissions, the most important feature of the US regulatory environment between 1987 and 2002 was that the market was open to global competition, despite the sometimes adverse impact on the domestic players.

Support stakeholders who lose out. Policymakers should consider measures to help dislocated stakeholders manage the transition. For example, they could offer job-retraining credits to employers, giving them an incentive to hire displaced workers, or provide continuing education grants for workers, giving them a chance to build skills in demand particularly from growing areas of the economy, such as healthcare, education, and social services. Severance packages can help, while portable medical insurance plans and pension benefits are essential to a workforce changing jobs more frequently.

Use regulation to promote rather than hamper diffusion. Governments should remove barriers to the spread of new products or processes, such as regulations imposing domestic content quotas on producers, and preventing them from buying higher quality parts if foreign companies make them. Regulations can also directly promote the diffusion of innovations: in the auto case, we found that federal environmental and safety standards led to the rapid spread of vehicle features that would otherwise have diffused more slowly.

Promote the sharing of key information. Governments can do a lot to help companies identify and emulate the most important innovations in their sector. In the auto sector, for instance, government research grants helped companies to study lean production techniques and understand that higher productivity was the root cause of Toyota and Honda's competitive advantage. The government can also encourage private sector players to help break down information barriers. The introduction of OEM and car model quality rankings, enabled both OEMs and consumers to make objective comparisons of their performance. Once consumers were able to compare the quality of different OEMs they could make more informed choices, so that market shares better reflected the underlying performance of manufacturers.

IMPLICATIONS FOR COMPANIES

Companies should not focus exclusively on developing their own innovations, but learn as well how to recognize, understand and adopt the significant innovations of other companies. To that end, the primary source of long-term, sustainable competitive advantage lies in achieving higher productivity than competitors.

Understand the drivers of relative strengths. Traditional financial benchmarks may not reveal the real source of competitors' productivity advantages.

Companies should also use a productivity-based diagnostic tool that can provide insight into the differences in company operations and capabilities that drive productivity, such as superior products or processes.

Recognize the importance of process innovations to productivity. Since product innovations are relatively easy to copy, isolated innovations cannot offer a long-term response to a new competitive challenge. Toyota's enduring strong performance in the US market demonstrates that competitive advantage derived from process innovation lasts longer: its roots are harder to understand and take longer to copy. Companies that want to differentiate themselves through product innovations need to excel in the process of product development—an organizational skill that is harder for competitors to emulate than copying a specific product.

Be flexible and ready to change. Responding to new global competition will often involve radical upheaval, including reworking of product development, process technology, supply chain management, marketing and distribution. Successful companies with a strong position in their domestic market will find it particularly difficult to recognize the seriousness of a new competitive threat. Why should they bother to make such profound operational changes in response? But in globally competitive markets, there is no room for complacency, even for market leaders.

From an organizational standpoint, strict rules-based relationships with employees and suppliers can be a significant barrier to implementing changes, because buy-in from all stakeholders is required to reap the advantages of rapid diffusion. Getting top management to focus on change makes organisations evolve faster. Companies need to ensure that their incentive structure recognizes and rewards the adoption and diffusion of best practices at every level, whether these originate from within or beyond the organization.

Synthesis: How Competition Drives Innovation and Productivity Growth

Over the period from 1987 to 2002, labor productivity in the US production of new vehicles (including parts and assembly) increased 3.3 percent annually. The hours required to produce the parts and assemble a vehicle fell, even while the average value-added per vehicle increased (Exhibit 1). Hours worked fell because of process innovations, shifts in market share to more productive players, and changes in product mix. Average value-added per vehicle rose because consumers purchased new, higher value-added models, and models with improved features and quality (Exhibit 2).[1]

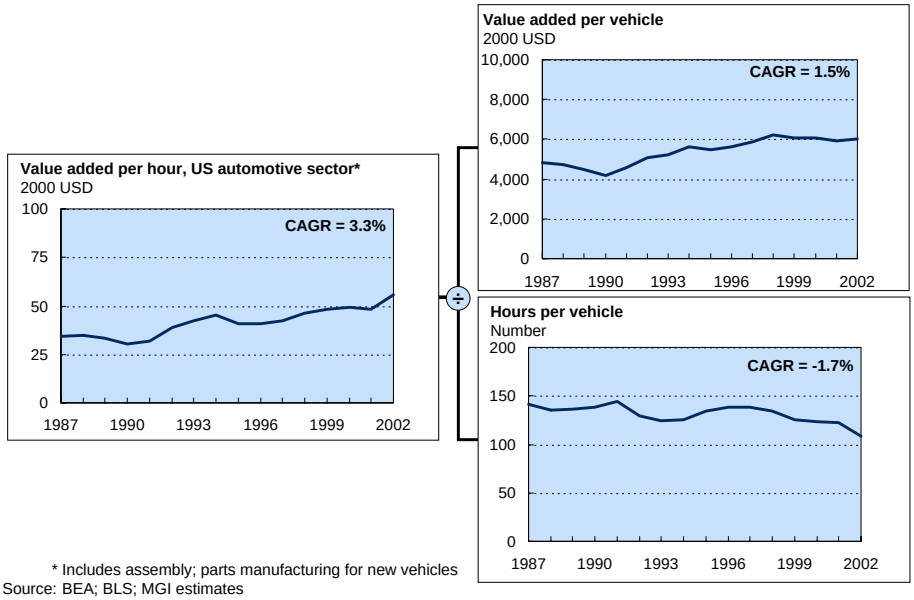
In particular, we found that for the production of new vehicles:

- Adoption of innovations that improved process efficiency accounted for 45 percent of the total increase in labor productivity between 1987 and 2002.
- The introduction of new higher value-added models was the next largest contributor, accounting for 25 percent of the increase.
- Shifts in market share to more efficient producers, improvement in existing models (including higher quality and more features), and changes in product mix, accounted equally for the remaining 30 percent.

1 We have chosen the 1987 and 2002 period for two reasons: it is the longest time frame for which there is consistent data, and after 1987, non-US OEM production facilities set up in the US played an increasingly important role in the competitive environment (see Exhibit 25). In our productivity calculations, real output is calculated from nominal value-added deflated by the gross output deflator. See the technical note for a discussion of why we use this approach to productivity measurement. The focus of this study has been the way global competition drives productivity within the US auto industry. The extent and nature of offshore outsourcing has not been a primary focus. (For a discussion see MGI's "New Horizons: Multinational Company Investment in Developing Economies," http://www.mckinsey.com/mgi/publications/newhorizons/index.asp).

Exhibit 1

LABOR PRODUCTIVITY GROWTH DRIVEN BY INCREASE IN VALUE ADDED AND REDUCTION IN HOURS PER VEHICLE

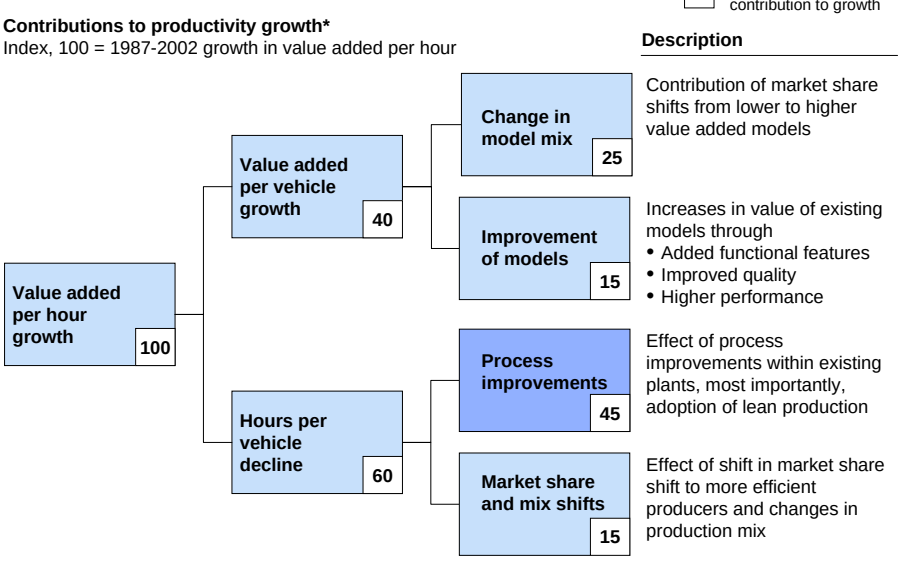


* Includes assembly; parts manufacturing for new vehicles
Source: BEA; BLS; MGI estimates

Exhibit 2

PROCESS IMPROVEMENTS WERE LARGEST CONTRIBUTOR TO AUTO SECTOR PRODUCTIVITY GROWTH

Contributions to productivity growth*
Index, 100 = 1987-2002 growth in value added per hour



* Contributions rounded to nearest five percentage points
Source: MGI

Our focus on new vehicle production differs from most common approaches. We include the assembly of new vehicles as well as the production of parts for new vehicles within our sector definition because parts is an important contributor to value added and the source of the majority of employment. This differs from most industry-based analyses which tend to focus on assembly and parts production separately. It also differs from most economic analyses which typically focus on a broader definition of the sector.[2] In what follows, all references to the US automotive sector refer to new vehicle production.

The productivity performance of US new vehicle production was strong—substantially faster than the 2.1 percent growth rate achieved by the non-farm business sector over the same period. It also compared very favorably with productivity growth in the rest of the manufacturing sector. (BLS estimates total manufacturing output per hour grew at 3.5 percent a year between 1987 and 2002. Based on output-per-employee, we estimate that productivity increased at 2.4 percent a year in manufacturing, excluding the high-tech and auto sectors.) Since new vehicle production is a relatively mature sector, it might have been expected to have grown sluggishly over this period but it didn't; its strong performance is therefore consistent with the view that global competition provided a spur to productivity improvement. Moreover, the largest boost to productivity growth came from process innovation brought into the US market by global competition—the lean production system developed in Japan.

Product innovations—that can also be linked to the arrival of global competitors—also contributed substantially to industry productivity growth. With their share of the car market rapidly eroded by foreign competitors, the Big Three looked for new products that would play to their strengths. They developed Sports Utility Vehicles (SUVs) and minivans that appealed to customer demand for larger vehicles which their global competitors were not offering and would not have the capability to offer for some years. Lower fuel economy standards on light trucks also made this segment attractive to the Big Three.

2 Typically, the sector is defined according to the GDP-by-industry accounts, which also includes production of parts for the aftermarket, heavy duty trucks, truck trailers and recreational vehicles. See the technical note for a complete discussion of our sector definition.

Although global competition provided the incentive for change, productivity growth in the US industry was primarily the result of actions and decisions made by the Big Three. In general, companies can respond to increasing global competitive pressure in various ways: they can seek trade and regulatory protection; they can build capabilities that will help them compete; or they can exit the segment, market, or industry (Exhibit 3). Between 1987 and 2002, there were no significant barriers protecting the US automotive sector from foreign competition, and none of the Big Three were driven to exit by competition (although Chrysler merged with Daimler Benz).[3] In fact, the Big Three reacted positively, building capabilities and improving their performance.

In the remainder of this section, we will describe the nature of the competitive challenge facing the US industry; the way the US industry responded; the impact on key stakeholders; and the implications for companies and policy makers. (For a discussion of regulation, see "The Impact of Regulation on Productivity Growth"; page 37.)

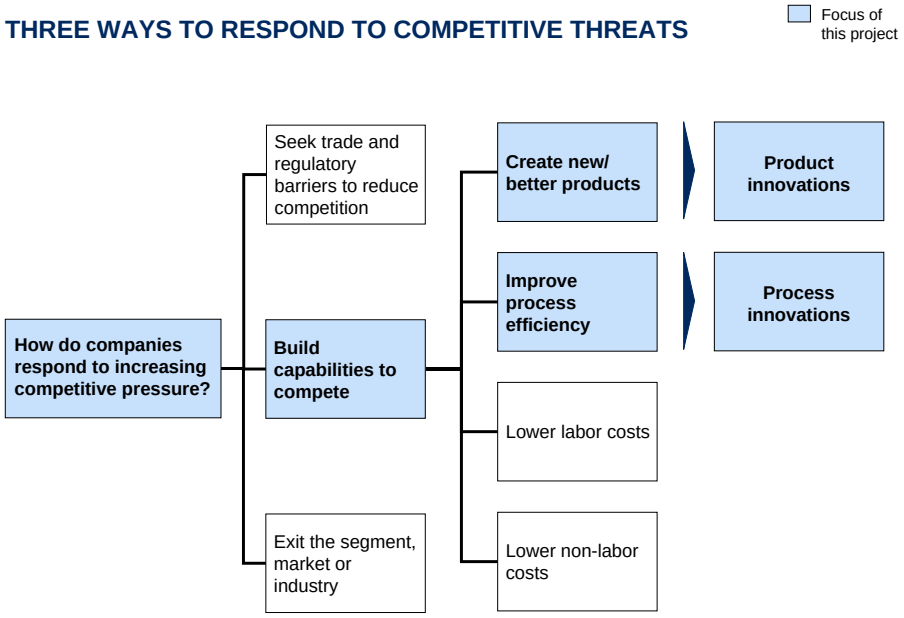
THE BIG THREE FACED A TRIPLE THREAT

The success of the global automotive players based in Japan, Germany and Korea created significant competitive pressures in the US auto market between 1987 and 2002. With the number of light vehicles sold in the US growing at only 0.8 percent annually over this period, competition for market share and profit margins was intense. A shift in consumer preferences from cars to light trucks played an important role in the competitive outcome over this period (Exhibit 4); so did environmental and safety regulations.

3 Two exceptions are worth noting. First, the voluntary restraint agreements we discuss below which limited automotive exports from Japan between 1981-1994. Second, the 25 percent tariff on imported pick-up trucks imposed in 1962 during a trade dispute with Europe. This tariff pushed non-US producers to locate in North America (Canada has always been exempt, and Mexico has been exempt since the signing of NAFTA). But, production location decisions were also strongly influenced by the US centric nature of the world-wide pick-up market. Thus, the tariff influenced competitive dynamics and hence productivity to the extent that it independently drove location decisions, and raised pick-up prices. These independent impacts were likely small during our period of study because many production facilities were already located in North America by 1987, and new plants were for pick-ups destined almost exclusively for the US market.

Exhibit 3

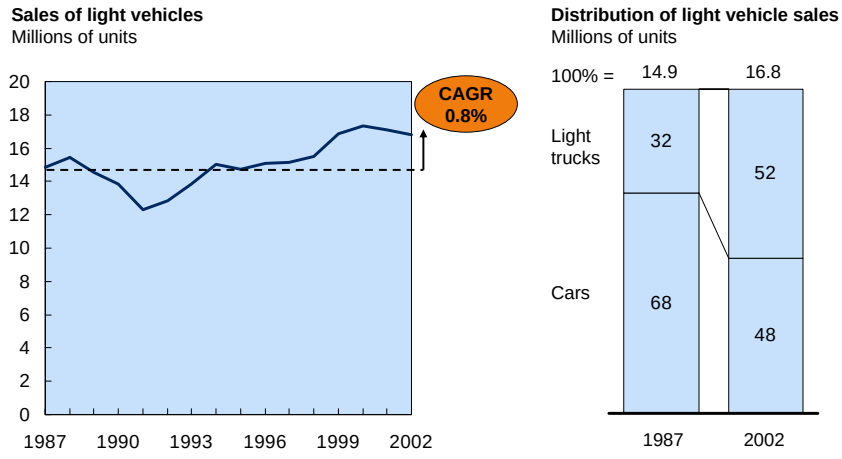
THREE WAYS TO RESPOND TO COMPETITIVE THREATS



Source: MGI

Exhibit 4

DEMAND SHIFTED TO LIGHT TRUCKS IN SLOW-GROWING MARKET



Source: BEA

Competition depressed Big Three market shares

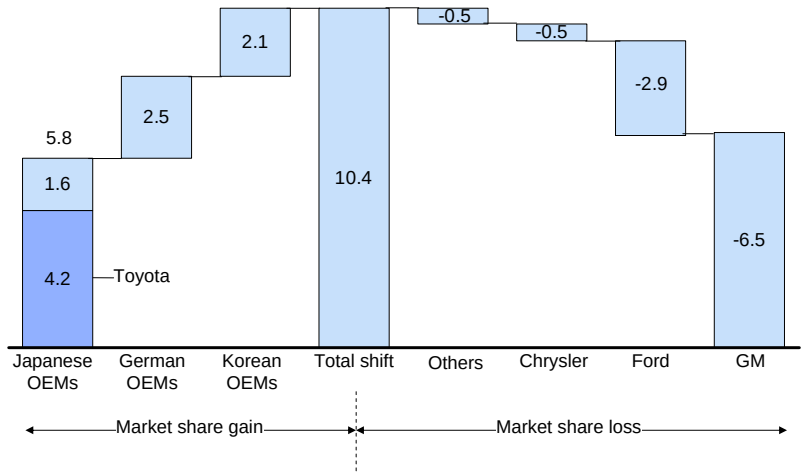
The Big Three lost more than 10 percentage points of their light vehicle market share during the period of our study; losses in the car market were a particularly dramatic 21 percentage points (Exhibits 5, 6). If market shares had been maintained and other trends remained the same, Big Three sales would have been nearly 20 percent higher—increases in overall market demand, although modest, would have increased sales 13 percent and the shift in consumer preferences from cars to light trucks would have added nearly 4 percent (Exhibit 7).

Competitive pressures arising from differences in quality, pricing, and product portfolios were driving these losses in car market share (Exhibit 8). The Japan-based OEMs primarily Toyota, Honda, and Nissan, scored their first successes in the US market during the 1970s, as demand for their fuel-efficient inexpensive cars increased in response to the two oil crises. After that, they refined their production processes, transformed their brands, and established a market-leading reputation for efficiency, quality, and good value from entry level models to luxury offerings. The Germany-based OEMs, primarily Daimler and BMW, were established leaders in design and performance, especially in the luxury and performance segments and their product portfolios continued to put

Exhibit 5

GM LOST MOST OVERALL MARKET SHARE

Light vehicle market share changes, US, 1987-2002
Percent

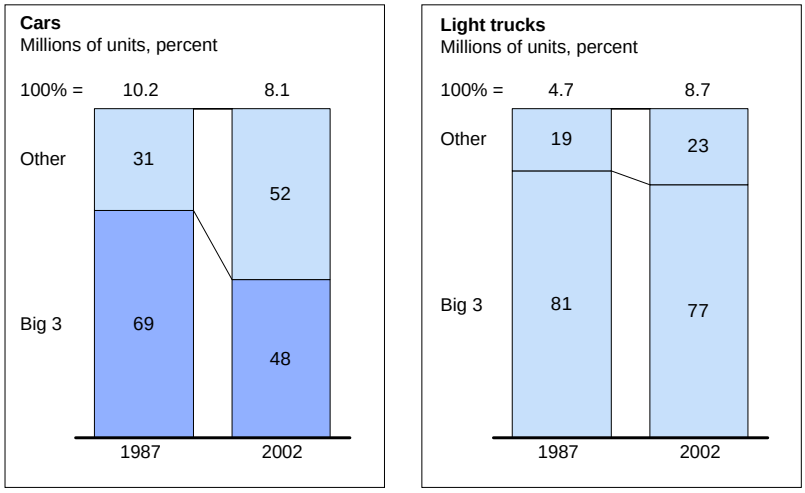


Source: Ward's

Exhibit 6

BIG THREE ALL LOST SIGNIFICANT SHARE IN CAR MARKET

Millions of units

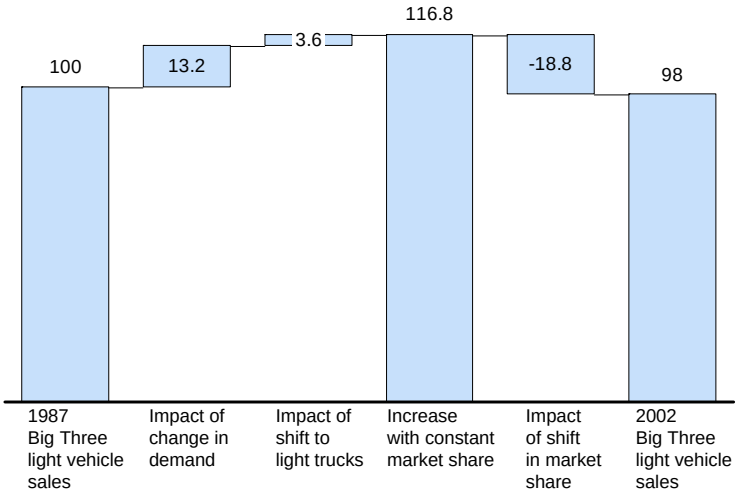


Source: BEA

Exhibit 7

MARKET SHARE LOSS HAD MAJOR IMPACT ON BIG THREE SALES

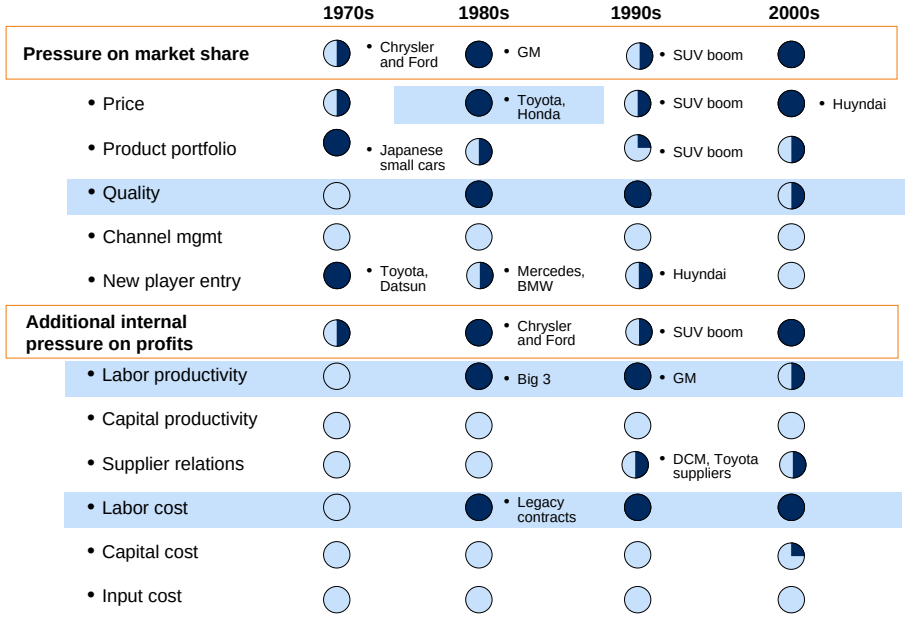
Index, 1987 = 10.8 million units



Source: Wards, BEA, MGI

Exhibit 8

PRESSURES DRIVING LOSS OF MARKET SHARE AND PROFITS



pressure on the Big Three in these areas. Later on in the period, the Korea-based OEMs, such as Hyundai, were establishing themselves as low cost producers and successfully attacking that end of the market. In addition, by 1987 most major players were producing vehicles in the US (Toyota started a joint venture with GM in 1984 and its own US production in 1988). This brought another dimension to the competitive dynamic.

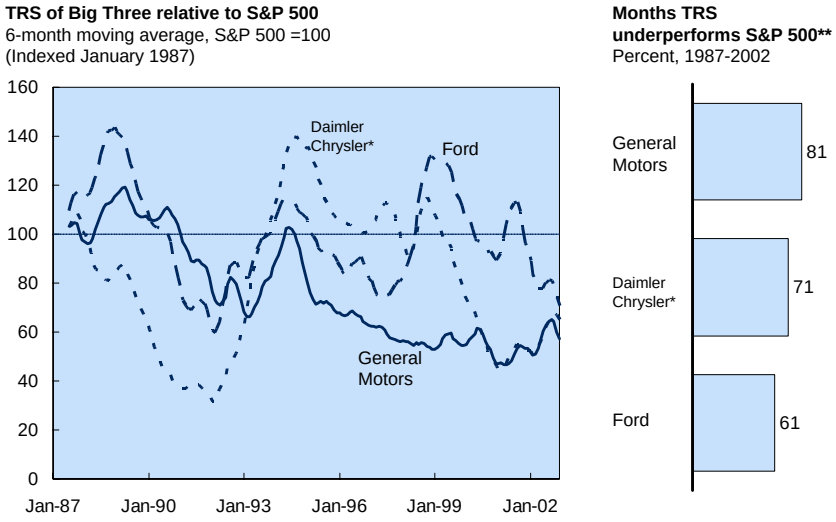
The Big Three continued to dominate the light truck market between 1987 and 2002, facing very little competition most of that time. Their established strength in this segment, combined with the rapid increase in consumer demand for light trucks, enabled the Big Three to mitigate the impact of their loss of car market share. By the late 1990s, however, global competitors had developed their own successful minivans and SUVs, and began capturing market share here too.

Financial performance suffered

Competition also put pressure on the Big Three's financial performance. Between 1987 and 2002, returns to their shareholders underperformed the broader market the majority of the time (Exhibit 9). In the case of GM, monthly total returns were below the S&P 500 for 81 percent of the time over the period; in the case of Chrysler it was 71 percent, for Ford, it was 61 percent.

Exhibit 9

BIG THREE RETURNS GENERALLY UNDERPERFORMED S&P 500

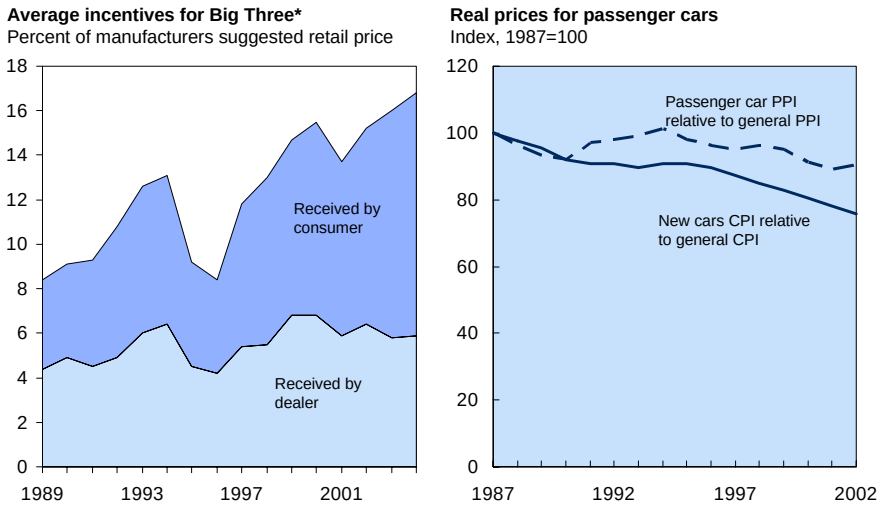


* Chrysler 1987-1996; DCX 1997-2002
** Based on actual TRS indexed in January 1987, not 6-month moving average
Source: Datastream as of 01/01/2003, MGI

This poor performance was partly because the Big Three competed by cutting prices—because they lagged the competition in vehicle quality and durability, they were forced to offer significant and increasing discounts to sell their cars (Exhibit 10). The Big Three also suffered some disadvantages on the cost side. At the beginning of our period, they were far less efficient than the Japan-based transplants measured in hours-per-vehicle (Exhibit 11), a major driver of their labor productivity disadvantage (as we shall examine in detail later). In addition to lower levels of efficiency, labor contracts negotiated by GM management and the UAW paid Big Three workers relatively generous wage packages. Average wages of production workers were 17 percent above those of the transplants; benefits were 32 percent higher (Exhibit 12).

Exhibit 10

DISCOUNTS OFFERED BY BIG THREE CONTRIBUTED TO FALLING REAL PRICES

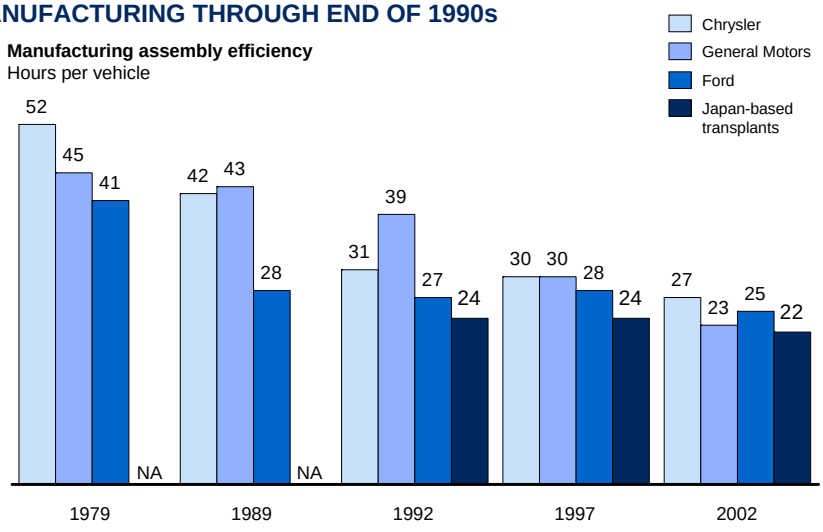


* Includes rebates, discounts or subvention finance rate incentives, lease incentives to customer, dealer discount

Source: CNW Marketing Research

Exhibit 11

BIG THREE REMAINED LESS EFFICIENT THAN TRANSPLANTS IN MANUFACTURING THROUGH END OF 1990s

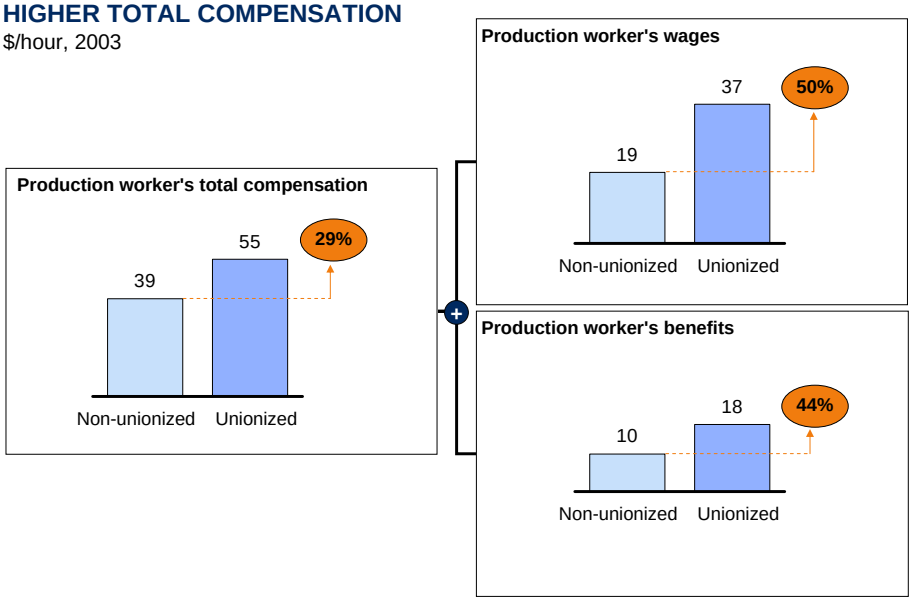


* Footnote

Source: Harbour Report

Exhibit 12

UNIONIZED WORKERS RECEIVE SIGNIFICANTLY HIGHER TOTAL COMPENSATION
$/hour, 2003



Source: McKinsey client survey of NA assembly plants, Center for Automotive Research

Just as increasing demand for light trucks helped stabilize overall Big Three market share, it also bolstered Big Three earnings. When the industry emerged from the Gulf War recession in the 1990s, they made significant profits from light truck sales. These strong profits attracted entrants, and, by the late 1990s, margins began to fall. By 2000, despite their strength in this segment, the Big Three were making only $350 per vehicle on average, compared with $1,940 for the Japan-based OEMs (Exhibit 13). In the car market, their margins had been reduced to essentially zero.[4]

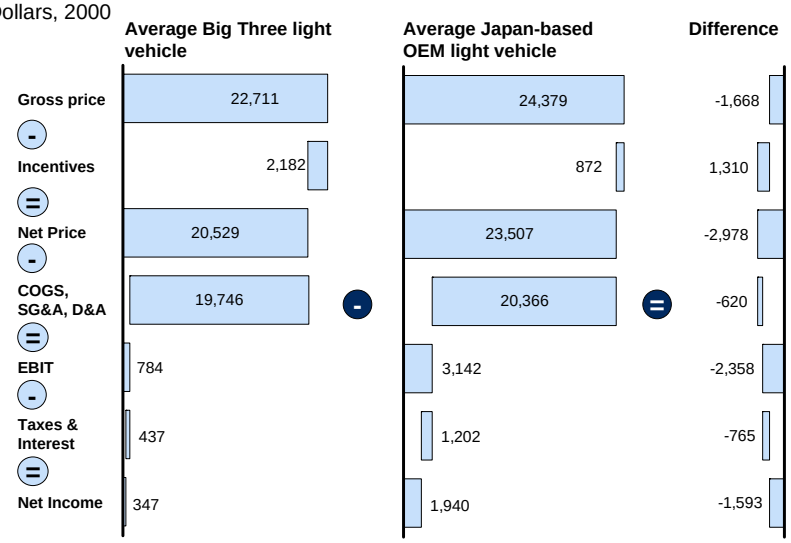
Finally, non-operational factors also had a big impact on the Big Three's financial market performance. For the Big Three, a significant driver of financial market performance was outstanding health care and pension liabilities. In 2001, GM faced $60 billion in unfunded liabilities (Exhibit 14). Workforces of the non-Big Three US-based plants are still too young for future health care liabilities to be material. We estimate that without these liabilities GM's return on invested

4 One reason that the Big Three continued to produce these cars even though they were unprofitable was that the CAFE regulations require an average MPG for the fleet of cars produced by OEMs which cannot be achieved by simply producing light trucks.

Exhibit 13

JAPAN-BASED OEMS' PRICE PREMIUM AND COST STRUCTURE CONFERRED COMPETITIVE ADVANTAGE

Dollars, 2000



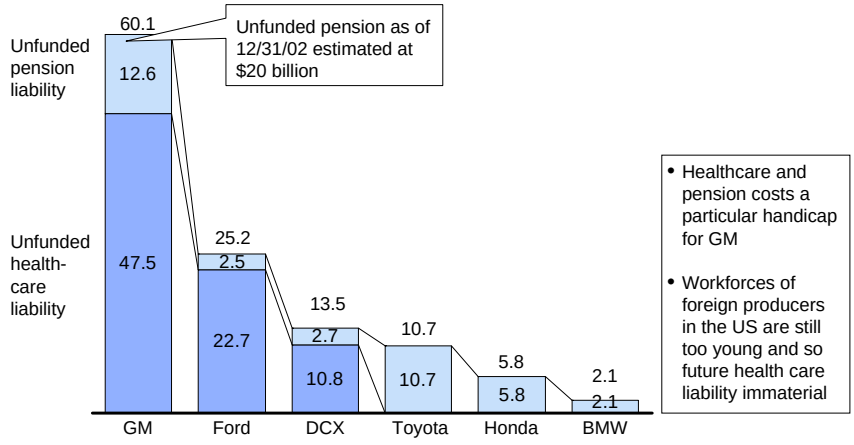
Source: Deutsche Bank Alex. Brown, "Why GM's and Ford's Auto Businesses May Not Stay Profitable for Long," August 2001, MGI

Exhibit 14

LEGACY LIABILITIES PLACED BIG THREE AT COST DISADVANTAGE

Total retiree liability – 2001*

$ bn



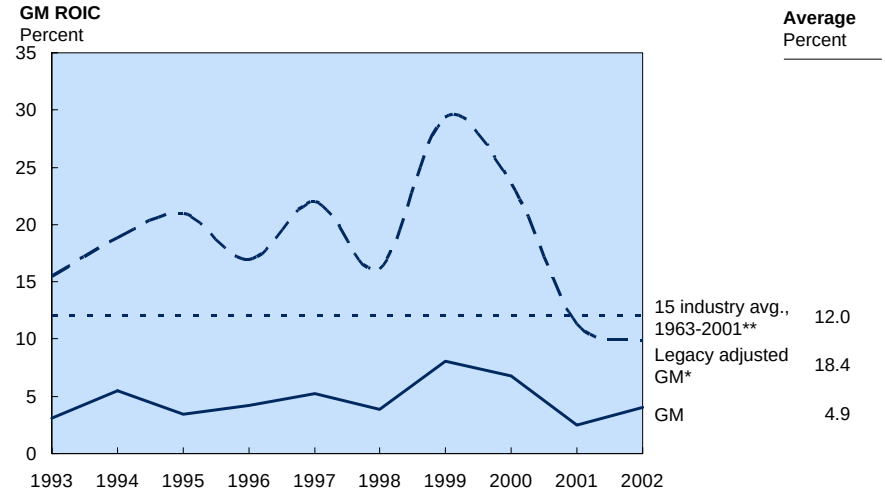
* Present value of what is owed – US and non-US pensions

Sources: Goldman Sachs; McKinsey analysis

capital (ROIC) would have been more than three times higher between 1992–2002, and roughly in line with broad industry trends (Exhibit 15). Such performance would have substantially boosted financial market returns to GM shareholders.

Exhibit 15

WITHOUT LEGACY COST BURDEN, GM WOULD HAVE DELIVERED MUCH HIGHER RETURNS



* GM Automotive after tax ROIC (excluding Hughes, including goodwill) calculated with pension expense adjusted to include only service costs; interest on retiree health care shifted reclassified as interest expense

** Highest (20) to lowest (7): pharmaceuticals, software, toiletries, semiconductors, computer hardware, trucking, medical supplies, defense, specialty chemicals, commodity chemicals, oil, telecommunications, paper, electric utilities, airlines

Sources: Goldman Sachs; McKinsey analysis

The Big Three were unable to sustain strong financial performance despite the significant gains in productivity between 1987 and 2002 which we will now document. (See “Productivity and Business Performance”, page 36.)

PRODUCTIVITY AND BUSINESS PERFORMANCE

Companies that increase labor productivity will initially improve profitability, but the relationship between productivity and profits is more complicated over the long term. In our case study of the US automotive sector between 1987 and 2002, productivity gains by the Big Three translated into temporary improvements in financial performance, particularly during the mid 1990's, but not a sustained increase in profit growth. This outcome is a consequence of the dynamic relationship between productivity and profitability, as well as non-operational firm specific factors, such as pension and health care liabilities as documented in the text.

The dynamic relationship between productivity and profitability can be explained using a simple example. Imagine a situation where two companies compete in the same regional market with access to the same factor inputs. Both have similar levels of productivity and profitability. If one company is able to increase its productivity, it will be able to produce the same quantity of goods and services at the same quality level with less labor, or materials, and/or hours. In this case, higher productivity will create a cost advantage, and the company can use the resulting profits for new investments, or it can distribute these profits to shareholders. The company may also choose to offer lower prices in order to gain market share or pay higher wages in order to attract higher-skilled labor.

A one-time increase in productivity, however, will usually not lead to a sustainable advantage in profitability. In order to stay competitive, the other company will have to follow suit and improve its productivity. Once the two companies reach the same level of productivity, they will compete primarily on price until any advantages in profitability have disappeared.

As documented in the main text, this dynamic generally played out within the US Automotive sector. The shift in demand to light trucks in the late 1990s increased productivity by raising value added per vehicle. The Big Three's experience with light trucks gave them an early competitive advantage, allowing them to dominate the market segment. Combined with their gains in manufacturing efficiency, this enabled the Big Three to reap substantial profits in the second half of the 1990s. By the year 2000, the Japan and Germany-based OEMs began to successfully challenge the Big Three in the light truck market. This trend was accelerated by the shift in demand from SUVs based on truck platforms, to SUVs based on cars, where the Japan and Germany-based OEMs have significant advantages and manufacturing know-how. The increased competition in light truck market materially eroded profit margins for the Big Three.

THE IMPACT OF REGULATION ON PRODUCTIVITY GROWTH

Specific features of government regulation of the auto industry impacted productivity growth both directly through mandates and indirectly through their effect on the nature of new product introductions.

Safety features and productivity growth

Regulation accelerated the diffusion of features and technologies. In the 1970s, cars were redesigned to protect the passenger compartment during accidents and were successful in reducing the impact damage to the occupants of vehicles. During the 1987–2002 period, passive restraint systems were mandated which rapidly pushed air bag penetration to 100 percent. OEMs added other safety features, such as anti-lock braking systems (ABS) without any government mandate. It is notable that safety was less stringent for SUVs and other light trucks.

Regulation generally increased the cost of production, and hence prices—pushing them some $2,500 to $4,000 higher than they would have been otherwise, according to one study.[5] Vehicle prices may or may not show increases at the precise time new regulatory features are added because other cost changes and market conditions are in play. Regardless of whether new regulatory features can be seen to have impacted on prices, the measurement methodology used by BLS in the US counts them as additions to real value-added in the industry (based on the estimated producer cost of adding the features). The benefits to consumers of regulated changes are hard to assess, and may be higher or lower than their production cost.

In our calculations, regulatory changes that drove the addition of safety features did increase value-added per vehicle. Whether or not they also boosted productivity depends on their impact on assembly hours and our interviews with industry experts suggest that these changed very little because of these added features. Additional hours were added in the parts sector to produce air bags, ABS, and other regulated components, but we found that cost-per-unit declined sharply as volume and penetration expanded. On balance, we judge that regulated safety features have had a small positive impact on measured industry productivity.

5 Daniel Sperlong, et.al, "Analysis of Auto Industry and consumer response to regulations and technological change, and customisation of consumer response models in support of AB 1493 Rulemaking," California Air Resource Board and the California Environmental Protection Agency, 2004

CAFE and emissions regulation and new products

Fuel economy standards were first introduced in the 1970s (when gas prices were very high); they favored imported vehicles because these were smaller, more fuel-efficient, and could meet emissions standards more easily. Over time, the Big Three responded to the pressures of regulation by developing smaller cars and using fuel injection and computer-controlled engines to preserve power and drivability while meeting regulatory requirements.

In the late 1980s, the Big Three recognized that consumer demand for large and powerful vehicles could be met by modifying commercial vehicles for widespread consumer use—minivans, SUVs, and pick-ups. These vehicles did not have to meet the fuel efficiency requirements established for cars, and when gas prices declined sharply in the late 1980s, the market expanded rapidly. Over time, consumer demand and further regulation caused OEMs to add additional safety features to these vehicles, but the CAFE standards remain less demanding in this segment.

When SUVs and minivans were introduced, they commanded price premiums that, measured by the BLS, were counted as additions to real industry value-added. Since hours-per-vehicle were not higher for this segment in general—and were actually lower for many SUVs and pick-ups—this change in vehicle mix contributed substantially to productivity growth.

THE BIG THREE INNOVATE

We have found that 45 percent of the productivity increase seen between 1987 and 2002 was driven by process innovation—primarily the adoption of lean production techniques by the Big Three. About 25 percent of this increase came from the shift to new higher value-added products; the remaining gain came from added features and quality in existing products, a shift within the industry to more efficient producers, and a changed product mix.

Innovating to improve process

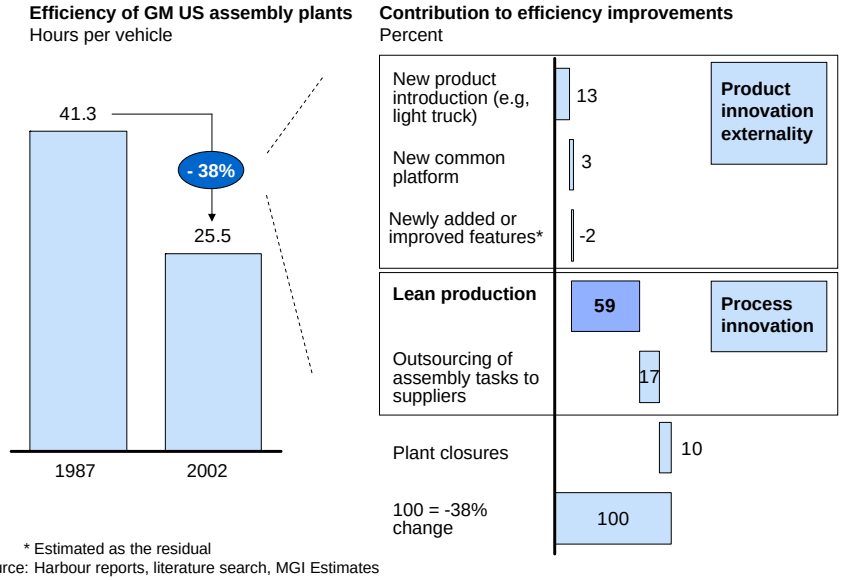
The leading Japan-based OEMs were clear efficiency leaders between 1987 and 2002. Their lean production techniques minimized the hours required for assembly and they improved quality by, for instance, nearly eliminating end-of-line re-work and establishing close privileged relationships with suppliers that raised quality and efficiency throughout the value chain. The Big Three lagged substantially behind on hours per vehicle and their catch-up to best practice was the largest driver of

productivity growth over the period. Adopting lean production techniques was the key (Exhibit 16), but catching the Japan-based OEMs proved difficult—it took nearly ten to fifteen years for the Big Three to learn, adopt, and implement these process improvements.

Exhibit 16

LEAN PRODUCTION MADE LARGEST CONTRIBUTION TO GREATER OEM EFFICIENCY

GM EXAMPLE



* Estimated as the residual

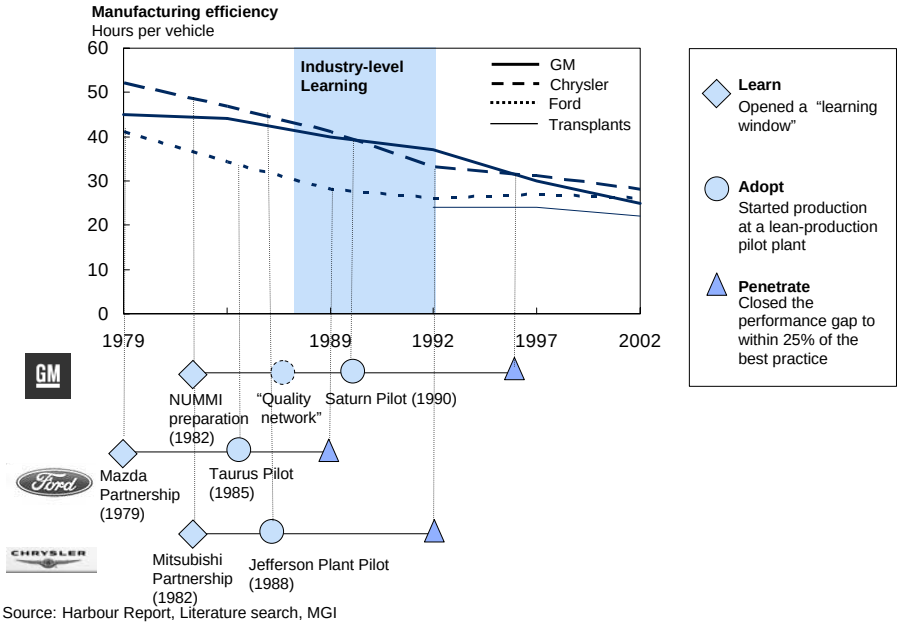
Source: Harbour reports, literature search, MGI Estimates

The Big Three began responding in the early 1980s. All of them made efforts to learn the lean production system, taking look-and-learn tours to Japan, and forging strategic alliances with the Japan-based OEMs. Although their responses seemed similar, in fact they took away different lessons and produced quite different results. In 1987, the beginning of our period of analysis, Ford was the only one of the three that had already reached best practice assembly hours-per-vehicle. It took Chrysler until 1992 and GM until 1997 to bring down hours-per-vehicle to a similar level (Exhibit 17).

These differences in rates of catch-up was due to the fact that competitive pressure hit their company performance at different times; they had different views of the nature of the initial competitive threat; and their organizations responded in their own ways to the barriers they had to overcome to make the required changes.

Exhibit 17

BIG THREE TOOK 10-15 YEARS TO MATCH TRANSPLANTS EFFICIENCY



Source: Harbour Report, Literature search, MGI

- **Timing of the competitive pressure**—Ford was suffering through its worst financial performance after the 1981-1982 recession, and was continuing to lose market share to the Japan-based OEMs. This combination precipitated the company's early focus process improvement. Although Chrysler required a financial bailout to survive in 1979, it was not until the late 1980s and early 1990s when its performance faltered again and it was forced to home in on the necessary process improvements. GM continued to lose market share to the Japan-based OEMs throughout the mid- and late 1980s; however, it wasn't until 1992, when their performance was undermined by the Gulf War recession, that GM was prompted to focus on process improvement.

- **Initial diagnoses of the competitive threat**—Ford's equity relationship with Mazda helped managers to recognize early that the advantages of the lean production system extended beyond assembly operations to encompass the entire value chain, design for manufacturing, total quality management, and developing close partnerships with their suppliers. Their tradition of using

external benchmarks to judge themselves made it easier for Ford to learn quickly. In contrast, when Chrysler and GM first started working with the Japan-based OEMs in the early 1980s, they focused almost exclusively on factory practices as the source of the efficiency advantage. They missed the broader nature of Japan-based OEMs' new production system.[6]

Chrysler's initial learning from Mitsubishi Motors focused on factory practices. They were more focused on new product development as a response to the increased competitive pressure. GM's initial position of strength in the industry made it less ready to acknowledge the large performance gap it faced. Their early efforts in process efficiency improvement strongly emphasized automation, exemplified by their acquisitions of Hughes Aerospace (for technology), Fanuc (for robotics), and EDS (for computer systems). GM failed to reap substantial gains from these acquisitions, and all these subsidiaries were eventually sold.

- **Organizational responses**—Ford's early success was based upon implementing process improvements as part of a company-wide transformation program, and on the good relationship between the UAW union and management. Ford's management was able to capitalize on a shared sense of crisis with the UAW and the UAW leadership helped the process of transforming the design of people's tasks as well as putting in place quality-related initiatives. Ford also involved its suppliers early on in quality improvements initiatives—the company sent its parts supplier groups to Japan in the early 1980s to learn what Mazda suppliers did in quality management. It took four years for Ford to go from a pilot program to closing the gap with best practice.

  Once Chrysler's CEO Lee Iacocca focused on the need to improve process efficiency, he exerted effective top-down leadership to force change. Iacocca reached out to Mitsubishi Motors to ask for full collaboration in transferring production know-how, and sent Chrysler engineers to Honda to learn how vehicles were designed efficiently and how the R&D teams and the production engineers collaborated. Iacocca, like Ford, was successful in

6 See Chapter 3 for a complete discussion of lean production

creating common cause with the UAW, inviting key representatives to board meetings. Chrysler also made significant efforts to partner more closely with their suppliers in the early 1990s and improved the cost, quality, and time required for design changes. After initiating these changes six years after the original partnership with Mitsubishi, it took an additional six years for Chrysler to register significant improvements.

GM did not see any pressing need for a large-scale change program. Furthermore, its decentralized organizational structure impeded its ability to carry out process transformation once it realized the need. As late as 1999, GM had a brand-focused structure in which division leaders managed all the major functions for their particular brand, including engineering groups, plant production, and sales channels. There weren't sufficient incentives for these division leaders to focus on cross-brand, within-company learning. Although some of GM's plants, including NUMMI, were successfully implementing lean production and were classified as best plants in the industry, this experience of internal best practice was not fully transferred to the company's weak performing plants; the gap between the best and worst plants at GM was therefore much wider than that of Ford or Chrysler.

GM initially faced UAW resistance and was only able to gain the union's cooperation after management had put the work in to create a shared understanding of the extent of the transformation required. To overcome the organizational challenges, they launched initiatives to help diffuse new process innovations across the company. This included transfers of experienced executives and mid-level managers and common platform projects (e.g., GMT 800). The Saturn pilot began in 1990, fully eight years after the NUMMI project was started and it took an additional seven years to reap the full benefits of the change program. However, although it took GM the longest to complete the transformation, its improvement was the most significant and GM is now the efficiency leader of the Big Three.

Parts manufacturers also improved their efficiency. The hours required to manufacture parts for new vehicles declined by 33 percent on a per-vehicle basis between 1987 and 2002.[7] This accounted for 24 percent of the

7 Recall that our industry definition includes parts manufactured for the production of new vehicles, and excludes the aftermarket.

overall sector increase in productivity over the period. Although the fragmented nature of the parts industry makes it especially difficult to analyze sources of productivity improvement, we were able to identify the main drivers in engine and transmission manufacturing. For these two sub-sectors, (which accounted for approximately 25 percent of employment at that time), nearly all the productivity improvement came from changes in internal processes, including the introduction of easier-to-produce models using design for manufacturing techniques. The entrance of more efficient global competitors also had an impact.[8]

THE IMPACT OF CAPITAL ACCUMULATION ON LABOR PRODUCTIVITY GROWTH

Our decomposition of the sources of productivity growth is based on attributing increases in value added per worker to specific actions taken by the OEMs that either raised value added or lowered hours per vehicle. We believe this approach has allowed us to understand the fundamental drivers of productivity growth by identifying the specific decisions and resulting activities undertaken by the Big Three. In some cases, the accumulation of additional fixed capital was the outcome of these decisions. A more traditional "growth accounting" approach is to decompose increases in value added per hour into contributions from capital deepening—increases in the ratio of capital services to labor hours—and total factor productivity (TFP).

There was essentially no capital deepening in the broadly defined US automotive sector (including production of parts for the aftermarket, heavy duty trucks, truck trailers, and recreational vehicles) for the first ten years of our period of analysis (Exhibit 18).[9] In the later half of the 1990s, the capital labor ratio rose with increased investment and a decline in overall hours. Because the capital labor ratio was essentially flat for this initial period, TFP growth drove changes in labor productivity between 1987 and 1996. Between 1997 and 2002, capital services

8 For the purposes of disaggregating the sources of contributions for the parts producers, we assumed that the remainder of the parts industry outside of engines and transmissions improved their productivity for the same reasons. Some of the improvements in hours for the parts industry could have come about because of shifting jobs out of the US, primarily to Mexico. It has not been possible to obtain quantitative estimates of this activity, although the qualitative evidence suggests that a large portion of parts imports are destined for the aftermarket.

9 Capital stock data is not available in a form which allows us to compute the growth accounting exercise using our more narrow sector definition of new vehicle production.

rose while labor hours remained flat or declined, so that capital deepening had a significant contribution during this period (Exhibit 19).

Capital deepening is often attributed to firms substituting capital for labor because of differences in factor prices. Although GM and Chrysler did push for increased automation in the early 1990s, this did not result in any significant capital deepening. The capital deepening that occurred in the later half of the 1990s was accompanied by significant organizational and institutional change, and labor cost arbitrage was only one factor driving these changes. Other factors include changes in physical plant required to implement lean production, the upgrading of plants to produce new model SUVs, the construction of new plants by non-US OEMs, and investments by the parts sector driven in part by OEM outsourcing.

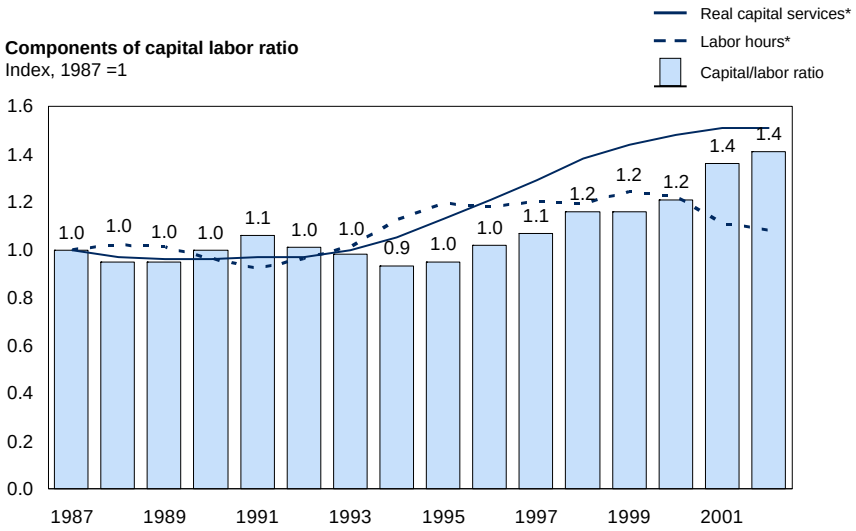
Beyond recognizing that a reduction in hours per vehicle would increase capital deepening (all else equal), there is no direct mapping between these two approaches, although both of them capture the impact of capital deepening and TFP growth. As we have decomposed the factors driving changes in value added and hours per vehicle, increased investment in capital equipment will increase efficiency, driving down hours per vehicle. It will also increase value added, to the extent that new equipment improves the ability of OEMs and parts manufacturers to increase quality and produce new functional features. Similarly, to the extent that increases in TFP captures such things as the efficiency impact of improved organizational structures it will reduce hours per vehicle. TFP will also capture the additional value that the OEMs were able to extract through selling higher value added vehicles including many of the new SUVs.

Innovating new light trucks

Light trucks' share of total light vehicle sales rose from 32 percent in 1987 to 52 percent in 2002; the Big Three's share of the segment, while falling from 81 percent in 1987 to 77 percent over the same period, was still dominant. The shift to light trucks increased productivity because it increased average value-added per vehicle by nearly 15 percent (Exhibit 20), accounting for 25 percent of the total change in productivity during these years.

Exhibit 18

INDUSTRY'S CAPITAL/LABOR RATIO DEEPENED IN LATE 1990s

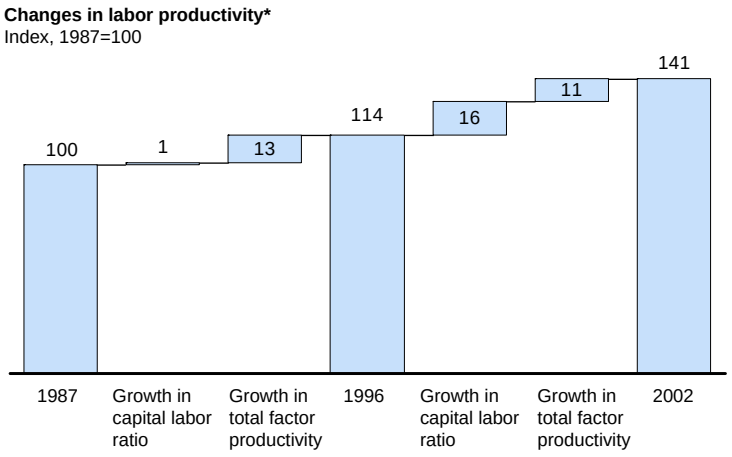


* NAICS definition of automotive and parts sector (including production of parts for the aftermarket, heavy duty trucks, truck trailers, and recreational vehicles)

Source: BEA, BLS, Federal Reserve, MGI analysis

Exhibit 19

CAPITAL DEEPENING WAS IMPORTANT FOR LABOR PRODUCTIVITY GROWTH 1996-2002

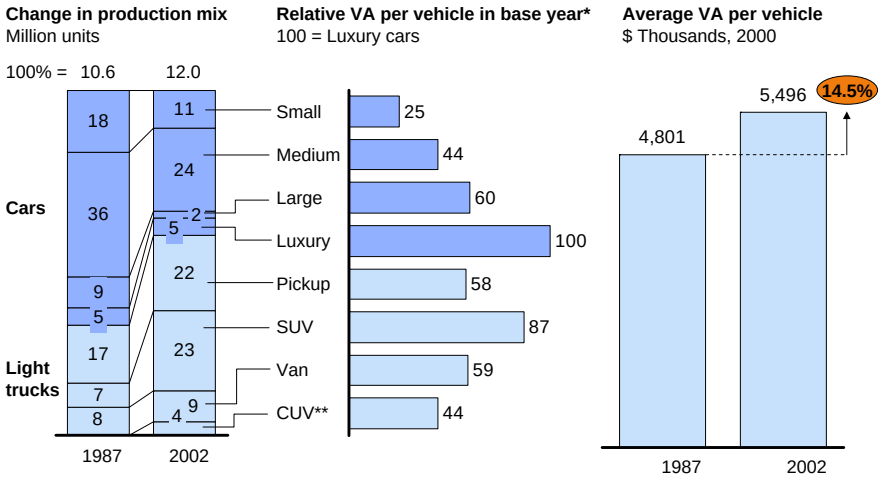


* NAICS definition of automotive and parts sector (i.e., includes parts production for aftermarket). Contributions computed with variable capital cost shares from the BLS.

Source: Federal Reserve; BEA; BLS; MGI analysis

Exhibit 20

SHIFT TO LIGHT TRUCKS RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 15 PERCENT



* Relative magnitudes estimated based on 1999 reference year
** Cross-utility vehicle assumed to have VA per vehicle of a small SUV
Source: Ward's Automotive yearbook; Goldman Sachs; BEA; MGI Analysis

The Big Three were well positioned to capitalize on the shift in demand, particularly to SUVs—the biggest growth area of light trucks—because of their experience in building pick-up trucks. The SUVs used identical underlying technology as the pick-ups, making it easy for the Big Three to penetrate this market. This technology was not only well known; it was cheaper than that being used in most cars, and far easier for the Big Three to assemble. Furthermore, less stringent CAFE regulations for light trucks meant that they could produce these vehicles without including expensive fuel-saving technologies. The strong profits they earned helped raise their overall, average value-added per vehicle.

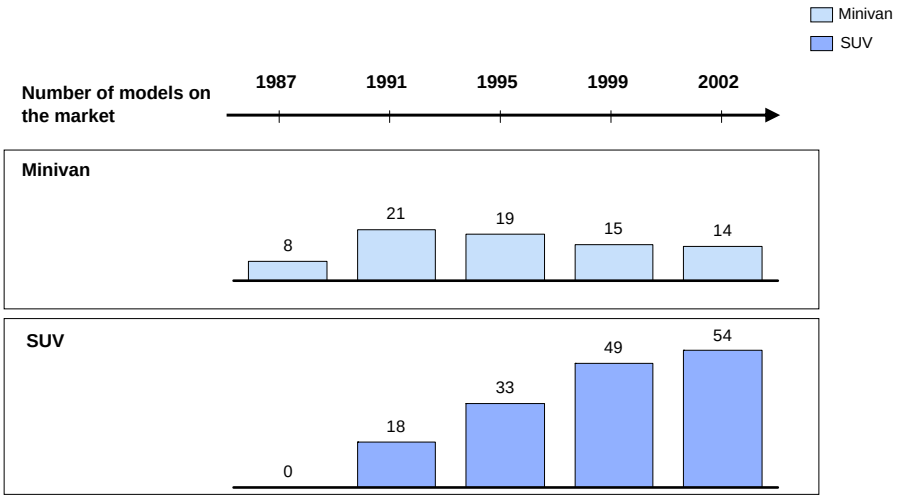
While the Japan-based OEMs were able to sustain a competitive advantage because of their superior production processes, Ford was not able to sustain much of an advantage after the introduction of the Ford Explorer—the first "modern" SUV—in 1991. (Chrysler and GM followed Ford quickly with their own models.) Although it took Japan- and Germany-based OEMs longer to respond because of their limited experience in US-style light trucks.

The number of modern SUV models jumped from zero in 1987 to 54 in 2002 (Exhibit 21). This was important for sector productivity growth because of the

widespread market penetration and the high value-added of these vehicles. On the downside, the fact that the Big Three responded to global competition through new model introductions reduced the sense of urgency that process improvement was needed, and is likely to have slowed productivity growth.

Exhibit 21

NUMBER OF SUV MODELS GREW WITH SUVS' POPULARITY



Source: Ward's, MGI analysis

Improvements in features and quality

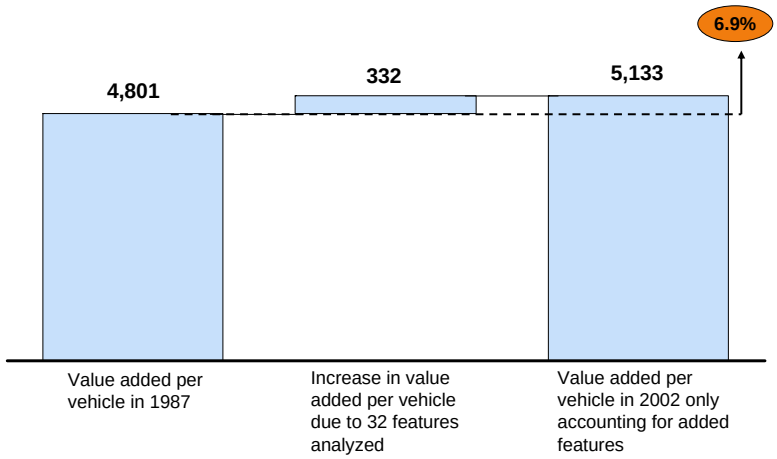
OEMs add new functional features to try and extract more value from their existing customers, to differentiate their products, and to try and maintain market share—and the Big Three increased the feature content of their vehicles significantly between 1987 and 2002. This was a natural response to the slow overall growth and competitive pressure in the market. We estimate that the addition of functional features alone would have produced a 7 percent increase in value-added per vehicle over the period (Exhibit 22). This is the equivalent of around a 9 percentage point contribution to the overall increase in productivity.

To understand how innovations embodied in functional features impact productivity growth, we studied the introduction, adoption, and market penetration of airbags and anti-lock brake systems (ABS). Airbags and ABS suffered from the kind of "infancy problems" encountered by many new technologies: technical difficulties, high costs, and limited consumer demand when first introduced.

Exhibit 22

NEW FUNCTIONAL FEATURES RAISED AVERAGE VALUE ADDED PER VEHICLE BY 7 PERCENT

$ 2000



Source: Ward's; BEA; McKinsey analysis

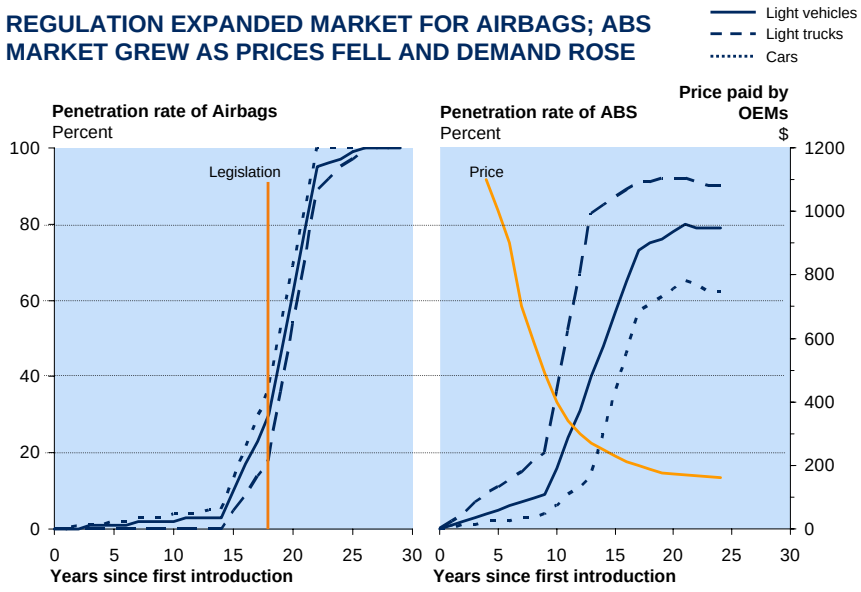
These problems, along with very little interest by consumers, caused the original innovators (GM for airbags, Ford for ABS) to withdraw these items from the market. Both of these technologies, with modifications, were later successfully introduced by Mercedes Benz, and adopted quickly by other luxury and performance brands.

Despite their successful introduction in high-end models, airbags did not achieve wide penetration in the US market until regulations were passed in 1991 requiring all new passenger vehicles to have passive-restraint systems installed. ABS did not achieve widespread penetration until their cost fell enough for them to be included in lower-end vehicles (Exhibit 23). It was widespread penetration that drove their contributions to productivity growth.

As well as adding new functional features, the Big Three made progress in closing the quality gap between them and the best-practice, Japan-based OEMs. The Big Three improved their initial quality, measured as the number of defects reported in the first 90 days, from about 55 percent of the best practice level in 1990 to around 74 percent in 2002 (Exhibit 24). It took the Big Three roughly 12 years to cut the gap in half, partly because Toyota kept pushing the standard upward at an astonishing rate of 5.8 percent per annum. The Big Three also improved vehicle durability, measured as the number of problems per vehicle in

Exhibit 23

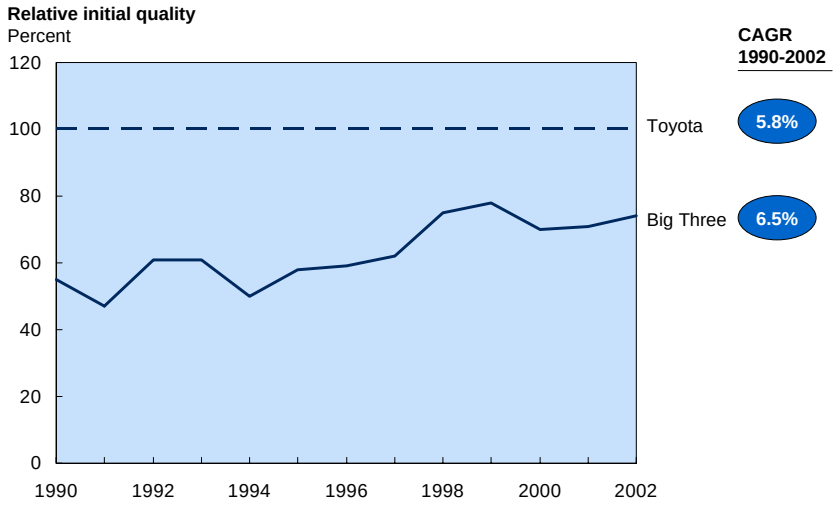
REGULATION EXPANDED MARKET FOR AIRBAGS; ABS MARKET GREW AS PRICES FELL AND DEMAND ROSE



Source: Wards; McKinsey Automotive Practice

Exhibit 24

BIG THREE HALVED INITIAL QUALITY GAP AGAINST TOYOTA

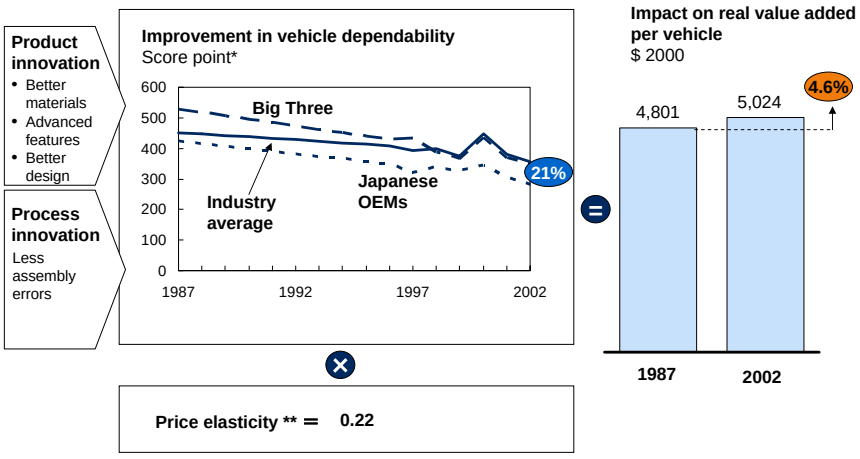


Source: JD Power, MGI

the first three years, to reach 70 percent of best practice levels by 2002. We estimate that increases in industry vehicle dependability alone would have increased value-added per vehicle by 5 percent over the period (Exhibit 25). This translates to an approximate 6 percentage point contribution to the overall increase in productivity.

Exhibit 25

IMPROVED DEPENDABILITY RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 5 PERCENT



* Includes initial quality and durability. Scores before 1996 were estimated based on improvement ratio from 1997-2002
** Models considered for price elasticity estimation were: Upper small cars (Ford Taurus, GM Impala, GM Grand Prix, Toyota Camry) and middle SUV (Ford Explorer, Chrysler Jeep Grand Cherokee, GM Blazer, Toyota 4 Runner)
Source: JD Power, Ward Automotive Yearbook, MGI

As noted above, part of the increase in quality is from the adoption of lean production techniques, which tend to reduce overall assembly errors, although our estimate of the magnitude of this positive spillover from process improvements is small. The majority of the quality improvements have come from the increased reliability and overall performance of components.

Shifting production to foreign transplants and changing the model mix

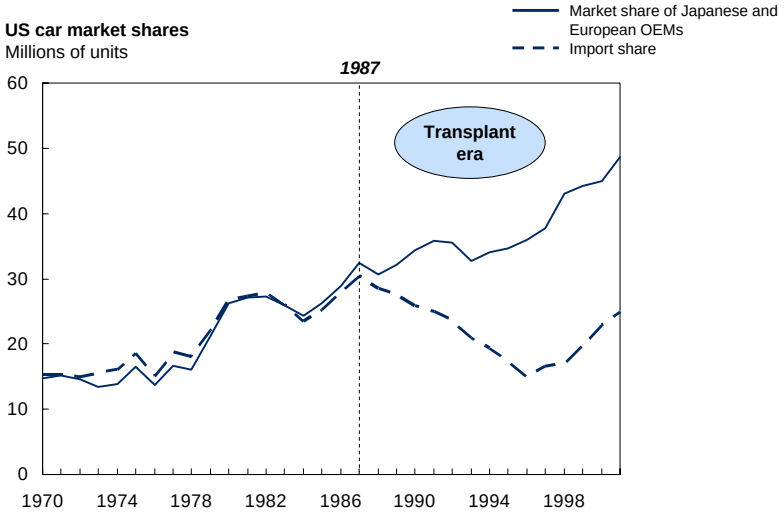
The Big Three's sales and financial positions were being battered by the 30 percent slump in demand during the early 1981-1982 recession which coincided with stiff competition from Japan- and Germany-based OEMs that were taking share in the car market. This combination led to calls for protection, and the US administration negotiated voluntary restraint agreements (VRAs) with the Japanese government in 1981, that restricted the number of cars that the

Japan-based OEMs could export to the US. The VRAs were in place until 1994.[10] (Interestingly, GM resisted the plea by Ford, Chrysler and the UAW for trade protection during this period.)

The VRAs accelerated a nascent trend: by 1987, all major foreign competitors had responded to the market opportunities, and changing economic and political environment, by setting up production facilities in North America. (Toyota had begun a joint venture with GM in 1984, and established its own US production in 1988.) The growth of the transplants meant that competition from global players was increasingly coming from facilities located in North America (Exhibit 26).

Exhibit 26

JAPAN AND EUROPE-BASED OEMS INCREASED MARKET SHARE AFTER 1987 WITH OUTPUT FROM TRANSPLANTS



Source: BEA, Wards

10 Estimates vary on how binding the VRAs were over this period. For a discussion and additional perspectives on the impact of the VRAs, see Steven Berry, James Levinsohn and Ariel Pakes, "Voluntary Export Restraints on Automobiles: Evaluating a trade policy," *American Economic Review*, vol. 89, no. 3 (1999), and references therein.

The increasing market share of domestic production facilities operated by non-US based OEMs was an important contributor to higher productivity. Together with concomitant improvements in the efficiency of parts manufacturing which also partially migrated to more efficient Japanese producers, this shift accounted for 10 percent of productivity growth over the period. In addition to this direct impact on productivity growth, the VRA's focus on numerical import targets rather than on the value of imports, created an incentive for the Japan-based OEMs to focus on creating higher value added models for export, and shifting the production of their entry- and mid-level cars in the US. The introduction of higher quality models and new brands (e.g., Lexus was launched in 1989) by the Japan-based OEMs was an important factor driving competitive pressure in the US market for years to come.

The move to light trucks also played an unintended role in improving process efficiency, since trucks are on average easier to assemble than cars. The externality produced by this shift in model mix shift accounted for 5 percent of productivity growth over our period of analysis. We have counted it separately from process innovation because it was not the result of deliberate actions taken by OEMs to improve manufacturing efficiency.[11]

GLOBAL COMPETITION AND PRODUCTIVITY DYNAMICS

This case study has allowed us to shed some light on the three key questions. How does global competition change domestic sector dynamics and productivity growth? How quickly do these changes occur and what factors determine the speed of adjustment? What will be the impact on the stakeholders?

How does global competition change domestic sector dynamics and boost productivity?

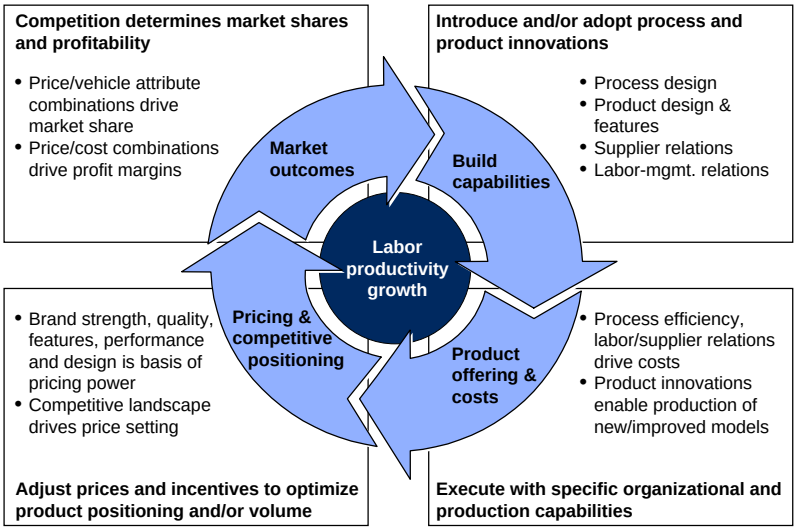
Global leaders with superior production processes and better quality products increase the competitive pressure on domestic players. This then kicks off a dynamic which leads to changes in company conduct, performance, and sector productivity growth. In particular, this pressure encourages companies to build the capabilities they need to compete, introducing process and product innovations and adopting the innovations of others.

11 In 2002, trucks assembly on average required more hours than cars assembly. This was not because of the truck body complexity, but because of the greater number of added-on features on trucks. The lack of consistent company level data about the fragmented parts sector prevented us from quantifying the potential net impact of product innovation externalities on this part of the industry.

Using our automotive case, it is helpful to illustrate this dynamic as a four-step process (Exhibit 27):

Exhibit 27

HOW GLOBAL COMPETITIVE PRESSURE DRIVES PRODUCTIVITY GROWTH



Source: MGI

- **Market outcomes**. Competition drives changes in market share and profit margins. Market shares are a reflection of price/value combinations that are being offered to consumers; profit margins are a reflection of price/cost relations within OEMs.

- **Build capabilities**. OEMs respond to market share challenges and the erosion of profit margins by building new capabilities. They do so by introducing process and product innovations and adopting the innovations of others. OEMs can also try and build distinctiveness in supplier and labor relations.

- **Product offerings and costs**. The capabilities developed by OEMs are combined to produce a portfolio of vehicles, with a targeted group of features, at a particular cost. Process innovations and enhanced supplier and labor relations improve efficiency and lower costs. Product innovations provide capabilities to build new and improved models. Both types of innovations influence vehicle quality.

- **Pricing and competitive positioning**. The OEMs set prices based on vehicle demand, value propositions, cost structure, and the pricing and availability of competitive brands. Prices are adjusted and incentives offered to improve the positioning of vehicles, the success of which determines the price/value and price/cost relationships which govern market outcomes. As outcomes change, the reinforcing process begins anew.

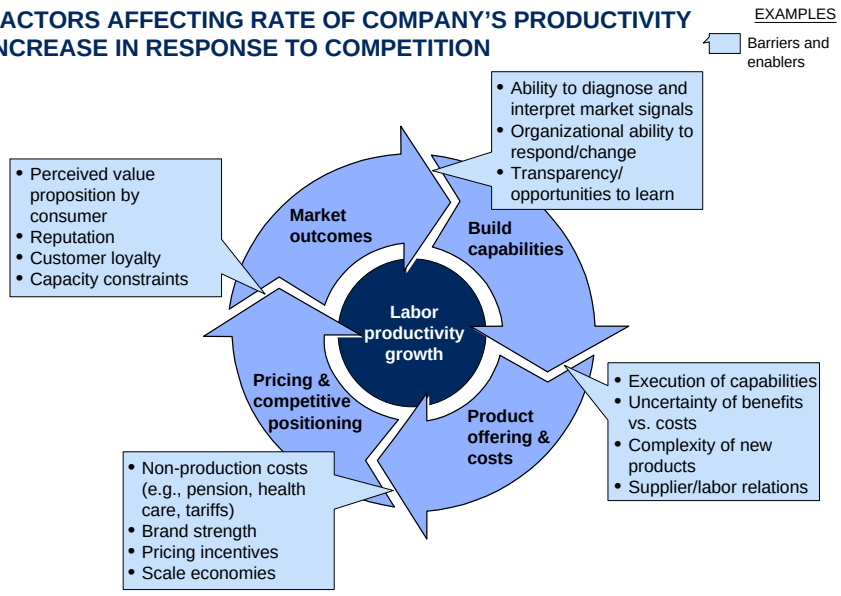
As this process repeats, labor productivity improves either through a reduction in hours per vehicle or through an increase in average value-added per vehicle.

How quickly do these changes occur and what factors determine the speed of adjustment?

Within the US automotive sector, we found that the speed with which competitive pressure translates into productivity growth depends crucially on the nature of the competitive challenge. It is typically easier for competitors to respond to the introduction of new products than to advantage based on process superiority. Beyond the specific competitive threat, companies face factors at each link in the dynamic process that can impede, or accelerate, the rate at which competition produces productivity growth. The reinforcing dynamic which drives this process does not flow uninhibited (Exhibit 28).

Exhibit 28

FACTORS AFFECTING RATE OF COMPANY'S PRODUCTIVITY INCREASE IN RESPONSE TO COMPETITION



Source: MGI

- **Diagnosing market outcomes and building capabilities to compete**. The nature of the competitive threat is important in this phase as new products are typically easier to gather intelligence about and emulate than new processes that are not very transparent from the outside. Alliances can help accelerate the gaining of insight into the competitive threat. Organizational flexibility and readiness to accept change are critical to building new capabilities.

- **Turning capabilities into new or improved products**. Once new capabilities are developed, new or improved vehicles must be created. To do this effectively, OEMs must be good at evaluating the uncertainties of whether a new vehicle or feature will be a success, as well as the complexity of production. Strong working relationships with suppliers and labor have proven to be a big plus in making this transition.

- **Creating a strong competitive position through pricing**. OEMs must often contend with additional, non-production-related costs that can limit their pricing options (e.g., health care and pension-related obligations for the Big Three). Aside from factors that impact costs, brand strength and reputation for quality are important sources of pricing power. The Big Three have to make aggressive use of price incentives to compensate for their perceived quality gap.

- **Turning competitive positioning into positive market outcomes**. Market outcomes are ultimately determined by the perceived value proposition of a particular vehicle, relative to price. Reputation is a significant driver of sales in the US automotive industry with consumers often willing to pay more for a product they perceive as superior. Customer loyalty is also very important for OEMs who actively strive to build long-term relationships with their customers. Once a customer shifts brands for whatever reason, they are difficult to win back.

What is the impact on consumers, shareholders, and workers?

Consumers have been the largest beneficiaries of increased global competition. As discussed above, consumers have been facing falling inflation-adjusted prices for light vehicles, partly as a result of increasingly large incentives (see Exhibit 11). At the same time, the shift in vehicle mix has raised average value per vehicle and more and more features are being included (see Exhibits 21, 23). Moreover, there has been a dramatic improvement in the overall quality and durability of vehicles over our period of analysis (see Exhibits 25, 26).

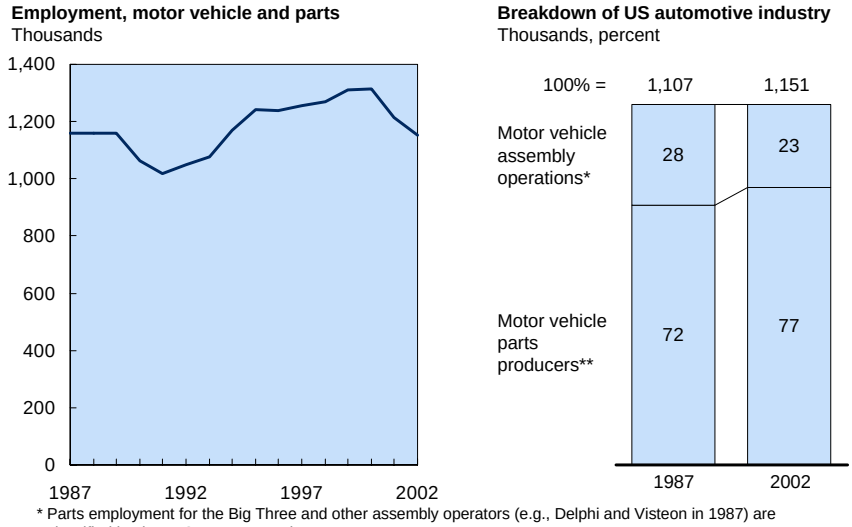
As we discuss in more detail above, the Big Three's shareholders have not fared as well; their returns have remained stubbornly below market averages as the Japan-based OEMs maintained a significant competitive advantage (see Exhibit 10, 14). They continue to suffer from a perceived quality/reliability shortfall for a range of Big Three products which equates to a $1,000 to $2,000 price discount to comparable products from Japan-based nameplates. The high mark-ups that had been available in the light truck segment have diminished sharply as industry supply has expanded and high fuel prices have made the segment less attractive to consumers. And, although this is not a focus of this study, the Big Three also face pension and health care costs that are substantially higher than their competitors (see Exhibits 15). Partly as a result of these factors, the productivity increases in the domestic industry have not yet translated into sustained profitability.

Workers, however, have benefited from relatively stable levels of employment and purchasing power. Employment in the US automotive sector was essentially flat between 1987 and 2002 at some 1.1 million workers despite the cyclical fluctuations caused by two recessions, substantial increases in productivity, the signing of the North American Free Trade Agreement, and general trends in globalization (Exhibit 29).[12] But employment has shifted between companies resulting in worker displacement. Big Three employment in assembly operations declined by about 190,000, while the transplants nearly doubled their employment from 15,000 to 29,000 workers already largely in locations different from where the Big Three plants were located.. In addition, GM and Ford spun off their parts divisions into Delphi (GM in 1999) and Visteon (Ford in 2000). In 2002, these two parts suppliers had 270,000 workers. It is difficult to get company employment data for the parts industry, which is so fragmented, but there was a wave of closures, mergers, and takeovers among suppliers as the industry consolidated into larger entities. Overall, the share of employment in assembly operations fell while the share of parts employment rose.

12 Unlike many industries that faced increased global competition, part of the reason that employment was so stable is that none of the Big Three exited the industry when faced with the competitive threat. As we note above, Chrysler needed a government bailout to survive in the late 1970s and then eventually merged with Daimler.

Exhibit 29

TOTAL EMPLOYMENT REMAINED FLAT, WITH SHIFT FROM ASSEMBLY TO PARTS MANUFACTURING



* Parts employment for the Big Three and other assembly operators (e.g., Delphi and Visteon in 1987) are classified by the BLS as parts employment

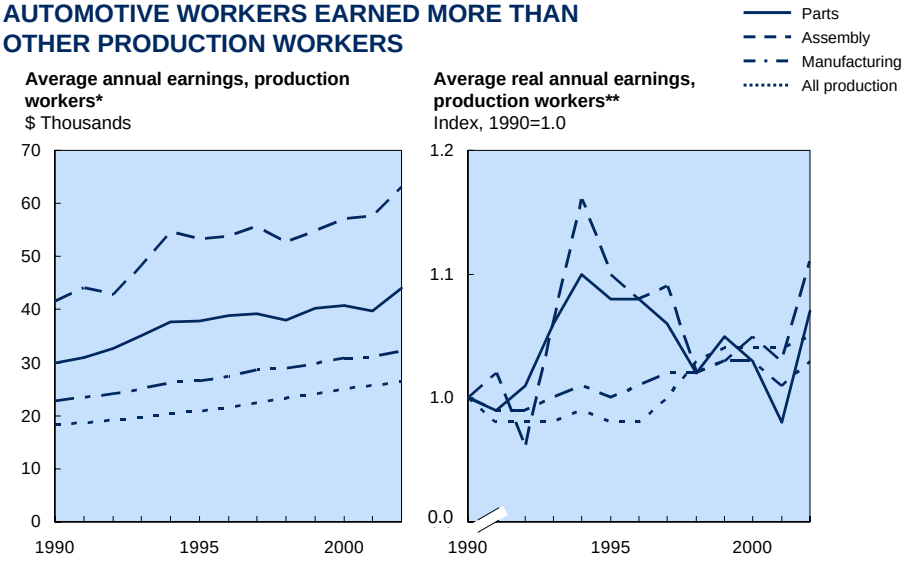
** Include companies that manufacture part, motor vehicle bodies, and trailers

Source: BLS

Although employment declined in the Big Three, workers with jobs at the beginning of the period were given considerable employment protection. GM and Ford workers won a moratorium on plant closings in 1987, while Chrysler workers won job security as well as a moratorium in 1988. In 1996, the Big Three increased their job and income security funds and the union secured wage, pension, and benefit increases—and further wage increases in 1999. As the workforce has aged, the companies have used retirements as a way to reduce employment. These successes by the union have helped automotive workers maintain average wages above those of production and manufacturing workers as a whole, and keep pace with inflation (Exhibit 30). Although an average of only 38 percent of workers belonged to the UAW between 1987 and 2002, non-union transplants have paid competitive wages too (Toyota matched UAW wages in 2004). Only non-union parts suppliers pay substantially lower wages (Exhibit 31).

Exhibit 30

AUTOMOTIVE WORKERS EARNED MORE THAN OTHER PRODUCTION WORKERS



* Based on average weekly earnings

** Deflated using CPI, all urban consumers

Source: BLS

Exhibit 31

TRANSPLANTS AND BIG THREE PAID SIMILAR AVERAGE WAGES

2002, US

	Total hourly workforce	Percent of workforce unionized	Average wage ($/hr)*
GM	147,880	100	21.43
Ford	94,450	100	22.04
Daimler Chrysler	60,170	100	21.80
Parts suppliers	487,805	23	16.20 (union) 11.00 (non-union)
Transplant OEMs*	44,000	17	18.87

* Production workers

Sources: Federal Reserve Board; Bureau of Labor Statistics; Center for Automotive Research

IMPLICATIONS FOR COMPANIES AND POLICY MAKERS

What can policy makers and companies elsewhere learn from the US auto sector experience? The policy case for economic openness is that prosperity depends upon the level of productivity in an economy and, as domestic companies and industries face increased global competition, they increase their productivity. But there are transition costs as the domestic industry adjusts to a more competitive environment. In this case study, we have identified ways in which policy makers and companies can help increase the benefits, and reduce the costs, of transition to more globalized sectors. To be effective, they must first understand how innovation ultimately drives productivity growth.

How innovation drives productivity growth

We have found three distinct phases in the evolution of a specific innovation, each of which has a different impact on productivity (Exhibit 32).

Exhibit 32

DIFFUSION OF INNOVATION DRIVES TOTAL INDUSTRY PRODUCTIVITY GROWTH

	Innovation	Diffusion of innovations		
		Learning	Adoption	Penetration
General description	Development and introduction by innovator	Competitors acquire capabilities and introduce imitations		Innovations are widely implemented within companies and across industry
Product innovation	• New models • New and improved features and designs	• Transparent to industry • Can be easy to imitate • Hard to maintain competitive advantage		• Cost and regulation drive penetration within companies • Demand and regulation drive penetration within industry
Process innovation	• Labor saving • Capital saving • Input saving	• Lack of transparency • Harder to "re-engineer" • Opportunities to learn from innovators is critical • Potential source of sustained competitive advantage		• Competition creates incentives to drive down costs and spread innovations • Organizational capabilities determine penetration within companies
Impact on industry productivity growth	Low	Med-ium		High

Source: MGI

- **Initial innovation**. This phase covers the initial development and introduction of the innovation, including a new technology or product class, or a superior process. While critical, this phase generally has a low impact on industry productivity because the innovation has not achieved significant market penetration or been widely implemented throughout a particular company.

- **Adoption and learning**. Either competitors within an industry adopt innovations, or a company rolls them out more widely within its own organization. The ability to adopt the innovations of others depends importantly on their nature. It is often easier to imitate product advancements than it is to reengineer process innovations. Depending on the adoption rate, this second phase can have a moderate impact on industry productivity.

- **Penetration**. The final step of diffusion occurs as innovations become widely adopted within companies, and across an industry. Widespread penetration is what drives significant changes in market outcomes and raises industry productivity.[13]

How policy makers and companies can better capture benefits and reduce costs of global competition

Policy makers and companies must understand the impact of different phases of innovation on productivity and take on board that it is the penetration of innovations within companies and across markets that has the biggest effect. This diffusion often involves significant changes in market shares among companies and an associated migration of jobs. Policy makers often support policies that promote innovation such as aid for companies' R&D. But they should also make sure that policies do not create barriers to the industry shifts required for diffusion. There is also a case for policies to help workers that are adversely affected by the resulting adjustments. As for companies, they must focus not only on developing the next innovation, but on learning how to recognize the significant innovations of other companies. They must build capabilities to ensure that best practice process advancements are adopted and diffused across their organizations, and that product innovations achieve significant market penetration.

13 For a review of economic literature on drivers of the rate of diffusion of innovations, see Hall (2004): Innovation and diffusion. NBER Working Paper 10212.

- **Policy makers can promote productivity growth**—Policy makers must promote a level playing field and a competitive environment; be prepared to help ameliorate the impact of restructuring that sometimes results from global competition; and target polices that encourage the diffusion of innovations.

  – *Promote competition from global players*

  Our US automobile sector case supports one of MGI's core findings from past productivity studies—that exposing domestic companies to competition from global best practice players is an effective way to generate strong pressure on performance and increase productivity growth.

  Given the potential costs to incumbent companies and employees, it may be tempting for policy makers to draw back and impose or retain barriers to global competition, but such a reaction would be a mistake. As we have seen, global competition has increased the overall productivity in the US auto industry and productivity is the ultimate driver of improvements in living standards.

  Avoiding, rather than facing, global competition means giving up future productivity and income benefits. In any case, economies that shrink from global competition cannot ultimately hold back the forces of change—eventually the adjustment to best practice has to take place, but it will be more difficult and costly because it has been delayed. The chances of ending up with a fully competitive industry are reduced, not enhanced, by the prolonged retention of barriers to competition.

  – *Help compensate for restructuring costs*

  Global competition can lead to restructuring that does not benefit all stakeholders. In the case of the automobile industry, consumers have fared relatively well over the period we studied; employment overall has remained stable, but individual workers have been dislocated. Policy makers must try to separate policies that promote economic transformation, and those that help alleviate the impact of worker dislocation. Arguably, the company and labor market transitions in the US automotive industry would have been smoother if effective policies to promote worker reallocation were in place.

  Several public policies could ease the transition—for instance, job-retraining credits to employers provide them with the incentive to hire

displaced workers. Continuing education grants give workers a chance to build skills in demand, particularly from growing areas of the economy, such as healthcare, education, and social services. Generous severance packages can help; and portable medical insurance plans and pension benefits are essential to a workforce changing jobs more frequently.

– *Target policies that encourage diffusion*

We found no evidence in the auto sector that direct government policies to support innovation had a significant effect on productivity growth. As we have seen, the largest boost to productivity growth came from the diffusion of lean manufacturing adopted from Toyota and others. In the broadest sense, the education system is important; support for basic science and the availability of strong engineering and design talent are positive for productivity. But our findings are that it is the diffusion process itself—including learning, adoption, and penetration—that is the key to productivity growth. So the priority for policy makers is to do everything possible to remove barriers to, and promote, diffusion. Promoting diffusion is mainly done to companies (by, for example, creating flexible organizational structures), but governments can potentially play a role if diffusion is explicitly considered in research funding and regulatory processes.

Regulations can impede the diffusion of best practices and innovations (e.g., domestic content restrictions), but they can also promote it. In the auto case, we found that environmental and safety standards led to more rapid adoption and penetration of vehicle features than would have occurred without regulation; in this case, therefore, regulation actually contributed modestly to measured industry productivity growth.

There is also a role to play in actively promoting information-sharing. In the auto sector, government research grants facilitated the learning process when US OEMs were trying to identify why their competitiveness was eroding relative to Toyota and Honda. Such research helped establish the broad realization that the higher productivity of lean production was the main source of the competitive advantage, rather than lower labor and capital costs.

The introduction of OEM and car model quality rankings is a good example of how more widely available information can make a difference. Once consumers were able to compare the quality performance of different

OEMs through information resources such as JD Powers and Consumer Reports, they were able to make better choices, changing the competitive dynamics of the industry. For instance, best performing models were now able to price at a premium to less reliable ones.

- **Companies must understand competitive threats and build new capabilities—** Companies must carefully diagnose the nature of the competitive threat, and understand their comparative advantages relative to global players. Developing new and improved products is important, but will be ineffective in the long-term if they are still suffering from gaps in their underlying process-driven performance or if such new product innovations are not refreshed at a high frequency. In the end, the primary source of long-term sustainable competitive advantage lies in achieving higher productivity than the competition.

  – *Understanding core drivers of relative strengths*

  Interpreting what is driving market outcomes and correctly diagnosing the nature of the competitive threat can be difficult, particularly if the challenger derives its advantage from less transparent internal characteristics such as production techniques or different costs structures. Traditional financial benchmarks may not reveal the source of a productivity gap; so companies should use a productivity-based diagnostic tool that can separate those factors driving differential market performance (such as reported profitability) and those that reflect fundamental differences in company operations and capabilities.

  In our US automotive case, we found that companies had to go well beyond tracking the visible differences in market performance to understand fully the sources of their competitive advantage or disadvantage. They used productivity-based benchmarking as a management tool, and actively sought ways to learn from their competitors. Some companies took these steps earlier than others and used the results to make substantial changes in their operations. Some companies formed alliances but largely ignored the learning opportunity for some years.

  – *Productivity advantage is key to sustainable performance*

  The Big Three were able to develop highly successful new products (SUVs and minivans), creating a segment in which global competition was less of a threat and higher mark-ups were available. These new products provided

substantial benefits, helping the Big Three sustain their light vehicle market share and profitability. The downside was that the "breathing room" this gave them made it easier to ignore the urgent need to change. The Big Three did continue to improve their operations, but rather slowly, and they continued to suffer from a quality/reliability gap.

Since product innovations are relatively easy to copy, they cannot be a permanent response to a new competitive challenge. It is a different matter with process innovation—Toyota, for one, has been able to sustain a strong performance through the process efficiency and quality control emanating from their production system. And Toyota has been able to maintain a lead against the Big Three because of the time and complexity they have faced in implementing changes in their production or business processes throughout their organizations. Companies that want to differentiate themselves through product innovations need to excel in the process of product development—an organizational skill that is harder for competitors to emulate than copying a specific product.

– *Organizational flexibility and readiness to change critical to new capabilities*

Responding to the new global competition will often involve a radical reworking of product development, process technology, supply chain management and marketing and distribution. Yet companies face different initial conditions that impact on their capacity to implement these changes. Those that start with a very strong initial position in their domestic market can find it particularly difficult to recognize the seriousness of the competitive threat and that substantial operational changes are necessary, changes that will require diffusing productivity-improving innovations throughout the company.

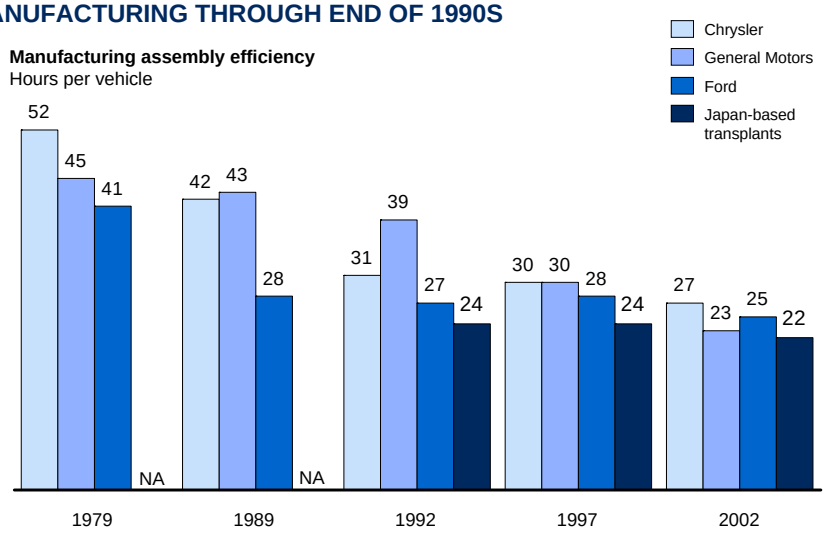
Strict rules-based relationships with employees and suppliers can be a significant barrier to implementing changes. Buy-in from all stakeholders is required to reap the advantages of rapid diffusion. A strong top-down management structure can help facilitate faster transformation throughout the organization, and existing alliances can provide insight into ways to close performance gaps. The incentive structure thus needs to recognize and reward adoption and diffusion of best practices, both from within the organization, and externally.

How the Big Three Learned, Adopted and Diffused Lean Production

A reduction in the hours required to produce a new vehicle, including parts and assembly, was the most important driver of productivity growth in the US automotive sector between 1987 and 2002. An annual decrease of 1.7 percent accounted for 60 percent of the total improvement in productivity over the period (Exhibits 1, 2). It was the competitive threat posed by the more efficient Japan-based transplants that forced the Big Three to improve their manufacturing efficiency and close the gap to best practice (Exhibit 3).

Exhibit 1

BIG THREE REMAINED LESS EFFICIENT THAN TRANSPLANTS IN MANUFACTURING THROUGH END OF 1990S



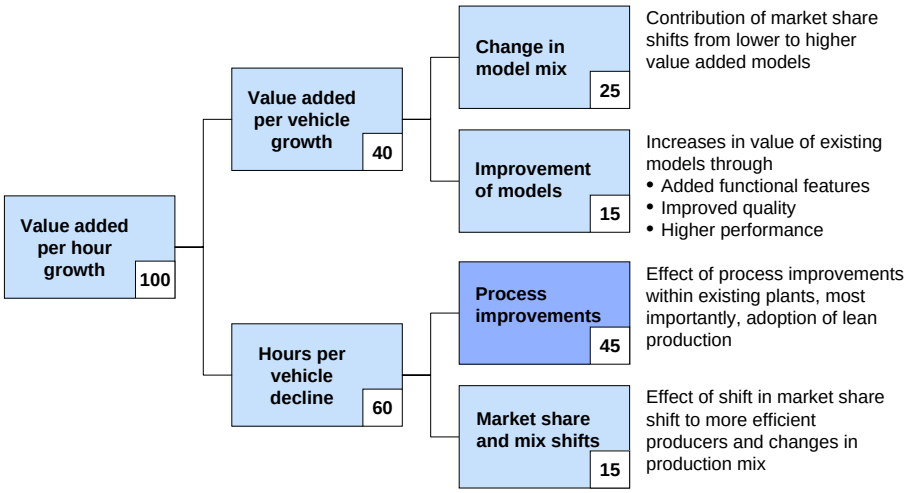
* Footnote

Source: Harbour Report

Exhibit 2

PROCESS IMPROVEMENTS WERE LARGEST CONTRIBUTOR TO AUTO SECTOR PRODUCTIVITY GROWTH

Contributions to productivity growth*
Index, 100 = 1987-2002 growth in value added per hour



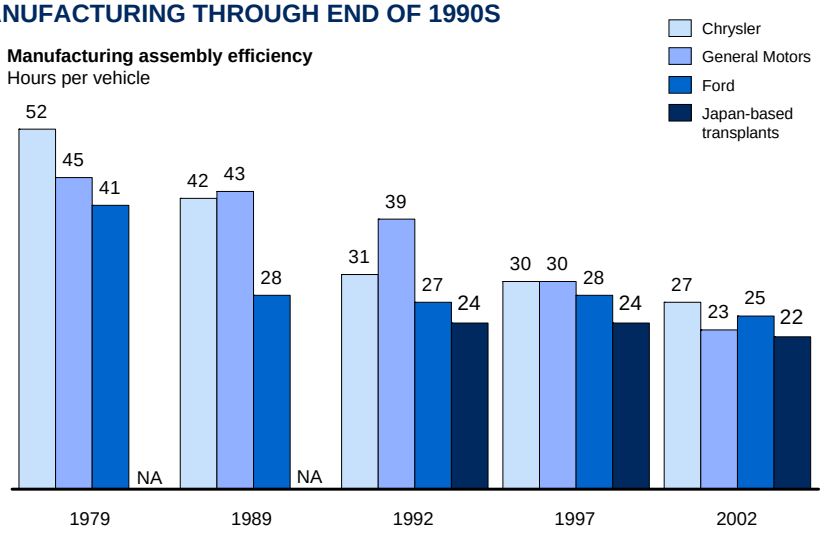
* Contributions rounded to nearest five percentage points

Source: MGI

Exhibit 3

BIG THREE REMAINED LESS EFFICIENT THAN TRANSPLANTS IN MANUFACTURING THROUGH END OF 1990S

Manufacturing assembly efficiency
Hours per vehicle



* Footnote

Source: Harbour Report

Process enhancements, driven primarily by the adoption of lean production techniques, accounted for 45 percentage points of the total 60 percent change. Lean production, which emphasizes the reduction of wasted materials and time, was first developed by Toyota in the 1960s. It is a "cross functional" system—working to reduce waste by integrating the effort across the organization's different functions such as production, R&D, purchasing, and quality control. These cross-functional efforts included supplier management, design for manufacturing, and factory practice improvements (see “Lean Production in Japan and the United States,” page 68). The remaining 15 percent points of the productivity boost during this period was derived from a combination of shifts to more efficient producers and changes in product mix.

The Big Three's improvements in assembly process efficiency—the primary focus of this chapter—did not take place at the same time for all companies. In 1987, Ford was the only one of the three that had already reached competitive levels of assembly efficiency. It took Chrysler until 1992 and GM until 1997 to bring down assembly hours per vehicle to a similar level. Overall, it took the Big Three 10 to 15 years to diffuse lean production techniques across their organizations. Yes, it was a long journey; but it was also a significant achievement. The Big Three were able to succeed where auto makers in other markets, as well as other manufacturing companies, have continued to struggle.

Differences in response times reflected when each of the Big Three felt the competitive pressure, how they interpreted the source of this pressure, and how they overcame internal barriers to change. More specifically:

- How did the Big Three determine the gaps they faced in process efficiency and product quality, and the steps they needed to take in order to close these shortfalls?
- What explains differences in the speed and effectiveness of individual company’s responses?
- How well did each company respond to barriers in adoption and diffusion processes? What determined Ford's early success in breaking them down? After less-than-successful initial attempts by GM and Chrysler, what did they do differently when they tried again?

By analyzing the different paths the Big Three followed, it will become clear why Ford understood the key nature of lean production more quickly, why Chrysler's second-wave attempt was quick and effective, and why GM was slow to get started but ended up making dramatic improvements in assembly hours per vehicle.

LEAN PRODUCTION IN JAPAN AND THE UNITED STATES

The Toyota Production System was largely developed in the 1950s by Taiichi Ohno. He recognized that a traditional mass production system would not work in Japan because the market was limited in size and demand so varied that Toyota needed to produce many different types of vehicles in small lots. There was a very tight labor market. There also bolstered the need for efficient production.

To match these needs and constraints, Ohno developed a new production system that would reduce waste (*muda*), smooth irregularities in the manufacturing process caused by, for example, fluctuating volume or unexpected errors (*mura*), and avoid overloading certain points in the process at the expense of overall efficiency along the value chain (*muri*). The term "lean production" was coined to describe this system in the 1990 bestseller "The Machine That Changed the World".[1]

Techniques of lean production

Lean production is a combination of several techniques that work together to reduce waste of time and materials, including (Exhibit 4):

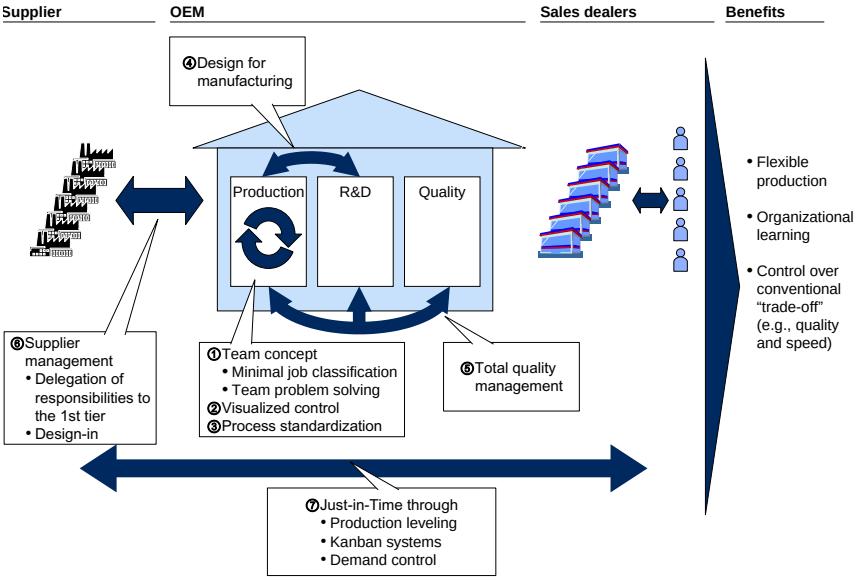
- ***Kanban* or just-in-time delivery**. This technique ensures that materials reach production workers just before they are needed. It has enabled manufacturers to reduce inventories dramatically and to avoid over- or under-producing parts. An important objective of the technique is to make suppliers accountable for their impact on production processes, simultaneously making them aware of their importance to the production system as a whole.

- ***Andon* or temporarily stopping production lines when problems arise**. This technique empowers all production workers to stop the production line when they see a problem. Although temporary stoppages cause delays, they prevent small problems from growing into bigger ones. If a problem remains unresolved until it becomes apparent in the form of product defects at the end of the line, extra time is needed to track back to the source of the problem, as well as for end-of-line rework. Such major stoppages can cause a significant increase in overall hours per vehicle.

1 "The Machine That Changed the World: The Story of Lean Production", by James P. Womack, Daniel T. Jones, and Daniel Roos

Exhibit 4

THE TOYOTA PRODUCTION SYSTEM IS A COLLECTION OF MANY INNOVATIONS



- **The *team concept* or fewer job classifications**. This concept involves training workers to do multiple tasks, ultimately reducing the number of people a plant needs to hire. If an assembly worker can repair machines, the factory does not need to hire someone dedicated to repair work. Similarly, if workers on one line are also trained to do jobs on others, then they can be relocated to other, busier lines when their line is quiet.

- ***Design for manufacturing.*** This technique ensures that ease of manufacture is taken into account when parts and components are designed. Industry experts emphasize that design for manufacturing and other upstream arrangements determine 70 to 80 percent of manufacturing efficiency, cost, and productivity.[2] Design for manufacturing entails engineers working with production managers to determine whether new designs will cause production problems and altering designs where necessary. Knowing about design changes in advance enables plants to prepare for their effect on production processes. When such pre-arrangements work well, production workers can integrate new parts smoothly into production, and so save time on vehicle assembly.

2 "Manufacturing Missionary," Automotive Industries, November 2000 (comments by Ron Harbour)

- ***Kaizen* or continuous improvement through day-to-day problem solving**. This technique requires workers and suppliers to make proactive proposals for improving efficiency, quality, and cost. Having learned the employee proposal system from Ford, Toyota institutionalized it by creating an internal competition, with rewards for those making the highest number of good suggestions. One such is the famous idea of a cart that moves along the assembly line containing the parts required at each stage. This saves the time it would take for workers to go back and forth between production lines and parts stock. Toyota extended its suggestion system to suppliers, thus boosting quality and efficiency throughout the value chain.

Required institutional skills

Two institutional skills are critical to making these techniques work well in combination: supplier management and organizational learning.

- **Supplier management**. Suppliers also need to change their work processes for techniques such as just-in-time and design-for-manufacturing to work effectively. Toyota has developed several practices to develop suppliers' skills in efficient production and quality control, including offering them long-term business relationships on the strength of their design capabilities and willingness to improve, as well as their cost competitiveness and quality. Toyota employees visit suppliers to help them improve their production efficiency and quality. Toyota also encourages suppliers to take the lead in developing new parts designs for Toyota's approval. This is in sharp contrast to the usual practice among OEMs whereby they control all parts designs, and suppliers just manufacture to specification.

- **Organizational learning**. Strong leadership from factory floor managers is critical to making this complex system work. Managers are responsible for ensuring that the firm becomes a learning organization, by encouraging continuous suggestions for improvement, ensuring smooth communications with other functions and suppliers, and developing multi-tasking workers.

Adoption of lean production by US OEMs

Lean production has many variants, even in Japan, depending on the context within which the system has been applied. The same is true in the United States. For example, at GM, different UAW branches have implemented different combinations of techniques. Although widely adopted by the Big Three, they have made less progress in developing the institutional skills required to combine these techniques to the greatest effect. All three have implemented just-in-time and design-for-manufacturing. They have also implemented early problem identification

well, reducing the time needed for rework. Their success in reducing job classifications varies, but is generally increasing.

Regarding supplier management, however, the Big Three spend little time working to improve suppliers' design and production processes compared with Japan-based OEMs. These continue to transfer skills to suppliers, including the new electronics suppliers with which they initiated relationships when they recognized the growing importance to autos of electronic features. In terms of organizational learning, the Big Three have yet to embrace fully the need to hold team-based problem solving sessions before or after every shift, and to reward people who bring problems forward. Toyota, Honda, and Nissan have institutionalized these practices. Because of these differences, the Big Three have not yet captured all the potential efficiency and quality enhancing effects of lean production.

LEAN PRODUCTION DROVE EFFICIENCY IMPROVEMENTS

The efficiency of OEM assembly operations located in the US improved by 30 percent between 1987 and 2002, driving down the average amount of time it takes to assemble a vehicle from approximately 36 hours to 25 hours (Exhibit 5). More than three-quarters of this improvement came from change at GM and Chrysler, with GM alone accounting for 60 percent. (Ford's contribution was modest because it had already improved efficiency by 1987.) Another 20 percent of the fall in average assembly hours per vehicle came from increased production by Japan-based transplants operating in the US. The hours required to manufacture parts for new vehicles also declined over this period, dropping 33 percent on a per vehicle basis.[3] Of the total 60 percent improvement in assembly hours per vehicle during the studied period, 35 percentage points came from the OEMs and 25 percent from parts manufacturers (Exhibit 6).

GM had the biggest impact of the Big Three because it had the largest market share, and the most significant performance gap to close. Nearly three-quarters of GM's improvement was derived from process changes, primarily the adoption of lean production techniques in its plants. The remaining advances came from changing its product mix and plant closures (Exhibit 7). GM also made the largest improvement after 1992, leaving it the most efficient producer of the Big Three.[4]

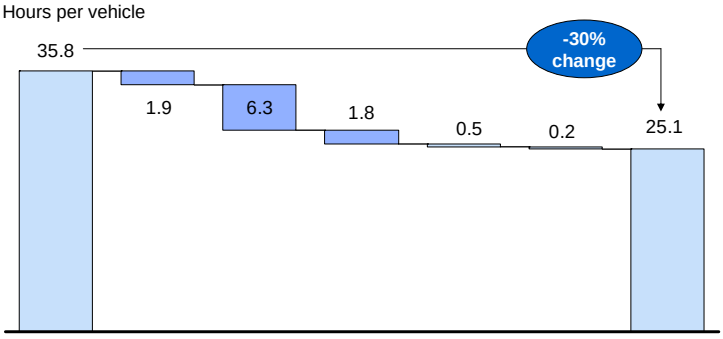
3 Recall that our industry definition includes parts manufactured for the production of new vehicles, and excludes the aftermarket.

4 The Toyota-GM joint venture, NUMMI, is run by a CEO assigned from Toyota. In 2001, he stated that GM had fully assimilated and adopted the Toyota Production System. See Nikkei Business, 2001

Exhibit 5

GM ACCOUNTED FOR 60% OF INCREASE IN OVERALL OEM EFFICIENCY

Efficiency of OEM production workers
Hours per vehicle



Contribution to the change %	18	**59**	**17**	4	2

* Including the impact of new entrant (Toyota) and the impact of share changes among the existing OEM
** Nissan, Honda, NUMMI, AAI

Source: Harbour report, MGI Estimates

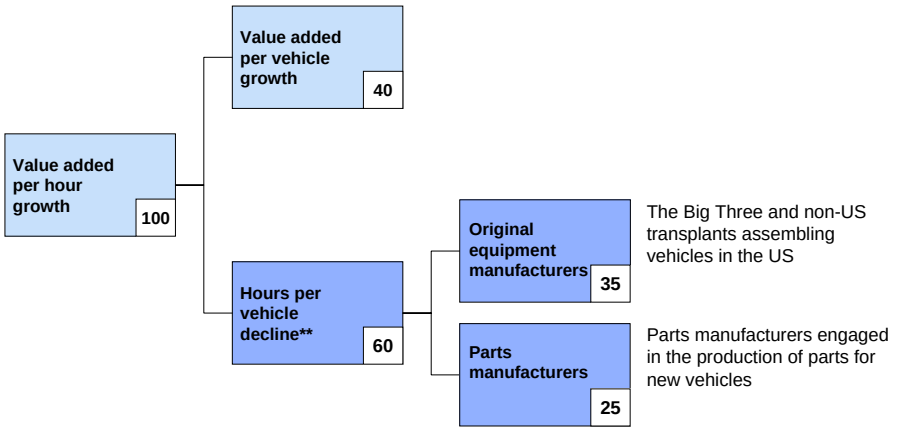
Exhibit 6

BOTH OEMs AND PARTS MANUFACTURERS IMPROVED EFFICIENCY

Percentage point contribution to growth

Contributions to productivity growth*
Index, 100 = 1987-2002 growth in value added per hour

Description



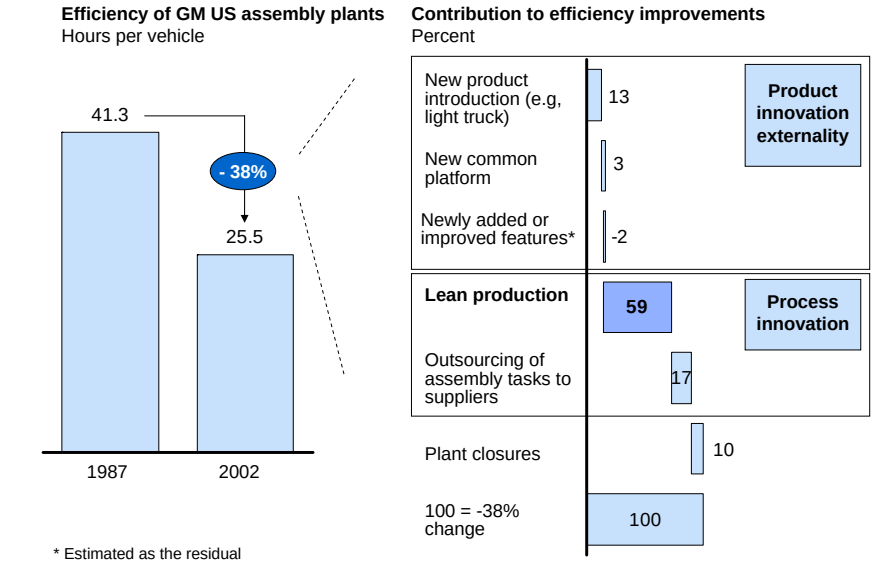
* Contributions rounded to nearest five percentage points
** Improvements in hours per vehicle for OEMs from outsourcing to the parts manufacturers is counted under parts. We estimate that this contributes 5 of the 25 percentage point improvement for parts.

Source: MGI

Exhibit 7

LEAN PRODUCTION MADE LARGEST CONTRIBUTION TO GREATER OEM EFFICIENCY

GM EXAMPLE



* Estimated as the residual
Source: Harbour reports, literature search, MGI Estimates

Because of the importance of GM's improvements in driving the overall numbers, we have assumed that the sources of productivity improvement for Chrysler and Ford were the same over this period. This allows us to disaggregate the drivers of improvements for assembly hours per vehicle (Exhibit 8).[5]

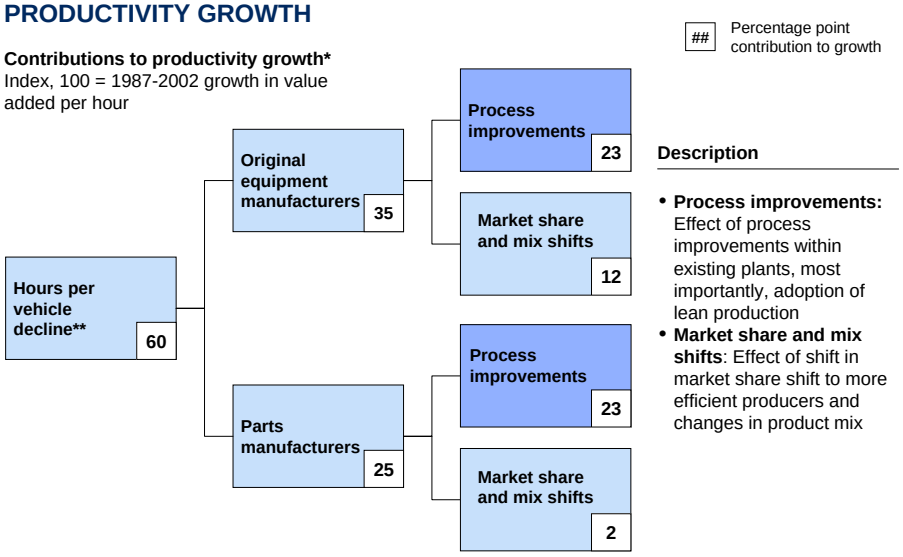
Although the fragmented nature of the parts industry makes it especially difficult to analyze the sources of productivity improvement, we were at least able to identify the main causes for engine and transmission manufacturing. For these two sub-sectors, (accounting for around 25 percent of employment over the period), nearly all the productivity improvement came from changes in internal processes including the introduction of easier-to-produce models using design for manufacturing techniques. The entrance of more efficient global competitors also had an impact.[6]

5 See the technical note for further explanation of the productivity decomposition

6 For the purposes of disaggregating the sources of contributions for the parts producers, we assumed that the remainder of the parts industry outside of engines and transmissions improved their productivity for the same reasons. Some of the improvements in hours for the parts industry could have come about because of shifting jobs out of the US, primarily to Mexico. It has not been possible to obtain quantitative estimates of this activity, although the qualitative evidence suggests that a large portion of parts imports are destined for the aftermarket.

Exhibit 8

PROCESS IMPROVEMENTS WERE THE LARGEST CONTRIBUTOR TO PRODUCTIVITY GROWTH



* Contributions rounded to nearest five percentage points
** Improvements in hours per vehicle for OEMs from outsourcing to the parts manufacturers is counted under parts. We estimate that this contributes 5 of the 25 percentage point improvement for parts.
Source: MGI

THE BIG THREE'S IMPLEMENTATION OF LEAN PRODUCTION

The application of lean production techniques by the Big Three—the focus for the remainder of this chapter—was a three-stage process (Exhibit 9):

- **Learning**—when the OEMs had the opportunities to gain significant inside knowledge of the production system through partnerships and alliances;
- **Adoption**—when pilot implementation of the program started;
- **Penetration**—when the implementation of these techniques closed the performance gap to within 25 percent of best practice.

It took between 6 and 8 years for the Big Three to move from learning to adoption and another 4 to 7 years to graduate from adoption to penetration—that's a total of some 10 to 15 years. GM was the slowest to move through the stages (Exhibit 10).

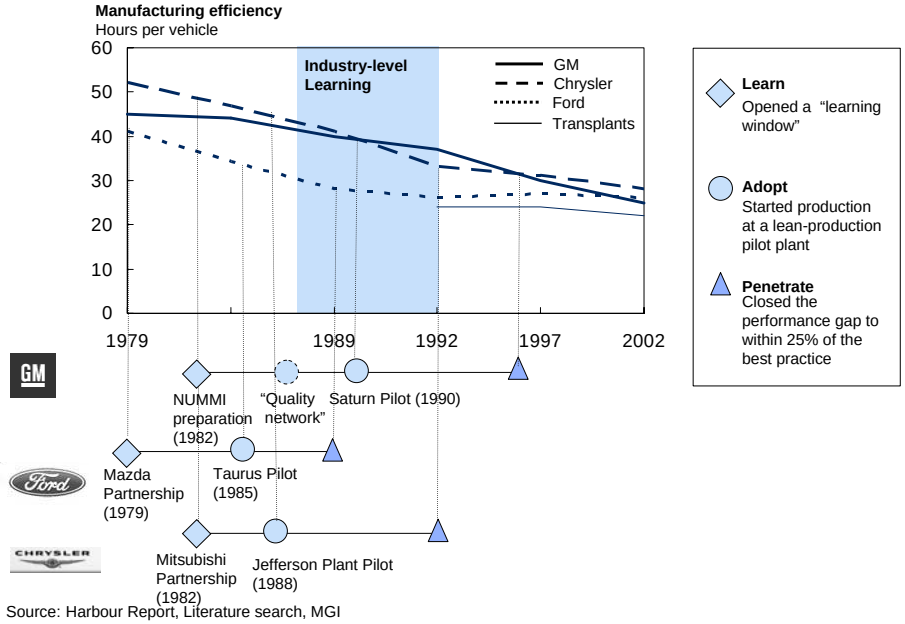
Exhibit 9

DIFFUSION OF PROCESS INNOVATION: LEAN MANUFACTURING

	Innovation	Diffusion of innovations: Learning	Adoption	Penetration
Timing	1960's	1980's ~	Mid to late 1980's	Late 1980's to late 1990's
OEMs	Japanese OEMs	US OEMs →		
Key events	• Development of Toyota Production System (TPS) in Japan • Adoption by other Japanese OEMs (Nissan, Honda, Mitsubishi), leading to their own manufacturing system based on unique strengths	• Big 3's acquaintance with Japanese production system through the "learning windows" – GM from Toyota – Ford from Mazda and Nissan – Chrysler from Mitsubishi and Honda	• Experiments at pilot plants – GM: Saturn plants – Ford: Atlanta plant (Taurus) – Chrysler: Jefferson plants • Adaptation to unique operating needs	• Diffusion of Big'3's version of lean practice to plants beyond the pilot plants

Exhibit 10

BIG THREE TOOK 10-15 YEARS TO MATCH TRANSPLANTS EFFICIENCY



Source: Harbour Report, Literature search, MGI

Learning and diagnosis of the threat

In many industries, process technology is kept secret, but the auto sector has traditionally been a learning-intensive industry with companies swapping ideas and industry-level studies well funded and widely publicized.

Any opportunities to learn from others were particularly important during the 1980s and 1990s. This is because the advantage enjoyed by Japan-based OEMs came from their superior processes which, unlike product innovations that can be readily observed, are opaque from the outside and difficult to reengineer. The Big Three all made efforts to learn the lean production system through observation tours to Japan and strategic alliances with the Japan-based OEMs —GM from Toyota through their NUMMI joint venture; Ford from Mazda in which it acquired an equity stake; and Chrysler from Mitsubishi Motors through an equity based relationship.

Not only were the Big Three willing to learn but the Japan-based OEMs saw benefits in sharing part of their know-how. They also gained information about the US market from the Big Three—including intelligence about the potential supplier base, the dealer network, and locations that might be amenable for building plants.

Industry-level learning—the Japan-based OEMs' success in capturing market share since the early 1970s persuaded industry, academia, and government to launch a broad set of initiatives aimed at understanding the sources of this competitive advantage. These initiatives helped everyone in the industry by revealing gaps in operational capabilities. Once revealed, the pressure was on corporate managers to respond accordingly. Examples of such initiatives include:

- **Production cost benchmarking**—a study conducted by the US Department of Transportation in the early 1980s revealed a production cost gap of $1,000 to $2,000 per unit between the US and Japan-based OEMs. It suggested that most of the gap came from differences in labor cost, driven primarily by differences in hours per vehicle rather than differences in wage.

- **The Harbour Report**—Jim Harbour, a former Chrysler production manager who studied lean production in depth, published the first Harbour Report in 1980. He and his team started including benchmarking data with the Japan-based OEMs in their third report in 1992.

- **The International Motor Vehicle Project (IMVP)**—led by a group of researchers at MIT and supported by the US Government, IMVP compared capabilities of the US and Japan-based OEMs in manufacturing and product development and coined the term "lean production." The group published the best-selling book entitled *The Machine that Changed the World* in 1990.
- **JD Power quality survey**—JD Power started to release quality benchmark data on initial quality and vehicle dependability in 1990, revealing the Japan-based OEM's quality advantages in quantitative indicators. The benchmark survey, as well as the Consumer Report, increased consumer attention to differences in vehicle quality among automakers.

These extensive benchmarking activities, which supplemented individual company efforts, revealed where competitive threats were coming from in operational terms and therefore helped to ratchet up competition in operational capabilities as well as those already established in market share and financial performance.[7] Through such multi-layered competition, the competitive threat was passed down to operational managers and engineers beyond top management. Since 1994, when Harbour started publishing their reports annually, the Big Three have used the data to evaluate production managers; and analysts used it to guage how well the Big Three were performing against their Japan-based competitors.

Executive transfers between the Big Three also accelerated mutual learning. For instance, Don Ephlin moved from Ford to GM to improve worker participation; Robert Lutz moved from Chrysler to GM with solid and successful experiences of engineering process improvements. Chrysler hired middle-level managers from GM and Ford to enhance their quality and design skills during the 1980s. All these key individuals transplanted best practices from one company to another.

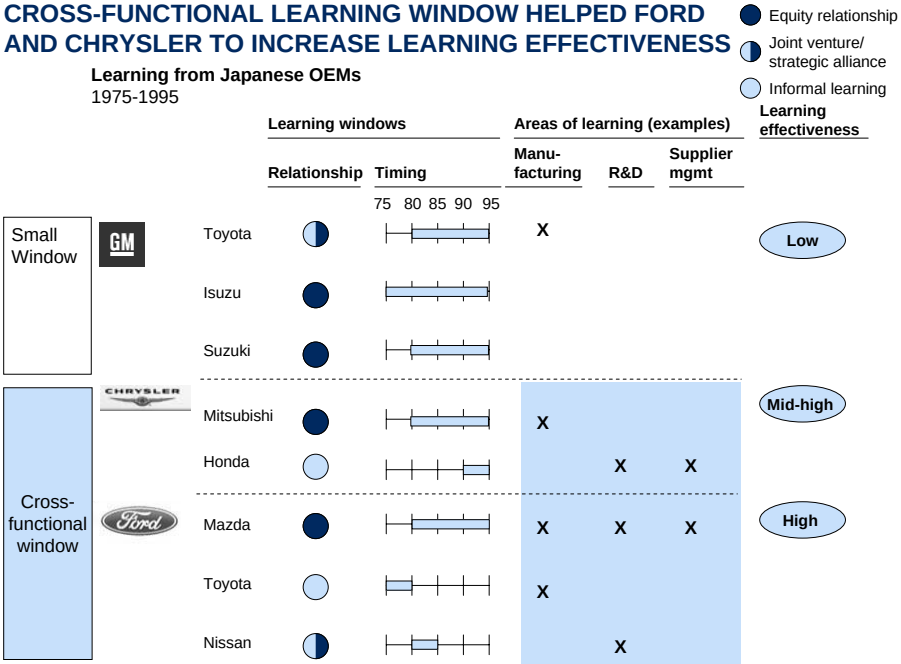
7 Takahiro Fujimoto argues that automakers in Japan have traditionally developed this type of competition at the operational layer and this has helped Japan-based OEMs to build competitive advantage in the manufacturing process. Takahiro Fujimoto, "Capability Building Competition (*Nouryo Kochiku Kyousou*)", Chuo Koron, 2003

Company-level learning—the Lean production system is made up of a set of interrelated processes and is complex and difficult to learn. The Big Three faced the additional challenge of adapting the system to their existing plants and workers. Differences in the speed of efficiency improvement among the Big Three depended partly on how quickly each learned the core essence of this system and adapted it to their own facilities. Understanding that it was based upon a cross-functional approach was the key to success (Exhibit 11).

Exhibit 11

CROSS-FUNCTIONAL LEARNING WINDOW HELPED FORD AND CHRYSLER TO INCREASE LEARNING EFFECTIVENESS

Learning from Japanese OEMs
1975-1995



Ford took a holistic learning approach from the beginning, attempting to develop expertise in a wide range of production processes, including just-in-time inventory control, design for manufacturing, total quality management, and supplier management. Its early success was driven by the number and types of learning windows they had.

Ford established an equity-based relationship with Mazda in 1979 that helped it to learn all the dimensions of lean production. It acknowledged the importance of quality improvement throughout the value chain, making sure its parts manufacturers learned from Mazda's parts suppliers. Then Ford widened its

learning opportunities beyond Mazda through extensive visits to Toyota plants in 1981 and, from 1987 on, worked with Nissan on a joint project to develop and launch the Quest, a minivan product.

Ford was fortunate, too, that some common ground had long been established with Toyota. As Toyota developed its production system it learned from Ford's worker involvement programs—which became the *kaizen* suggestion system in Toyota plants. Additionally, it learned about Ford's quality management system and integrated elements of it into its own production system.[8] Because of these commonalities, it was easier for Ford to learn the system than its US rivals.

In contrast, GM and Chrysler initially focused largely on manufacturing operation improvements, including automation and factory layout. This failure to understand the importance of a cross-functional approach—including design for manufacturing—had a significant impact. In 1979, Ford was only nine percent ahead of GM in hours per vehicle; by 1989, it had stretched that advantage to 35 percent. At that point, GM conducted comparative research to identify why it lagged behind and attributed 41 percent of the gap to the fact that it had not adopted the design for manufacturing technique[9]; GM only started implementing it in the early 1990s.

Only when GM and Chrysler focused on the broader elements of the system were they able to realize significant efficiency improvements. Chrysler started to take a more holistic, cross-functional approach in their second-wave trials when its performance was slipping again in the late 1980s. It initially learned from Mitsubishi Motors in the early 1980s. It then expanded its intelligence gathering to include Honda in the mid 1980s (without any formal alliance) from which it set out to learn the company's approach to R&D-manufacturing collaboration, and supplier management.[10] Chrysler also learned from NUMMI, the US industry's best practice example.

As for GM, it had a strong tie with Toyota, the best teacher of best practice, from the early 1980s, but did not start to incorporate a cross-functional approach, including design for manufacturing, until the mid 1990s.

8 Takahiro Fujimoto, "Capability Building Competition (*Nouryo Kochiku Kyousou*)", Chuo Koron, 2003

9 James Womack et al, "*Machine that Changed the World*", Ranson Associates, 1990

10 Jeferry H. Dyler. "How Chrysler Created an American Keiretsu", *Harvard Business Review*, 1996.

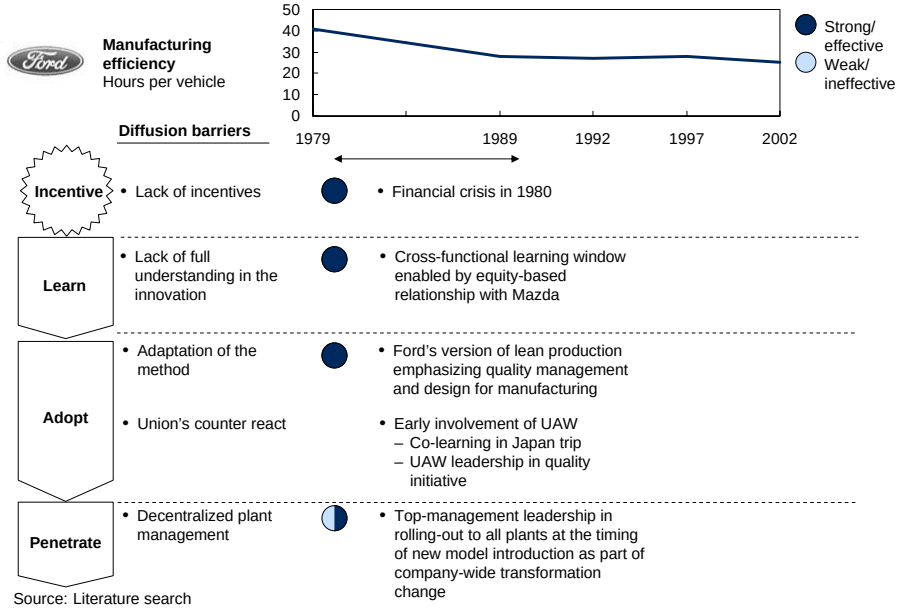
Adoption and penetration

Leveraging its original strength in manufacturing, Ford put process innovation at the center of its corporate transformation when it was struck by a serious financial crunch during the 1982 recession. The sense of crisis was shared with people in every part of the organization, including union leaders. Top management introduced an Employment Involvement program to make sure that operational leaders were involved in, and part of, the company turnaround plan. These were the people who would have to execute the change strategy throughout the company and their buy-in helped to quicken the penetration process (Exhibit 12).

In the case of Chrysler, it was only after the company faced its second critical financial crisis in the late 1980s when top management gave increased attention to radical process innovation. Under Lee Iacocca's leadership, the company was aggressive in acquiring skills from both US competitors (NUMMI) and the Japan-based OEMs (Mitsubishi Motors, Honda) to enhance Chrysler's capabilities (Exhibit 13).

Exhibit 12

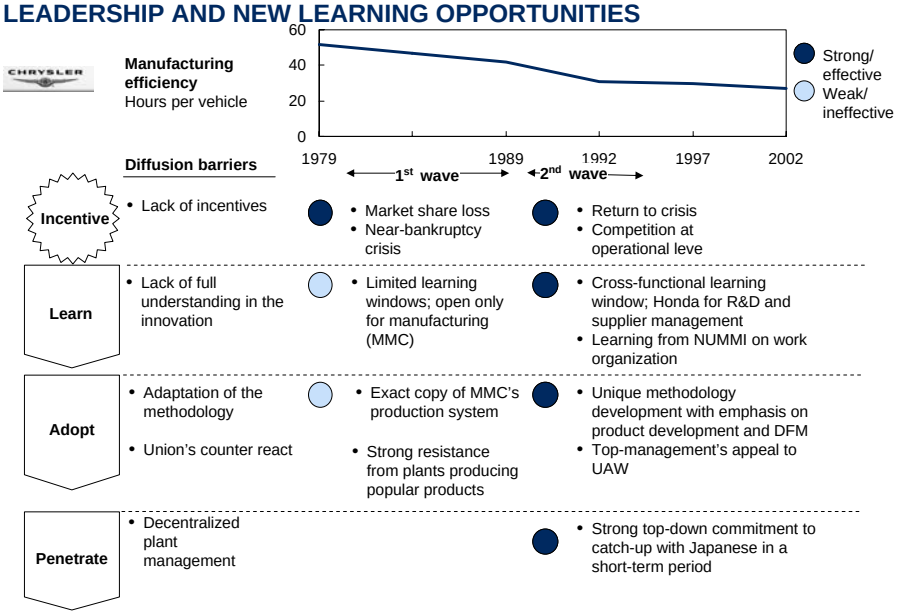
FORD'S EARLY SUCCESS BUILT ON CROSS-FUNCTIONAL LEARNING AND EARLY INVOLVEMENT OF UAW



Source: Literature search

Exhibit 13

CHRYSLER'S SUCCESS WAS DRIVEN BY STRONG TOP-MANAGEMENT LEADERSHIP AND NEW LEARNING OPPORTUNITIES



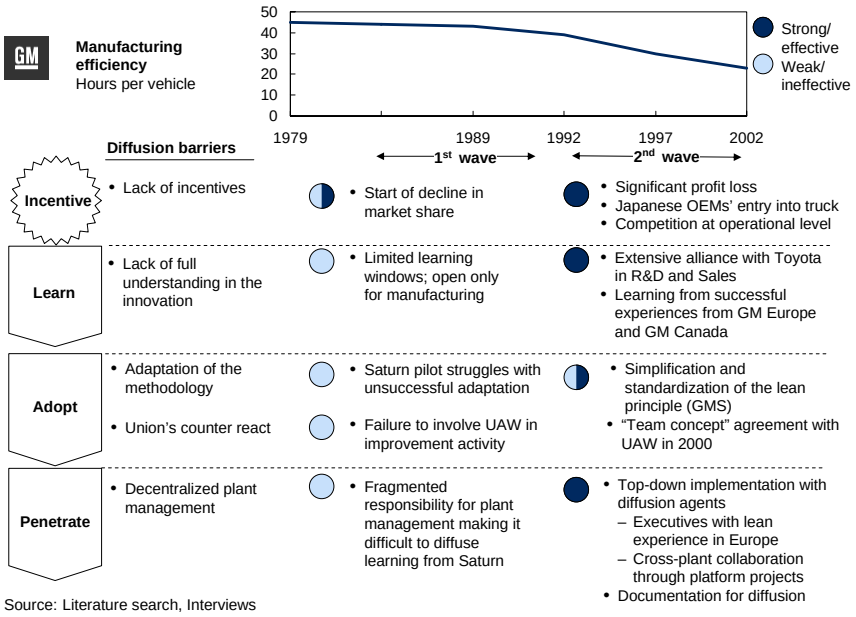
Source: Literature search

GM started to focus more directly on comprehensive process innovation after 1992, when the Gulf War recession was contributing to its very poor financial performance. John Smith, CEO at the time, took the lead on process innovation, drawing on his successful experience from GM Europe (Exhibit 14).

Ineffective decentralization—Ford recognized early that adoption of lean production techniques would require company-wide transformation. In contrast, GM's decentralized organizational structure impeded its ability to carry out the transformation process. As late as 1999, GM had a brand focused structure in which division leaders individually managed major functions such as engineering groups, plants, and sales channels for their brands. This provided insufficient incentives for intra-company learning. Although some of GM's plants, including NUMMI, were the most efficient plants in the industry, the lessons of this internal best practice was not fully communicated to low-performing plants. As a result, the gap between the best and worst plants at GM was much wider than that of Ford or Chrysler.

Exhibit 14

GM RESOLVED DIFFUSION BARRIERS IN THE SECOND WAVE



Source: Literature search, Interviews

From the mid- to late-1990s, GM embarked on a different tack and started to learn from experience. During this period, there were several transfers at executive and mid-manager level to bring internal best practice models of process improvements from NUMMI, GM Europe and GM Brazil to GM North America. In addition, common platform projects such as GMT 800, put in place as part of the company's product strategy, created opportunities for plants to collaborate with each other and enabled best practice to transfer from high-performing to low-performing plants.

Top management commitment to change—Chrysler's success in improving manufacturing efficiency between 1989 and 1992 was started by CEO Lee Iacocca's effective top-down leadership. Iacocca reached out to Mitsubishi Motors to ask for full collaboration in transferring production know-how. He also sent Chrysler engineers to Honda to learn how vehicles were efficiently designed. R&D and production collaborated at Honda even though Chrysler did not have an equity-based relationship with the Japanese OEM. Building on Iacocca's leadership in improving R&D productivity by learning from Honda, Chrysler's chief of R&D, Robert Lutz, pushed further in improving engineering efficiency and quality.

Overcoming labor rigidity as a barrier to adoption—a team-based approach, minimizing job classification, and encouraging team-based problem-solving, has been central to the lean production system; the UAW's resistance to these concepts created a significant barrier to adopting them.

Ford overcame this resistance early by creating a sense of common cause with the union. It involved UAW workers in the initial stages of implementation and it invited the UAW leadership to accompany management on a trip to Japan to learn the lean production system. Ron Gettelfinger, the current UAW president, led workers' initiatives in process improvements at Ford at that time and contributed to the creation of Ford's version of lean production that emphasized quality management. Such effective involvement of UAW members determined Ford's successful early adoption.

At Chrysler, Lee Iacocca took a strong, top-management leadership approach to communicating with the union and welcomed the UAW chairperson at Chrysler to the corporate board. As with Ford, Chrysler was able to create a shared sense of crisis with the UAW. It was the first company to institute a Modern Operating Agreement which reduced job classifications, facilitated a flexible production system, and so lessened labor rigidity as a barrier to change.

In the case of GM, it took a long time before UAW members implemented the new system, despite the fact that the union formally agreed with the company to do so as early as 1990. It took a long time, but eventually, a serious understanding of the critical need to change was shared in every part of the organization. Now, GM is the most advanced of the Big Three both in its labor practices and in terms of its formal labor agreements.

Relationship with business partners—given that over half of car value comes from parts, the success of programs to improve OEM products and processes critically depends on the quality of parts suppliers. In any case, quality improvement along the entire value chain is central to the success of lean production. Ford involved its suppliers in its quality improvement initiatives early on. It sent its parts supplier groups to Japan to learn what Mazda suppliers did in terms of quality management as early as the 1980s. Chrysler also adopted a more collaborative model of supplier management in the early 1990s.[11] This

11 Jeferry H. Dyler. "How Chrysler Created an American Keiretsu", *Harvard Business Review*, 1996

improved the cost, quality and time required for design changes which, in turn, may have helped the company's rapid catch-up both on the product and process sides. The effective involvement of suppliers helped both these companies to build new capabilities for change.

Localization of the knowledge—the Big Three understood that full penetration of the new production system would be impossible as long as they tried to make an exact. So they put considerable effort into localizing lean production.

Ford developed its approach early on by reinforcing the strength of its quality management. This emphasis certainly helped Ford to acquire cumulative advantages in manufacturing efficiency improvement, given that 20 to 25 percent of assembly worker hours had been used for rework at the end of the line.

In the second wave of change at GM, the company made significant efforts to document the essence their system in simple terms, the idea being to establish greater shared understanding across their plants of what it acknowledges is a complex, Toyota-inspired system. Such attention to building knowledge helped GM to rapidly improve manufacturing efficiencies across all its plants in recent years.

Although Chrysler's first attempt to improve its production efficiency in the early to mid-1980s was focused largely on copying Mitsubishi Motors' production system; its second crack at it came from the late 1980s onwards; at this point, the company focused more intently on making the system work in its own operational context. In addition to its work with suppliers, it also made its design process more integral.[12]

12 Ibid

Product Differentiation as a Strategic Lever to Create Competitive Advantage

Between 1987 and 2002, the Big Three were facing intense competitive pressure from the Japan-, Germany-, and Korea-based OEMs. They responded by improving their product offerings in three ways:

- **They introduced the very popular minivans and SUVs**—this enabled the Big Three to slow their loss of market share in light vehicles over the period, and earn substantial returns, especially in the late 1990s.
- **They added innovative functional features to their cars and SUVs**—but these were swiftly copied throughout the market and failed to produce a differentiating advantage.
- **They increased the average quality of their vehicles**—but, similar to their experience after introducing innovative features, their rate of increase in quality was nearly matched by their global competitors, so that a quality gap remained.

These product changes impacted both the market situation of the companies and the level of productivity in the industry—but whether they actually helped improve the competitive position of the Big Three depended upon how easy it was for competitors to emulate the products and quality improvements and adopt them.

In the case of the introduction of the minivan, Chrysler won a sustained advantage because it was difficult for competitors to create a comparable product. For their part, the Japan-based OEMS created a lasting advantage with higher quality, more reliable vehicles.

The introduction of the SUV did not provide a unique advantage to any one company because all of the Big Three were able to develop their own comparable models quickly. However, SUVs did give the Big Three a lasting advantage relative to their global competitors because they lacked the capability of copying the product for their own customers. The addition of functional features did not give the Big Three an edge because all companies adopted similar features.

The impact of product innovations on aggregate productivity is determined by their final level of penetration. In the case of anti-lock brake systems, penetration occurred gradually, as the cost/benefit ratio improved over time. Air bags achieved widespread market penetration because of regulatory change, an exogenous factor. In some cases—as happened with the minivan—the potential impact on aggregate productivity of an innovation is limited because the innovation is only marketable to a limited number of consumers; (although for this limited group, penetration might be high, and that is important for an individual company's performance).

THE IMPACT OF MINIVANS AND SUVS

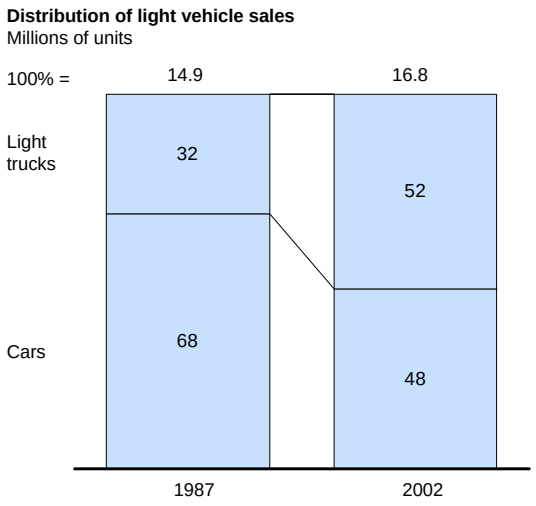
The shift to light trucks—from 32 percent of light vehicle sales to 52 percent between 1987 and 2002 (Exhibit 1)—had a big impact on productivity growth because it raised average value added per vehicle. We estimate that this change in model mix alone increased average value added per vehicle by nearly 15 percent (Exhibit 2). That's some 25 percent of overall productivity growth over the period, making model mix the second most important driver of higher productivity (Exhibit 3).

We have looked at the introduction of the modern Sport Utility Vehicle (SUV) by Ford and the minivan by Chrysler as examples of important product innovations, both of which played a role in influencing consumers to switch to trucks (Exhibit 4). Both companies were aiming to differentiate themselves from other OEMs as competition intensified. Chrysler's strategy was to be the only player in what it saw as the niche market of the "new minivan"; by revamping the SUV, Ford also aimed at first mover advantage in its segment.

In fact, SUVs captured the largest shift in market share between 1987 and 2002. And, because of their high value added and widespread market penetration, they had the largest impact on productivity growth overall. In

Exhibit 1

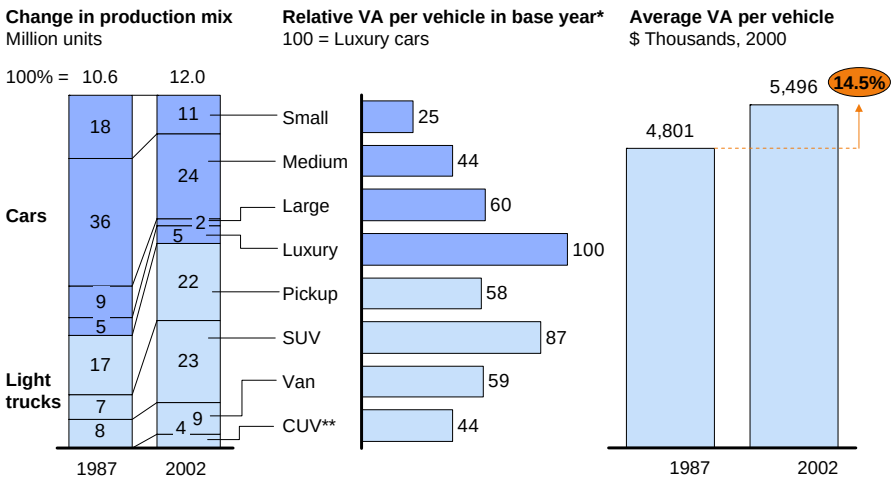
DEMAND SHIFTED TO LIGHT TRUCKS IN SLOW-GROWING MARKET



Source: BEA

Exhibit 2

THE SHIFT TO LIGHT TRUCKS RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 15%



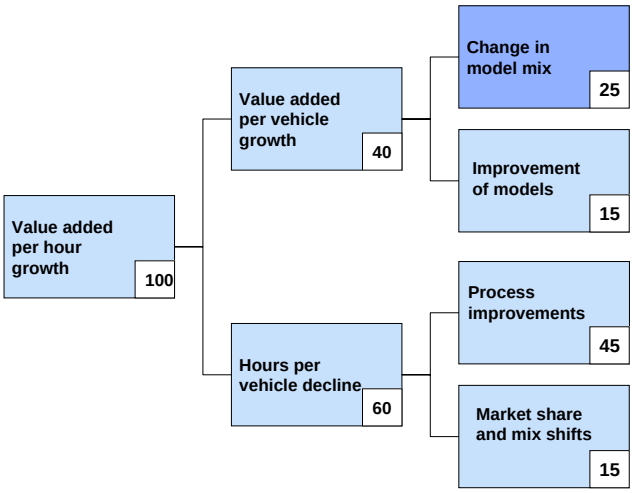
* Relative magnitudes estimated based on 1999 reference year
** Cross-utility vehicle assumed to have VA per vehicle of a small SUV
Source: Ward's Automotive yearbook; Goldman Sachs; BEA; MGI Analysis

Exhibit 3

CHANGES IN MODEL MIX WERE THE SECOND LARGEST CONTRIBUTOR TO PRODUCTIVITY GROWTH

Percentage point contribution to growth

Contributions to productivity growth*
Index, 100 = 1987-2002 growth in value added per hour



Description

- Change in model mix: Contribution of market share shifts from lower to higher value added models
- Improvement of models: Increases in value of existing models through
  - Added functional features
  - Improved quality
  - Higher performance
- Process improvements: Effect of process improvements within existing plants, most importantly, adoption of lean production
- Market share and mix shifts: Effect of shift in market share shift to more efficient producers and changes in production mix

* Contributions rounded to nearest five percentage points
Source: MGI

Exhibit 4

WE ANALYZE TWO NEW PRODUCT INNOVATIONS: SUVs AND MINIVANS

	Innovation	Diffusion of innovations: Learning	Diffusion of innovations: Adoption	Diffusion of innovations: Penetration
SUV	• **1991: Ford introduces the modern SUV**: a "compact" four door with car-like features	• **1991– 2002: Rapid adoption and imitation by OEMs** • Chrysler and GM immediately react by offering modern SUVs • Foreign OEMs also create new models to benefit from the growing modern SUV market	• **1991–2002: Modern SUV market grows rapidly** with intense competition • New SUV models and sub-segments available, with number of new features	
Minivan	• **1983: Chrysler offers the new generation minivan**: a cross-over between a van and a traditional station wagon	• **1983–1996: Other OEMs offer rapidly competitive products** • The minivans from competitors are not as popular as Chrysler's products due to lack of quality and attractiveness	• **1983–2002: Chrysler continues to maintain market leader position** • 1996 : Honda challenges Chrysler with the Odyssey model	

Source: Press clippings, Waros Automotive Yearbook

contrast, although the minivan was a highly successful innovation for Chrysler, its aggregate impact on productivity growth was limited because it was targeted at a narrow customer slice, and never achieved the significant rates of penetration of the SUV. (Many minivans were also made in Canada.)

It is an interesting conundrum that, despite the fact that Ford was unable to maintain its competitive edge with the SUV, this product innovation still had a much larger impact on productivity growth than the minivan with which Chrysler enjoyed an advantage for some time. Because the impact on productivity is driven by diffusion, and in particular, market penetration, the success of a new model for a particular company is not necessarily in line with aggregate outcomes.

Modern minivans and SUVs tap into new markets

The introduction of the Ford Explorer in 1991 launched the modern SUV segment. It marked a departure from the trucks already on the market such as the Jeep Grand Cherokee and Chevy Blazer in offering a light truck with four doors—so combining the comfort of a car with the features of an adventurous vehicle and appealing to a wide range of customers, including luxury car owners.

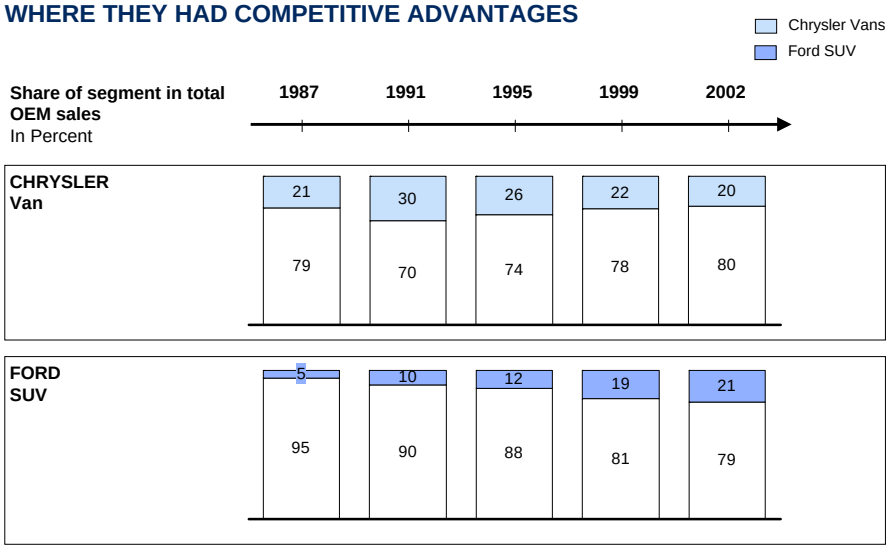
The Minivan was a cornerstone of the new product strategy put together by Chrysler as it emerged from the 1980 government bailout from near bankruptcy. A primary reason why Chrysler had been in trouble was that it couldn't compete with imports from Japan following the twin oil crises. It was also hobbled by ageing plants and a relatively weak market position in the then-rising segments of smaller, front-wheel-drive, and diesel-powered cars. The minivan, introduced in 1983, targeted women with children. The "mommy shuttle," as the minivans were dubbed, had several advantages over the station wagon and other vans available in the market at the time—it could accommodate seven passengers comfortably, it had plenty of cargo space, and it was front-wheel-drive and easy to handle. It proved very popular, easily supplanting the competition.

Both the SUV and the Minivan were classified as light trucks, which meant they had to meet less stringent environmental standards (e.g., CAFE regulations), and at least initially, less demanding safety standards. The result was that they could incorporate less expensive technology and this gave them a cost advantage relative to other models (see box on regulation in Section 1).

Their introduction created new markets that subsequently showed strong growth. These models were more successful than their predecessors not only because of their expanded value proposition, but also because of successful positioning and marketing. For instance, Ford changed the structure of its marketing spend the year it launched its new SUV. Normally, Ford invested more in price incentives than advertising campaigns, but on this occasion Ford decided it would not benefit from any price incentives, and chose instead to spend aggressively on advertising the product's attributes—Ford was the largest spender on advertising in the US in the spring of 1990. The minivan and the SUV eventually accounted for one fifth of the total sales of Chrysler and Ford respectively (Exhibit 5). While Chrysler was able to maintain production in a market that was essentially flat, SUVs became more important for Ford because the market was growing rapidly.

Exhibit 5

BOTH FORD AND CHRYSLER CONCENTRATED ON SEGMENTS WHERE THEY HAD COMPETITIVE ADVANTAGES



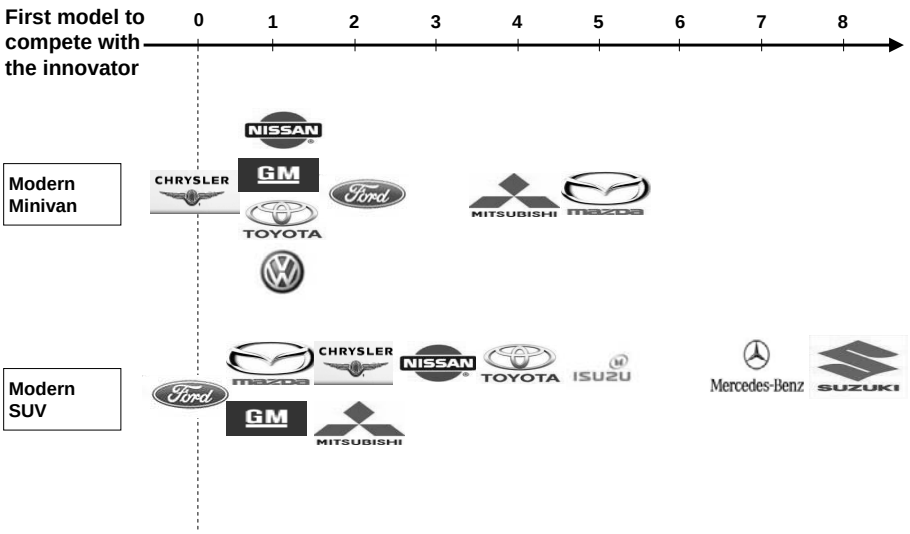
Source: Ward's, MGI analysis

Ford's modern SUV easier to imitate than Chrysler's minivan

Competitors quickly moved to follow the lead of Ford and Chrysler (Exhibit 6), but the competitive responses to SUVs and minivans were quite different. Although the growing SUV market quickly spawned many popular models, the first minivans competing with the original Chrysler model were not initially well-liked because they did not offer competitive features. Competing minivans did not achieve high acceptance among customers for some time.

Exhibit 6

NEW GENERATION MINIVANS AND SUVS WERE ADOPTED RAPIDLY BY US AND FOREIGN COMPETITORS



Source: Press clippings, MGI Analysis

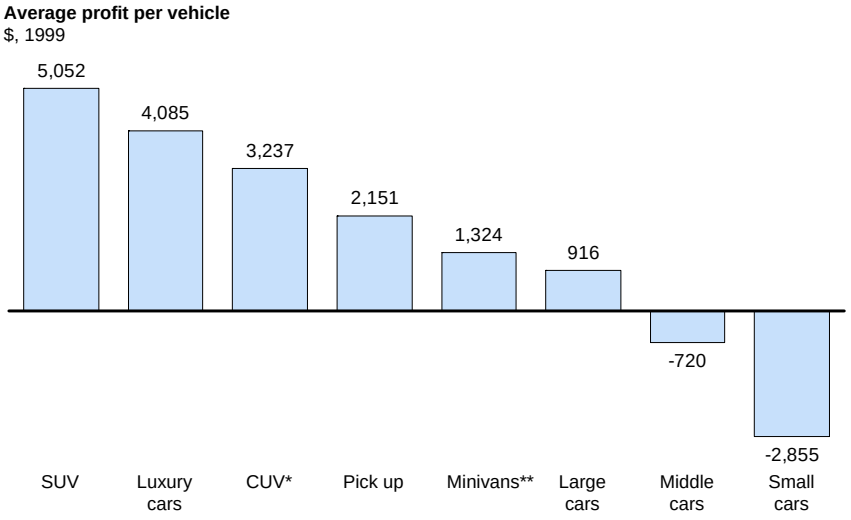
The SUV was relatively easy to imitate for OEMs with experience of building pick-up trucks because they used the same underlying "body-on-frame" technology. This meant that the creation of all-new SUV models did not require significant investment. GM and Chrysler were best positioned to follow quickly while significant competition from the Japan- and Germany-based OEMs took longer to develop.

Another advantage to copying SUVs was that body-on-frame was a relatively inexpensive technology and also made the process of assembling a car easier. This, combined with the less stringent environmental regulations, meant that there were very high margins on the SUVs (Exhibit 7) and so a strong incentive for other OEMs to introduce competing products.

In contrast, competitors were initially unwilling to take the risks required to develop products to compete with Chrysler's minivan; for one thing, they were skeptical that the minivan had sufficient market potential. One deterrent was that the minivan was based largely on car technology (unibody construction) which is more costly to assemble and requires significant investment in stamping

Exhibit 7

IN 1999, SUVS HAD THE HIGHEST PROFITABILITY PER UNIT OF THE WHOLE LIGHT VEHICLE MARKET



* Cross-utility vehicle assumed to have profitability per vehicle of a small SUV
** Includes other vans
Source: Goldman Sachs

and other plant specific capital. In total, Chrysler spent more than $700 million on developing the Caravan and Voyager minivan models, including the cost of a new plant, designed using lean production principles, in Windsor, Ontario.

The first model to present a real challenge to Chrysler's leadership was the Ford Windstar, launched in 1994. However, it was the introduction of the Honda Odyssey in 1995, followed quickly by the Toyota Sienna in 1997, that significantly turned up the competitive heat—it was the Japan-based OEMs, focused on improving car technology, that finally brought competitive minivan products to market.

Explorer did not provide a sustained boost for Ford; Chrysler retained edge in minivans

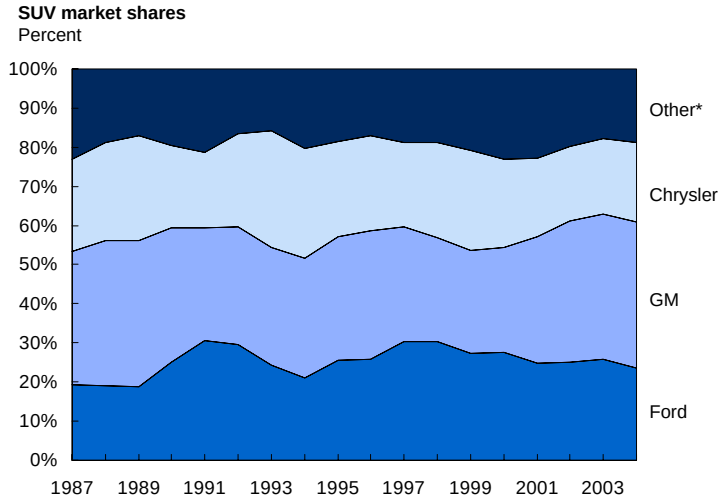
Although Ford lost its leadership position in the modern SUV market to GM about two years after its innovation, it maintained its position in the segment (Exhibit 8). During the 1990s, rising demand for SUVs outpaced supply, allowing the Big Three to earn substantial profits from this segment despite the fact that none had a unique product. By the late 1990s, there were more than 50 SUV

models on the market (more than three times the number earlier in the decade); they included luxury models from BMW, Mercedes, and Lexus (Exhibit 9). The SUV market became divided into many sub-markets, including compact, large, and luxury. A new car-based SUV segment called CUVs (Crossover Utility Vehicles) was even derived from the original SUV segment. After 2000, supply caught up with demand as global competitors finally developed attractive products—both SUVs and minivans—and mark-ups were driven down.

In contrast, the uncertainty that prevented GM, Ford and other OEMs from developing minivans enabled Chrysler to sustain competitive leadership in the minivan market for about 10 years. Chrysler made a name for itself as "the minivan company." Over time, it has lost half its market share but, even by 2002, it was still leading the market with 30 percent share from only two models. On a per-model basis, therefore, Chrysler has almost five times the market share in minivans as Ford has in SUVs (Exhibit 10).

Exhibit 8

DID NOT PROVIDE A SUSTAINED ADVANTAGE AFTER THE 1991 INTRODUCTION OF THE EXPLORER

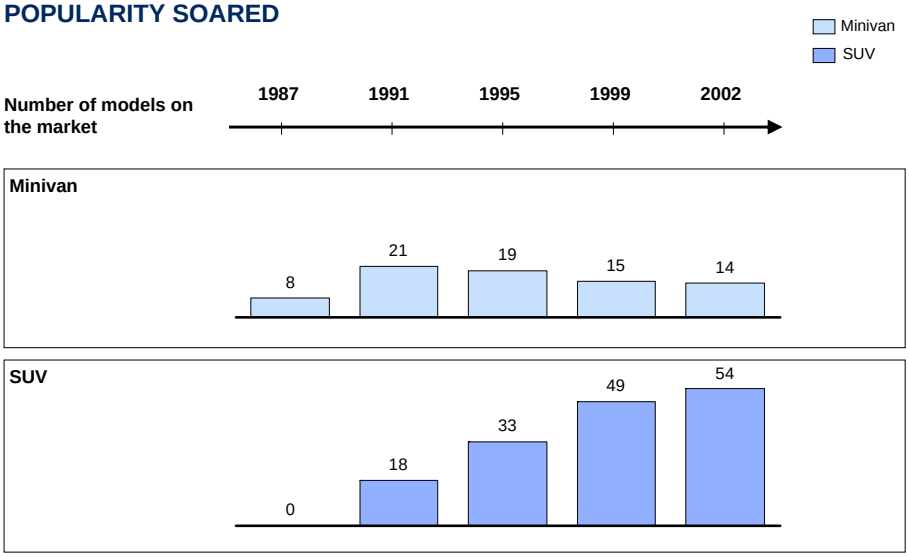


* From 1987-1995 includes primarily Izuzu, Mitsubishi, Nissan, Suzuki, Toyota; after 1995, Mercedes, Kia and Honda also gain shares

Source: Wards

Exhibit 9

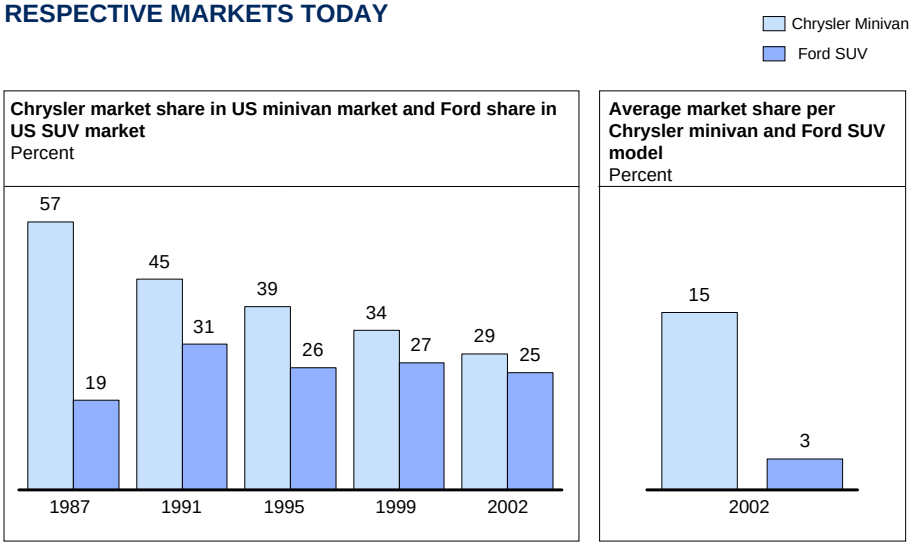
THE NUMBER OF SUV MODELS GREW TREMENDOUSLY AS THEIR POPULARITY SOARED



Source: Ward's, MGI analysis

Exhibit 10

CHRYSLER EXPERIENCED A STRONGER MARKET POSITION IN MINIVANS THAN FORD DID WITH SUVS, BUT BOTH HOLD SIMILAR SHARES IN THEIR RESPECTIVE MARKETS TODAY



Source:Ward's, MGI analysis

ADDED FUNCTIONS BOOST PRODUCTIVITY BUT STRUGGLE TO SUSTAIN ADVANTAGE

The Big Three increased the feature content of their vehicles significantly between 1987 and 2002. This was a natural response to the competition they faced and the slow overall growth in unit sales in the US market. The targeted bundling of functional features can enable an OEM to create a unique value proposition for a vehicle, to extract more value from its existing customers, to differentiate its products, and to gain, or at least maintain, market share.

Added functional features collectively increased the average value per vehicle significantly. Based on the analysis of 32 features and their change in penetration in the period of our study, we estimate that these extras alone would have caused a growth in value added per vehicle of nearly 7 percent over the period (Exhibit 11). This is the equivalent of a contribution of some 9 percentage points to the overall increase in productivity. Sixty percent of the total impact came from the leading six features: leather seats, audio equipment, Anti-lock Brake Systems (ABS), airbags, automatic transmission, and four-wheel drive (Exhibit 12).

We have looked at ABS and airbags as examples of technological innovations that started to diffuse and achieve large-scale penetration during the period we analyzed (Exhibit 13). Both relate to the safety of the vehicle and are therefore acutely relevant both to consumers and regulators. Furthermore, both stand out as features that have achieved an impact on aggregate productivity through a high degree of diffusion. If an innovation remains confined to a narrow segment of consumers and products, its impact on aggregate productivity is limited.

The stories of these two technologies show that adding a single innovative feature can incrementally improve a company's competitive advantage but does not necessarily confer a sustainable edge. If an innovation is fairly simple to copy, competitors can wait to see whether it is a hit with customers and, if it is, quickly copy it. The stories also show that sometimes it takes an outside force such as regulatory pressure before an innovation becomes widely diffused.

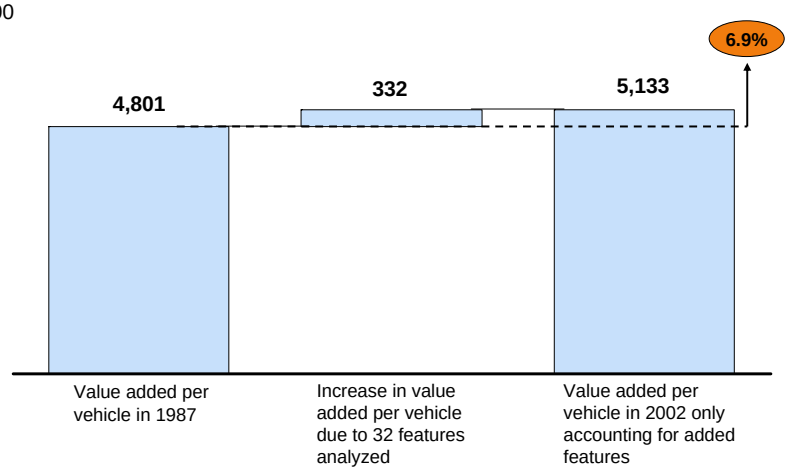
ABS and airbags initially face low acceptance

GM introduced the first airbag in 1973, winning a development race against Ford, which found overcoming the technical hurdles more difficult. Unfortunately, consumer demand for this product was low and, after three years when it sold only 10,000 airbag-equipped cars, GM withdrew the system from the market.

Exhibit 11

THE ISOLATED IMPACT OF THE 32 FEATURES ANALYZED RAISED AVERAGE VALUE ADDED PER VEHICLE BY 7 PERCENT

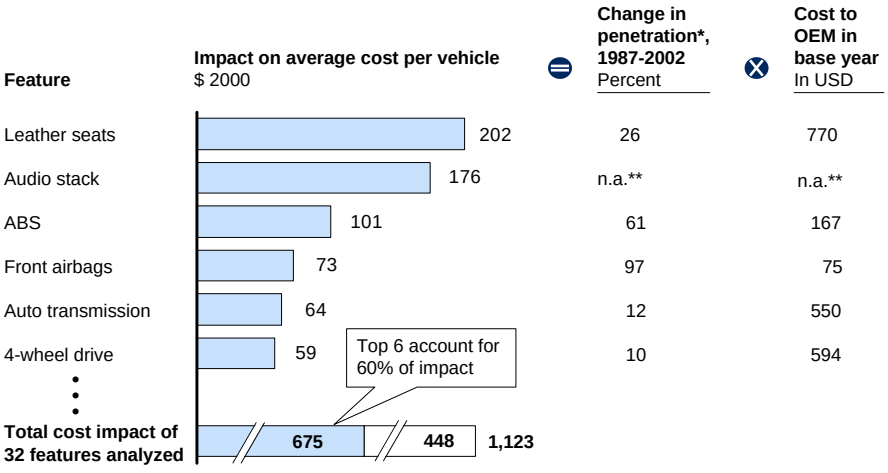
$ 2000



Source: Ward's; BEA; McKinsey analysis

Exhibit 12

WE ESTIMATED THE IMPACT ON COST PER VEHICLE OF 32 FEATURES



* Adjusted for model mix change cars vs. trucks

** Estimated as net effect of audio stacks of different complexity (i.e., CD changer vs. FM radio)

Source: Ward's; McKinsey analysis

Exhibit 13

WE ANALYZE TWO FEATURES IN DETAIL: AIRBAGS AND ABS

	Innovation	Diffusion of innovations: Learning	Diffusion of innovations: Adoption	Diffusion of innovations: Penetration
Airbags	**1950's – 1970's: First introduction of airbag unsuccessful** ▪ First patent in 1953 ▪ Market introduction by GM in 1973. Retired after 3 years due to lack of consumer acceptance	**1980's: Airbags offered as luxury feature** • Federal legislation pushes restraint systems, but not airbags specifically • Strong OEM resistance to widespread diffusion • Offered as "fancy" feature in luxury segment		**Late 1980's & Early 1990's: Legislation drives penetration to 100%** • 1987-1991: Legislation passed to make front airbags mandatory by – 1997 for cars – 1998 for trucks
ABS	**1920's – Late 1970's: First introduction of analog ABS fails** ▪ First patent in 1936 by Robert Bosch ▪ First introduction by Ford in 1969 on the T-Bird, retired in 1978 due to low acceptance ▪ First "modern" ABS in 1978 by Bosch	**Early 1980's: Technology widely available but not adopted on large scale** • Technology available to all OEMs. • Adoption in cars slow due to consumer reservations • Diffusion in trucks faster because incremental impact on safety larger and relative cost impact lower		**Mid 1980's – mid 1990's Penetration takes off due to reduced cost** • GM offers ABS at low price in 1991, triggering diffusion in passenger cars • Truck segment rapidly converges towards 100%

Source: GM; MIT; Global Industry Analysts; Just-Auto

ABS systems also suffered early problems. ABS was first introduced in passenger vehicles by Ford in its T-Bird in 1969, followed by Chrysler which offered a similar system in 1971. However, these systems were withdrawn from the market in 1978 due to technical problems.

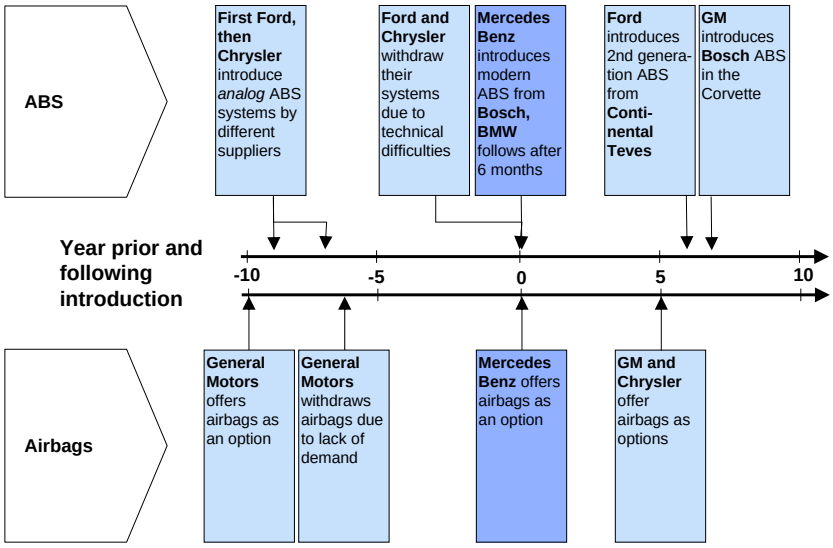
Such difficulties are typical for early-stage innovations—they have infant teething troubles and are expensive because of low volumes—and it is often difficult for the original innovator to create a lasting competitive advantage. In the case of both airbags and ABS, it was not the innovator that, in the end, successfully introduced these features into the market—it was Mercedes Benz. It launched the modern hydraulic ABS (developed by Robert Bosch) in 1978, the year that Ford and Chrysler were forced to withdraw their systems from sale. They reintroduced airbags in 1983 (Exhibit 14).

ABS and airbag adoption depends on strategic intent—not technology

Chrysler and GM chose not to start offering airbags until five years after Mercedes' reintroduction. This wasn't because they lacked the technical know-how—GM had its own airbag technology and could have offered it at any time. It was a strategic

Exhibit 14

ONCE ABS AND AIRBAGS WERE INTRODUCED IN THE MARKET FOR GOOD, ADOPTION WAS A QUESTION OF STRATEGIC INTENT, NOT CAPABILITIES



Source: McKinsey

decision. Mercedes' move was not immediately relevant to the more volume-oriented Big Three. GM and Chrysler decided to wait and see how successful airbags would be before making their own move.

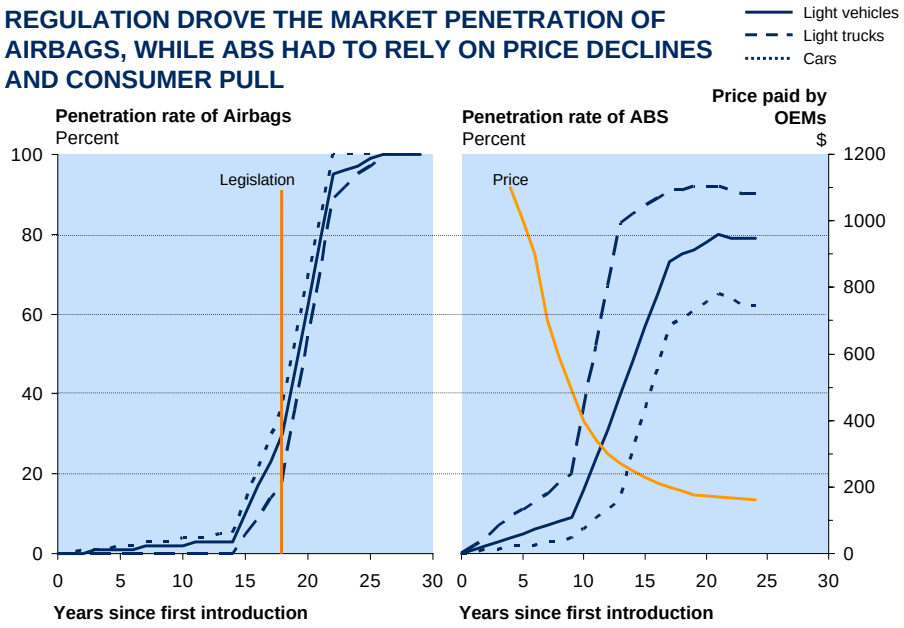
As it turned out, GM and Chrysler did not introduce airbags until 1987 when the National Highway Traffic Safety Administration issued a requirement to phase in front airbags in new vehicles. Chrysler's and GM's move a year later to start fitting their cars with airbags was clearly a response to this regulatory change, rather than to Mercedes Benz. In 1991, the law was passed making fitment mandatory by 1997 and the diffusion curve of front airbags precisely reflects these regulatory changes (Exhibit 15).

Similarly, the adoption of ABS was more the result of strategic decisions than a lack of technological capability. BMW introduced Bosch's ABS in its 7-Series a few months after its first introduction in the Mercedes S-Class, but it was another seven years until GM included the Bosch system in one of its cars.

The story of ABS follows a classical pattern for innovations—diffusing comparatively slowly because it was dependent on a gradual improvement in its

Exhibit 15

REGULATION DROVE THE MARKET PENETRATION OF AIRBAGS, WHILE ABS HAD TO RELY ON PRICE DECLINES AND CONSUMER PULL



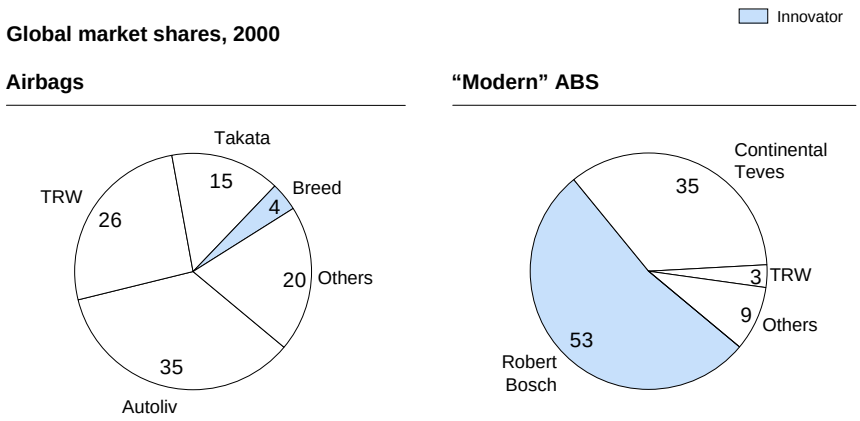
Source: Wards; McKinsey Automotive Practice

cost/benefit ratio. Comparing the penetration of ABS with its cost curve over time shows that penetration rises as costs decline. This causality seems intuitive but it can actually work in both directions—costs decline as penetration rises due to the potential effect of scale. As production of the innovation increases, scale economies can be exploited and cost per unit goes down. The fact that the global ABS market is highly consolidated today provides some support for this hypothesis; Bosch and Continental Teves command 88 percent of the market. A similar pattern can be observed in the airbag market (Exhibit 16).

The introduction of new technologies is largely confined to the luxury car segment. By the time the technology is mature enough to be adopted in volume segments of the market, access to that technology is unlikely to be a barrier to adoption, and therefore the competitive advantage from a single functional feature is short-lived. Some OEMs, such as Mercedes Benz, have adopted a strategy of continuous technological improvement and have thus created a leading edge brand image extending beyond the niche segment in which their innovations are first introduced.

Exhibit 16

WHILE BOSCH RETAINS A DOMINANT POSITION, BREED LOST AIRBAG MARKET TO OTHER PLAYERS



Source: McKinsey

THE BIG THREE RAISE QUALITY BUT BEST PRACTICE GAP REMAINS

The Big Three undertook significant efforts to close the gap between themselves and their best practice competitors in quality. But even as they stepped up their response, Toyota—the leading Japan-based player in terms of quality—kept pushing the best practice level ever higher at an astonishing rate of 5.8 percent a year (Exhibit 17). As a result of the overall rise in vehicle quality as this competition raged, industry productivity increased too.

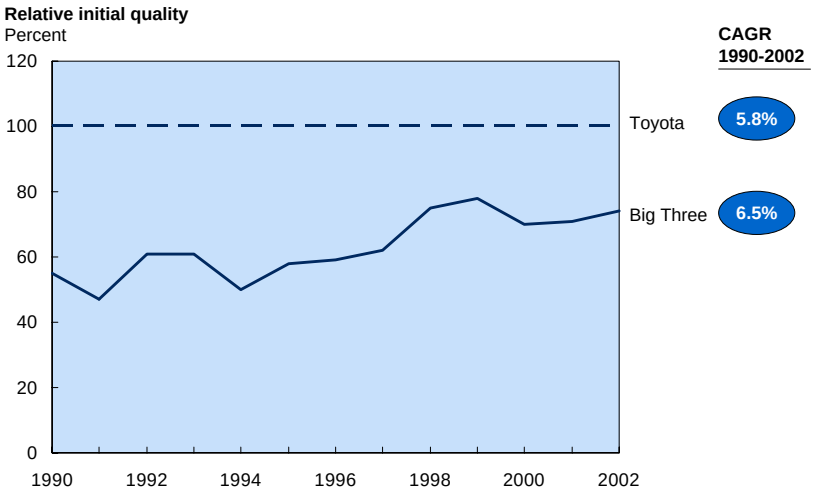
We estimate that quality improvements alone would have grown value added per vehicle by nearly 5 percent (Exhibit 18). While a significant quality gap remains between Toyota and Honda on the one hand and the Big Three on the other, there is no doubt that, whichever OEM they buy from, vehicle consumers today receive products far superior to those offered 15 years ago.

Lean production key driver of Japan-based OEM product quality

Superior quality—both in terms of defects in new vehicles (initial quality) and defects occurring within the first three years (reliability)—has given a major competitive advantage to Japan-based players, particularly Toyota and Honda. High quality is an inherent by-product of their lean systems. Reduction of end-of-line rework and the instant resolution of problems as they arise on the line not

Exhibit 17

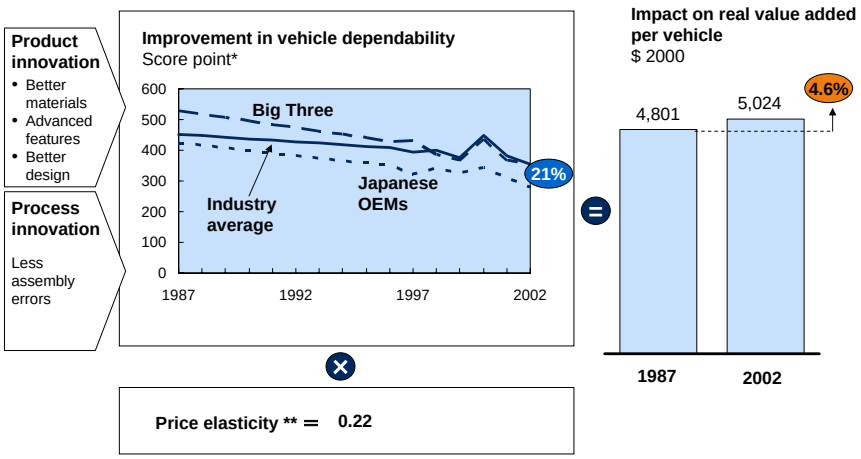
THE BIG-3 WERE ABLE TO CUT COMPETITIVE GAP IN INITIAL QUALITY IN HALF



Source: JD Power, MGI

Exhibit 18

THE ISOLATED IMPACT OF IMPROVEMENTS IN VEHICLE DEPENDABILITY RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 5 PERCENT



* Includes initial quality and durability. Scores before 1996 were estimated based on improvement ratio from 1997-2002
** Models considered for price elasticity estimation were: Upper small cars (Ford Taurus, GM Impala, GM Grand Prix, Toyota Camry) and middle SUV (Ford Explorer, Chrysler Jeep Grand Cherokee, GM Blazer, Toyota 4 Runner)
Source: JD Power, Ward Automotive Yearbook, MGI

only lowers production costs but also improves quality. The Japan-based OEMs do not just apply lean production principles to their own organizations, but also along the value chain, including privileged suppliers. This way, they ensure the quality of their own work, but also that of their parts suppliers.

Significant quality and durability gaps to best practice level remain

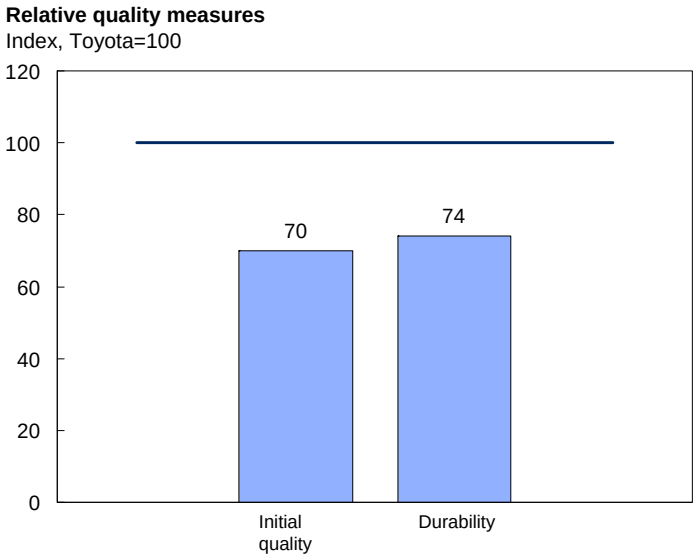
On average, the Big Three have achieved a level of 74 percent of best practice for initial quality, and 70 percent of best practice for reliability (Exhibit 19). Progress was extremely slow—it took the Big Three 12 years to cut the gap roughly in half. The Big Three have found it difficult to reap clear financial benefits from the quality improvements they have achieved; Toyota can still commands price premium for its superior dependability and established brand power (Exhibit 20).

One explanation for this slow progress may be that US OEMs did not adopt lean production fully. They chose a very different approach to that of the Japan-based OEMs in their sourcing strategies and supplier relationships. Over the period we studied, the Big Three disintegrated vertically and spun off their internal parts manufacturing divisions. Their sourcing strategies then focused on highly competitive bidding for discrete purchasing contracts, and drastic price competition. The concepts of close cooperation with the supply base and privileged suppliers were both abandoned. By opting for this strategy, the Big Three ceded quality control over a large part of the value chain.

Exhibit 19

BIG THREE STILL LAG TOYOTA ON INITIAL QUALITY AND DURABILITY

2002



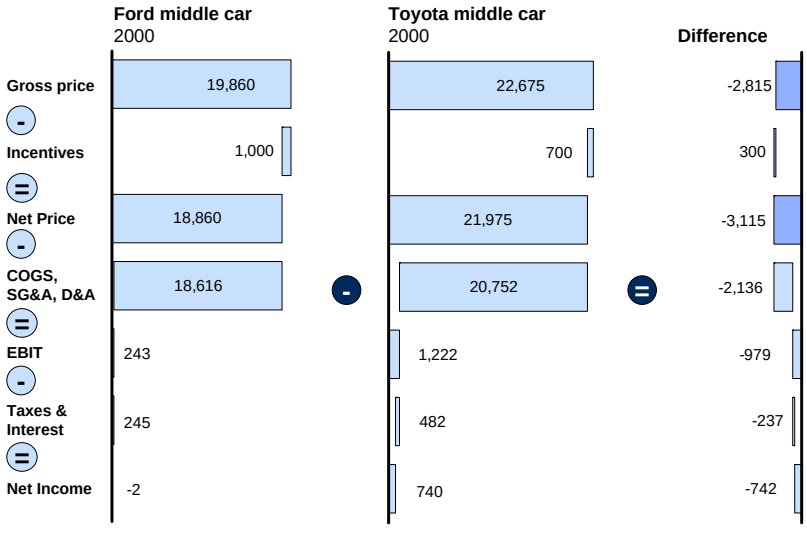
Source: JD Power, MGI

Exhibit 20

TOYOTA MAINTAINED A PRICE PREMIUM OF $3,000

EXAMPLE

Dollars



Source: Deutsche Bank Alex. Brown, "Why GM's and Ford's Auto Businesses May Not Stay Profitable for Long," August 2001, MGI

Technical Notes

The objective of this technical note is to provide an overview of our data sources and our analytical approaches. We have not attempted to be exhaustive, but rather to highlight the critical inputs and assumptions. This technical note has nine sections:

- **Aggregate data and adjustments**—where we discuss how we estimated our measure of sector productivity growth
- **Aggregate productivity decomposition**—where explain how we decomposed productivity growth into changes in value added per vehicle and changes in vehicle per hour
- **Model mix analysis**—demonstrates how we estimated the impact of the introduction of new models on value added per vehicle
- **Added features analysis**—shows how we the impact of increased feature content on value added per vehicle
- **Quality and durability analysis**—explains how we derived quantified the impact of increased quality and durability on value added per vehicle
- **Assembly efficiency improvement analysis**—demonstrates how we derived changes in hours per vehicle for OEMs producing in the US and who were the main players driving the change
- **GM's efficiency improvement analysis**—detailes the analysis of drivers of efficiency improvement for GM
- **Parts efficiency improvement analysis**—demonstrates how we estimated the impact of market share shifts and process improvements on changes in parts hours per vehicle
- **Combining micro-level insights with aggregate productivity decomposition**—shows how we used our micro level analysis of changes in value added per vehicle and hours per vehicle to understand the underlying drivers of productivity growth.

AGGREGATE DATA AND ADJUSTMENTS

Data sources:

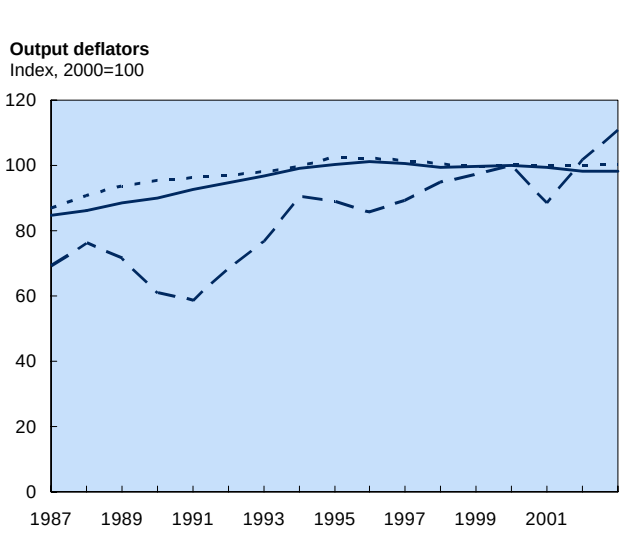
- **Gross output and value added**. Base data was obtained for "Motor vehicles and equipment" in the GDP-by-industry accounts (NAICS codes 3361, 3362, 3363). It includes light vehicle assembly, and automotive parts production. It also includes heavy duty trucks, truck trailers and recreational vehicles. For nominal gross output and value added, we use the NAICS based series the Bureau of Economic Analysis (BEA) reports back to 1987.

- **Deflator for real gross output and value added**. We used the gross output deflator for both gross output and value added. The primary reason for this choice is that the value added deflator is derived as an implicit deflator: nominal value added (computed as gross output less intermediate inputs) is divided by real value added (computed as real gross output less real intermediate inputs). As such, the value added deflator captures all the deficiencies in both the gross output and intermediate input estimates. Because intermediate inputs account for approximately 75 percent of gross output in this sector between 1987-2002, small changes in the measurement of intermediate inputs, sales and their prices can have large impacts on the computation of value added, and hence the value added implicit deflator. Not only is the value added deflator far more volatile, the growth rate of the value added deflator is significantly larger than both the gross output and intermediate input versions (Exhibit 1).

  Using the gross output deflator does increase the compound growth rate of productivity from 3.0 percent to 3.3 percent annually, and raise the total change from 55 to 63 percent (Exhibit 2). However, decomposing the sources of productivity growth, we find that declines in hours per vehicle account for approximately 60 percent of the total 1987-2002 productivity change regardless of which deflator is used. Increases in value added per vehicle account for the remaining 40 percent (Exhibit 3). Using the value added deflator reduces the growth rate of value added, giving more emphasis to the change in hours, but as we are rounding our decomposition estimates to the nearest 5 percentage points, these small differences do not impact our interpretation of the sources of growth.

Exhibit 1

VALUE ADDED DEFLATOR IS FAR MORE VOLATILE THAN GROSS OUPUT AND INTERMEDIATE INPUTS DEFLATORS



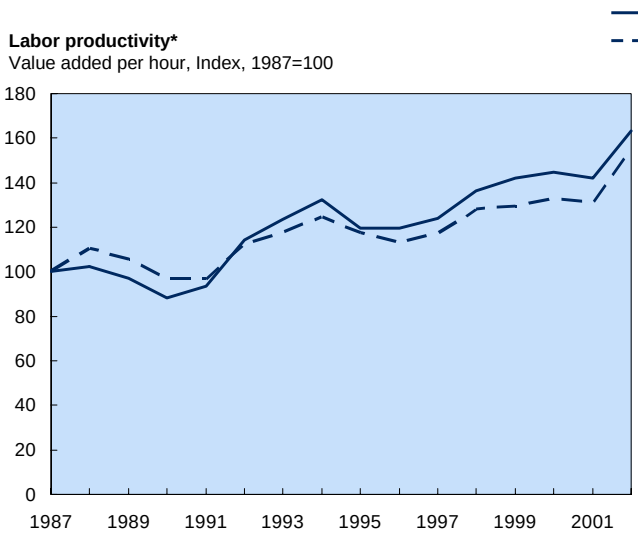
1987-2002
Percent, s.d.

	CAGR	Total change	Standard deviation
VA	1.3	19.5	9.7
II	0.9	15.3	4.2
GO	1.0	15.9	5.4

Source: BEA

Exhibit 2

USING THE GROSS OUTPUT DEFLATOR RAISES 1987-2002 PRODUCTIVITY GROWTH BY 15 PERCENT



1987-2002
Percent

CAGR	Total change
3.3	63
3.0	55

* Value added and hours adjusted to include only new light vehicle assembly and parts produced for new light vehicles. See technical note, page 97

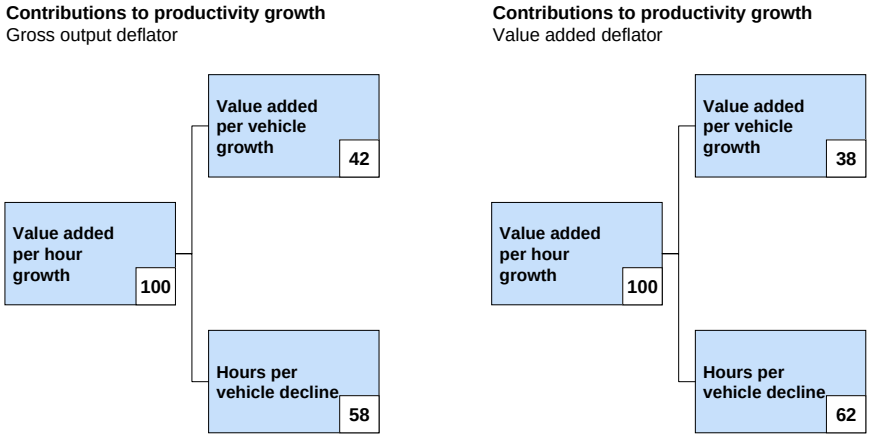
Source: BEA, BLS, MGI

Exhibit 3

CHOICE OF DEFLATOR DOES NOT APPRECIABLY IMPACT PRODUCTIVITY DECOMPOSTION

Index, 100 = 1987-2002 growth in value added per hour*

Percentage point contribution to growth



* Value added and hours adjusted to include only new light vehicle assembly and parts produced for new light vehicles. See technical note, page 97

Source: BEA, BLS, MGI

- **Employment**. The employment series from BEA is available on a NAICS basis only back to 1998. To estimate an employment series back to 1987, we use NAICS-based employment growth rates from the Bureau of Labor Statistics (BLS).[1]

- **Average Hours per employee**. These are taken from BLS. The total hours worked then result by multiplying the average hours from BLS with the employment series from BEA.

- **US vehicle production and sales**. Production data is taken from the Ward's automotive yearbook. Aggregate unit sales data is from BEA.

1 http://www.bls.gov/lpc/iprdata1.htm

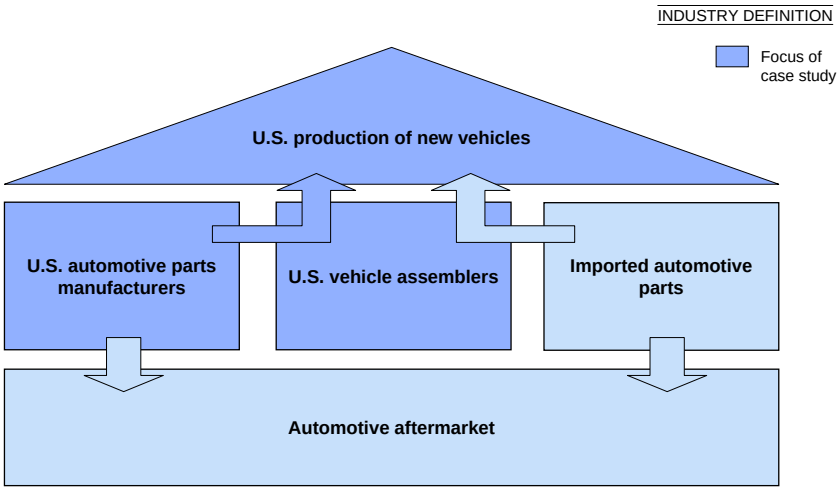
Adjustment for elements not related to new cars and trucks

The "Motor vehicles and equipment industry," published in the GDP by industry accounts includes vehicle assembly and parts production. Assembly includes light vehicles, heavy duty trucks, truck trailers and recreational vehicles; parts production includes parts for new vehicles and the aftermarket. We are focusing on the production of new light vehicles including assembly and the manufacturing of parts. Therefore, we need to adjust our value added and hours data to create time series that reflects just these elements of production. For each sub-sector defined in the GDP-by-industry accounts, we identified the share of output that flows into the sub-sectors "passenger car assembly" and "truck assembly." All other elements are excluded (Exhibit 4).

These adjustment change the labor shares of parts and assembly which drives the impact on productivity growth (Exhibit 5). They increase the level of productivity by reducing the labor share of the less productive parts sector (Exhibit 6). They also increase the growth rate of productivity because the labor share of parts is reduced by an increasing amount over time because the share of parts sales to other sectors and final demand is growing (Exhibit 7). Overall, new vehicle production is more productive than the complete motor vehicle and parts sector (Exhibit 8).

Exhibit 4

WE FOCUS ON THE US BASED PRODUCTION OF NEW VEHICLES AND THE CONTRIBUTION BY THE US PARTS MANUFACTURING SECTOR

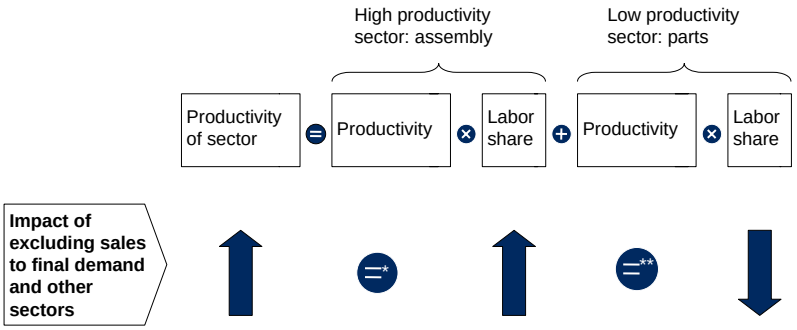


Source: McKinsey analysis

Exhibit 5

CHANGES IN LABOR SHARES DRIVE IMPACT OF ADJUSTMENT ON PRODUCTIVITY

CONCEPTUAL



- Adjustment increases level of productivity by reducing labor share of parts sector
- Adjustment increases growth of productivity because labor share of parts is reduced by an increasing amount over time (because the share of sales of parts to other sectors and final demand is growing)

* Assembly productivity is unchanged since 100% of production goes to new vehicles
** Parts productivity is unchanged because we assume that the productivity to produce parts is the same regardless of whether the parts are used in new vehicles or not

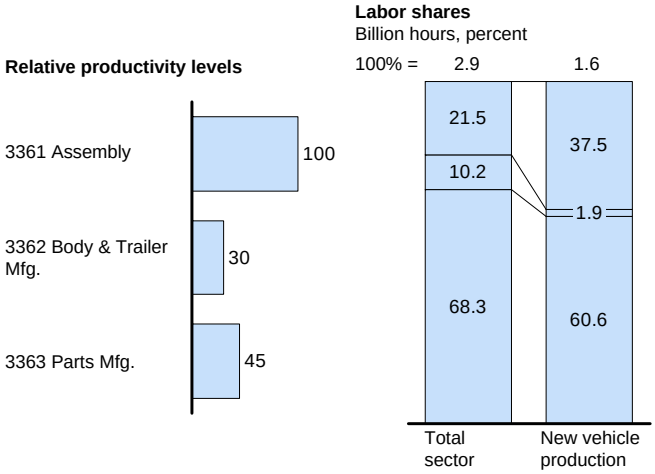
Source: BEA; MGI

Exhibit 6

ADJUSTMENT TO HOURS SHIFTS LABOR SHARES AND RAISES THE LEVEL OF PRODUCTIVITY

1997

EXAMPLE

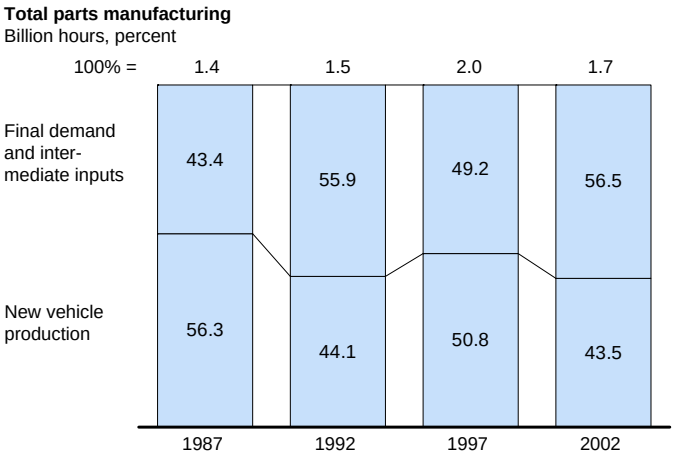


Labor share weighted average relative productivity	**55.3**	**65.3**

Source: BEA; BLS; MGI

Exhibit 7

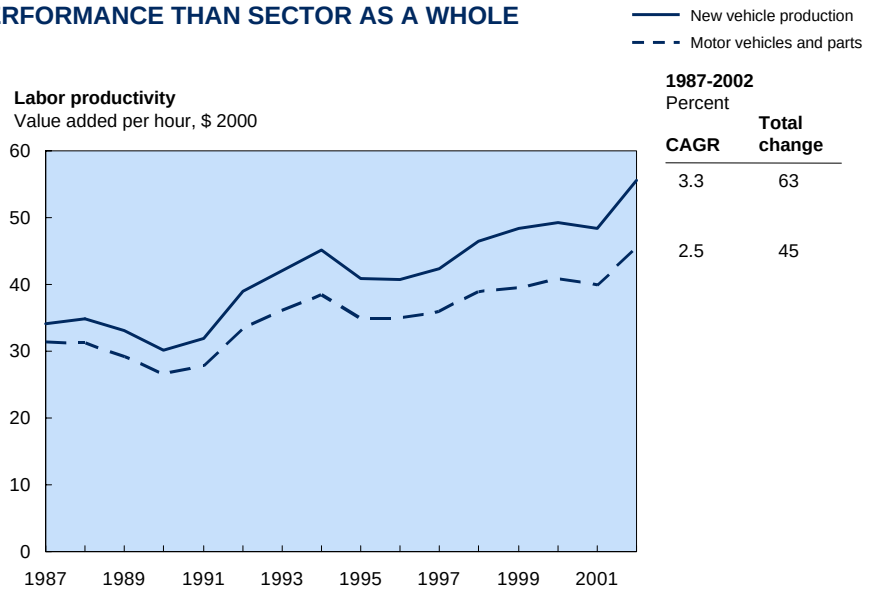
DECREASING ADJUSTMENT RATIO REDUCES PARTS LABOR SHARE IN NEW VEHICLE PRODUCTION INCREASING PRODUCTIVITY GROWTH



Source: BEA; BLS; MGI

Exhibit 8

NEW VEHICLE PRODUCTION HAS STRONGER PRODUCTIVITY PERFORMANCE THAN SECTOR AS A WHOLE



1987-2002
Percent

CAGR	Total change
3.3	63
2.5	45

Source: BEA, BLS, MGI

Deducting imports from industries' commodity use. Our adjustments rely heavily on the "use table" contained in BEA's input-output tables in census years and sub-sector gross output and employment data from the ASM.[2] The use-table specifies the total amount of a commodity used by industry but does not specify how much comes from domestic production or imports. For imports, we know how much of a commodity comes into the country, but we do not know whether it is destined for new vehicle production or the aftermarket. To create an estimate of imports destined for new vehicle production, we assume that the import share for each commodity is equal across all industries and final consumption.

Determining the share of production flowing into new vehicles. For the sub-sectors engaged in the assembly of new light vehicles, nearly 100 percent of their total output flows to final consumption. For parts production, we estimate the proportion of sub-sector output that flows into new vehicle production by the ratio of commodity used by assemblers to total output of that commodity as specified in the use table. For gross output, we use total commodity output from the use-table; for value added, we exclude intra-industry purchases. With this approach, we construct gross output and value added adjustment ratios for each sub-sector. The total adjustment ratio for the industry is a sub-sector weighted average.

For 1987, 1992, and 1997, data for gross output and value added are available on an SIC rather than a NAICS basis. A NAICS-consistent adjustment ratio must be estimated for these census years. We have used the published 1997 NAICS-SIC bridge to calculate a 1997 SIC based aggregate adjustment ratio that is comparable to 1992 and 1987. By splicing the pre-1997 growth rate to the 1997 NAICS ratio, we estimate a NAICS based time series of adjustment ratios.

Forecasting sub-sector use-table for census year 2002. The year 2002 sub-sector use-table will not be available until 2008, so we needed to construct estimates. The use-table is available on a more aggregated level for 2002, so our estimates of sub-sector detail were constrained to the published aggregates. For 2002, import adjustments described above were only done at the more aggregated level. Several steps were required to estimate the sub-sector detail required:

2 The "use table" shows how much of a commodity is used by each industry, final consumers and for exports.

- Total industry output and total commodity input were estimated using value of shipment growth rates from the Annual Survey of Manufacturers (ASM).
- Value added margins (value added divided by gross output) of all sub-sectors were assumed to change by the same factor between 1997 and 2002. This factor was set so that the gross output weighted sub-sector margins added up to the correct margin for the aggregate in 2002.
- Sub-sector value added were estimated as the product of the gross output and value added margins, and intermediate inputs as the difference between gross output and value added.
- Intermediate inputs from domestic production were estimated using the material cost data from the ASM.
- For each industry, each sub-sector commodity use is then grown using the factor difference between the industries forecasted 2002 total and the 1997 total.

Estimating adjustment ratios between census years. Once we have estimated adjustment ratios for the census years, we estimate the values for the intervening years. This was done by interpolating the sub-sector adjustment ratios, and then using the sub-sector shares of employment and gross output from the ASM to create an aggregate adjustment ratio.

- The gross output adjustment ratio, the value added adjustment ratio, and the value added margin were interpolated geometrically.[3]
- Relative shares of sub-sectors in gross output were estimated value of shipments information from the ASM.
- Relative shares of sub-sector hours were estimated using by combining employment information from the ASM and average hours per employee from the BLS.
- A weighted average was then computed by multiplying the relative sub-sector shares with the sub-sector adjustment ratios and summing.

3 We calculate the CAGR of the adjustment ratio between 1987 and 1992 and then grow the 1987 ratio into the 1992 ratio using this CAGR

To adjust total hours worked in each sub-sector we use the same adjustment ratio as for value added. This assumes that sub-sector labor productivity is the same regardless of what the output is ultimately used for.[4]

Determining the split between OEMs and parts for gross output, value added and hours worked

To determine the relative contribution of OEMs and parts manufacturers to productivity growth, we estimated their relative shares of gross output, value added and total hours. All estimates are based on our adjusted numbers. There are three key steps involved in this calculation:

- First, we compute the relative sub-sector values of gross output, value added and total hours worked from the ASM.
- Second, using the sub-sector adjustment ratios, we determine the adjusted values for each sub-sector.
- Third, we link the NAICS and SIC based numbers together, based on the SIC growth rates.[5] The result is a complete time-series for the NAICS codes 3361, 3362 and 3363 and their relative shares in gross output, value added and total hours. 3361 is taken as the value for OEMs, the sum of 3362 and 3363 is taken as the value for parts.

Determining the split between production and non-production workers in total hours worked

To link to our company-level analysis with the aggregate data, we estimated total hours worked for production and non-production workers for both OEMs and parts. The share of production workers for each NAICS sub-sector is based on data from BLS, which reaches back to 1987. The shares can therefore to our time series of sub-sector NAICS hours we derived for the OEM and parts split in the last section. The NAICS sub-sectors are then aggregated.

4 This does not mean that the adjustment ratio for the total sector is equal for value added and hours. Our assumption is applied at the sub-sector level. As a sector usually has different share in value added than it has in total hours worked (because productivity across sub-sectors varies), the impact of the adjustment ratio on industry hours worked is different than it is on industry value added.

5 The sub-sectors that remain after our adjustments in SIC and NAICS fit relatively well. NAICS 3361 corresponds to SIC 3711, NAICS 336211 corresponds to 3713 and NAICS 3363 roughly corresponds to SIC 3714.

AGGREGATE PRODUCTIVITY DECOMPOSITION

Calculating the required metrics

This section explains how the raw data and adjustments described so far are used to calculate various metrics we use to describe the evolution of the auto sector between 1987 and 2002. The metrics are always based on the adjusted data (i.e. the data excluding elements not related to new vehicles):

Deriving the contribution to productivity growth

Relative contribution of OEMs and parts to productivity growth. Since we use the same gross output deflator for OEM and parts value added (see discussion above), real sector value added is the sum of OEM and parts real value added. The contribution of OEMs to value added growth is then

$$con^{VA}_{OEM,t} = \frac{VA_{OEM,t} - VA_{OEM,t-1}}{(VA_{OEM,t-1} + VA_{Parts,t-1})}$$

The same holds true, for total hours worked. OEM's contribution to total hours growth is

$$con^{H}_{OEM,t} = \frac{H_{OEM,t} - H_{OEM,t-1}}{(H_{OEM,t-1} + H_{Parts,t-1})}$$

The contribution of parts sector is computed similarly. If Z represents aggregate labor productivity, productivity growth equals

$$\frac{Z_t}{Z_{t-1}} = \frac{VA_t / H_t}{VA_{t-1} / H_{t-1}} = \frac{VA_t}{VA_{t-1}} \times \frac{H_{t-1}}{H_t}$$

Subtracting one from both sides, rearranging and denoting the growth rate of a variable between t-1 and t as g(t), this can be rewritten as:

$$g^Z_t = \frac{1}{\left(1 + g^H_t\right)} \times \left(g^{VA}_t - g^H_t\right)$$

As we already know the contributions to value added growth and total hours growth, the contribution to productivity growth for each sector i at time t equals

$$con^Z_{i,t} = \frac{1}{1 + g^H_{i,t}} \left(con^{VA}_{i,t} - con^H_{i,t}\right)$$

Using these formulas, total productivity growth is just the sum of the contributions, i.e.

$$g_t^Z = \sum con_{i,t}^Z$$

Relative contributions of value added per vehicle and vehicles per hour.

Value added per hour can be expressed as

$$\frac{VA}{H} = \frac{VA}{V} \times \frac{V}{H}$$

The contributions are calculated using the additive properties of logarithmic growth rates

$$\Delta \ln \frac{VA}{H} = \Delta \ln \frac{VA}{V} + \Delta \ln \frac{V}{H}$$

Other relative contributions (e.g., production worker and non-production worker hours) are computed similarly. Based on these calculations, we computed the following contributions to growth:

CONTRIBUTION BY/TO	VA/H	VA/V	H/V
VA/H	100%	–	–
VA/V	42%	–	–
H/V	58%	–	–
OEMs	68%	74%	63%
Parts	32%	26%	37%
OEM PW H/V	–	–	70%
OEM NPW H/V	–	–	-7%
Parts PW H/V	–	–	33%
OEM NPW H/V	–	–	4%

MODEL MIX ANALYSIS

Data sources

We use the value added per vehical estimates from the 1999 Goldman Sachs report "Automobiles, United States, November 7, 2000". They report model-based income statements for OEMs for 15 vehicle classes. This data was combined with the income statements of the Big Three in 1999. From these combined income statements, value added was estimated for each vehicle class as the sum of labor costs, engineering costs, depreciation and amortization, and profits. Since the index year for our real values is 2000, we believe that using 1999 relative value added levels across models will be representative.

The 15 classes in the Goldman Sachs report were regrouped and to match the Ward's Automotive Yearbook, our principle source for production data.

WARD'S CLASSIFICATION	GOLDMAN SACHS CATEGORIES
Small cars	Small cars
Medium cars	Lower middle cars + Upper middle cars + Low/mid sports cars
Large cars	Large cars
Luxury cars	Luxury cars + High end sports cars
Pickup	Small pickup + Large pickup
SUV	Small utility + Middle utility + Large utility + Luxury utility
Van	Minivan + Large van
CUV	Small utility

This provides us with an estimate of the OEM value added per vehicle for the eight vehicle classes in the Ward's automotive yearbook.

Including the US parts sector in the value added per vehicle levels

To provide a result of the model mix analysis that is comparable to the aggregate numbers, we need to modify the value added per vehicle levels for each model to include the value added of the parts sector. We used the OEM share in adjusted gross output and value added from the aggregate numbers, and average profit margins of North American automotive suppliers in 1999 to make this adjustment:

- Labour cost, engineering cost and depreciation and amortization were adjusted by dividing the OEM levels by the OEM share in value added.
- Although the profit per vehicle varies widely across vehicle classes for OEMs, we do not believe that there is as much variation for the suppliers. We therefore assume that the supplier profit margin is constant across the vehicle classes. We calculate the supplier gross output per vehicle, and multiply this by the average supplier profit margin to get supplier profit per vehicle. This is then added to the OEM profit per vehicle.

Executing the model mix analysis

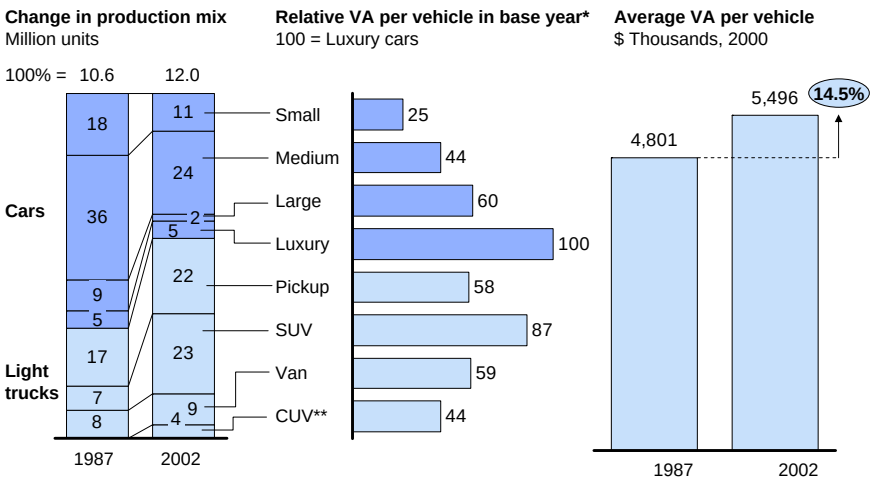
The above adjustments provide us with an estimate of value added per vehicle levels for eight vehicle classes for the year 1999. The impact of model mix change on average value added per vehicle was then calculated by holding relative value added per vehicle levels constant, and changing the production mix across the vehicle classes.

$$g^{Mix}_{1987-2002} = \frac{\sum_{i=1}^{8} s^{i}_{2002} \times \left(VA/V\right)_{1999}}{\sum_{i=1}^{8} s^{i}_{1987} \times \left(VA/V\right)_{1999}} - 1$$

Where s^{i}_{t} represents the production share (from Wards) of vehicle class *i* in year *t*. Average value added per vehicle rose approximately 25 percent between 1987-2002. We found that the mix effect accounted for 14.5 percentage points of this growth (Exhibit 9). The remaining 9.5 percentage points are attributable to changes in features, reliability, and durability (Exhibit 10).

Exhibit 9

THE SHIFT TO LIGHT TRUCKS RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 15%

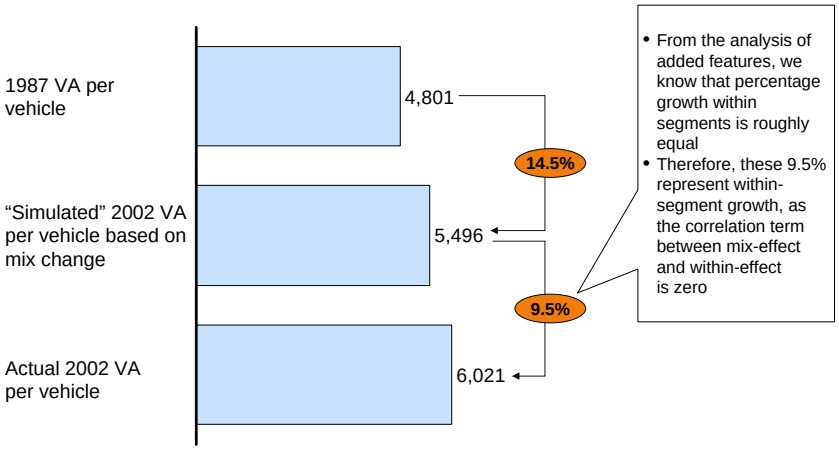


* Relative magnitudes estimated based on 1999 reference year
** Cross-utility vehicle assumed to have VA per vehicle of a small SUV
Source: Ward's Automotive yearbook; Goldman Sachs; BEA; MGI Analysis

Exhibit 10

THE REMAINING PERCENTAGE GAP AFTER ACCOUNTING FOR MODEL MIX REPRESENTS WITHIN-SECTOR PERCENTAGE CHANGE

In constant 2000 USD



Source: Ward's Automotive yearbook; Goldman Sachs; BEA

ADDED FEATURES ANALYSIS

Data sources

The diffusion rates for the features were taken from Ward's Automotive yearbook. The cost per feature to the OEM was estimated based on analysis and client surveys conducted by the McKinsey Automotive and Assembly practice.

Adjusting the diffusion rate for car/truck shift

In each year the penetration rate of a given feature in total vehicle production is given by:

$$\Pi_t^{Total} = s_t^{Cars}\Pi_t^{Cars} + s_t^{Trucks}\Pi_t^{Trucks}$$

Where s is the share in total vehicle production and Π is the penetration rate. The total diffusion rate can therefore change through a shift of production from cars to trucks, or through a genuine change in penetration in either cars or trucks.

We are only interested in genuine increases of penetration within the vehicle classes. To isolate the mix effect, we multiply the gain in market share of trucks with the average difference in penetration of the feature between trucks and cars, i.e.

$$Mixeffect = \left(s_t^{Trucks} - s_{t-1}^{Cars}\right) \times \frac{1}{2}\left[\left(\Pi_t^{Trucks} + \Pi_{t-1}^{Trucks}\right) - \left(\Pi_t^{Cars} + \Pi_{t-1}^{Cars}\right)\right]$$

The change in penetration used for our analysis is then calculated as

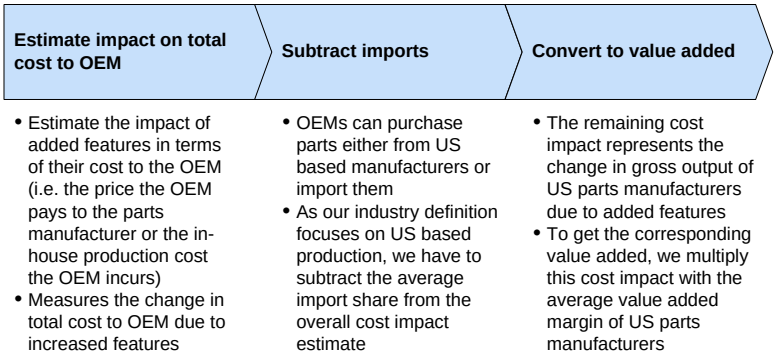
$$\Delta\Pi^{adjusted} = \Delta\Pi^{Total} - Mixeffect$$

Execution of the added features analysis

The added features analysis is conducted in three steps: estimate the impact on total cost to the OEM, subtract imports, and convert to value added (Exhibit 11).

Exhibit 11

THE IMPACT OF ADDED FEATURES ON AVERAGE VALUE ADDED PER VEHICLES IS DERIVED IN THREE STEPS



Source: MGI

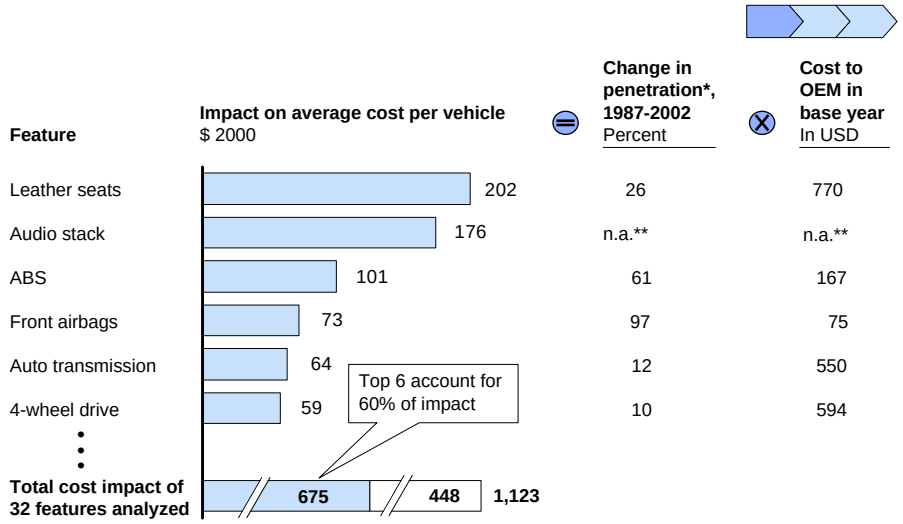
The impact on average cost per vehicle of a change in penetration of a feature is calculated as the difference in penetration between the beginning and the end of the period multiplied by the cost of the feature in the reference year. Thus, we evaluate the real value of the feature as its price in the base year 2000 and then assume that the real value of the feature has remained constant between 1987 and 2002.[6] Let C be the average cost per vehicle, the total impact of the 32 features analyzed on average cost per vehicle to the OEM is calculated as (Exhibit 12):

$$\Delta C^{Total} = \sum_{i=1}^{32} \left(\Pi^{i}_{2002} - \Pi^{i}_{1987}\right) \times C^{i}_{2000}$$

6 Note that assuming constant real value is not assuming that prices remain constant. As we have no quality adjusted deflator by feature, we believe this is the fairest assumption to make. It is conservative in the sense that the real value of features (e.g., the quality of ABS brakes) has likely been increasing because of improvements in quality, so this assumption arguably creates a lower bound for the impact of features.

Exhibit 12

WE ESTIMATED THE IMPACT ON COST PER VEHICLE OF 32 FEATURES



* Adjusted for model mix change cars vs. trucks
** Estimated as net effect of audio stacks of different complexity (i.e., CD changer vs. FM radio)
Source: Ward's; McKinsey analysis

To get to the impact on value added per vehicle, we adjust for imports and the value added margin (Exhibit 13):

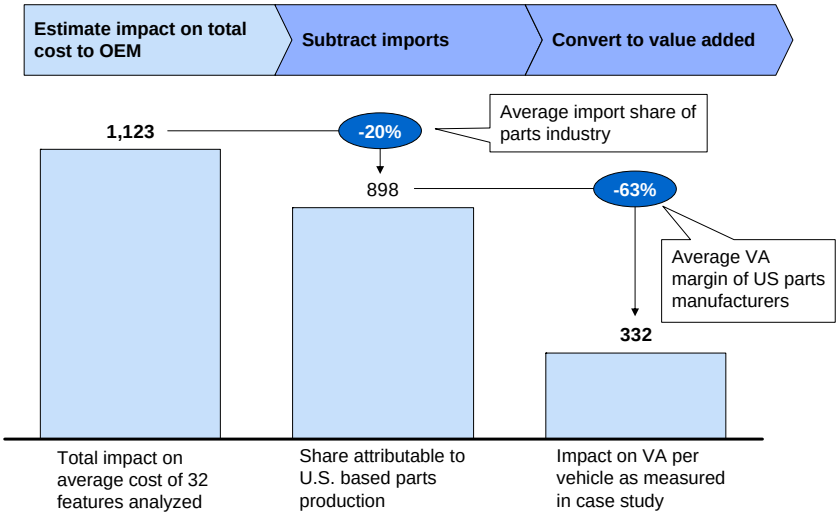
- Given that this is the total effect of the features, irrespective of whether they were supplied from a US based supplier or imported, we have to subtract the average import share in total automotive supplies consumption
- Assuming that the cost to the OEM equal gross output to the supplier of the feature, we have to multiply the impact with the value added margin of parts in the base year.

After these adjustments, we see that added features increased value added per vehicle by nearly 7 percent between 1987-2002 (Exhibit 14).

Exhibit 13

THE COST IMPACT OF NEW FEATURES MUST BE ADJUSTED FOR IMPORTS AND THE VALUE ADDED MARGIN

In constant 2000 USD

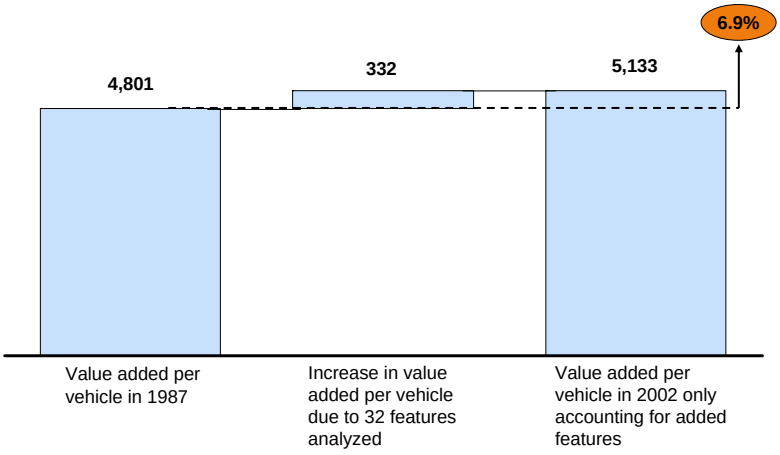


Source: Ward's; BEA; McKinsey analysis

Exhibit 14

THE ISOLATED IMPACT OF THE 32 FEATURES ANALYZED RAISED AVERAGE VALUE ADDED PER VEHICLE BY 7 PERCENT

$ 2000



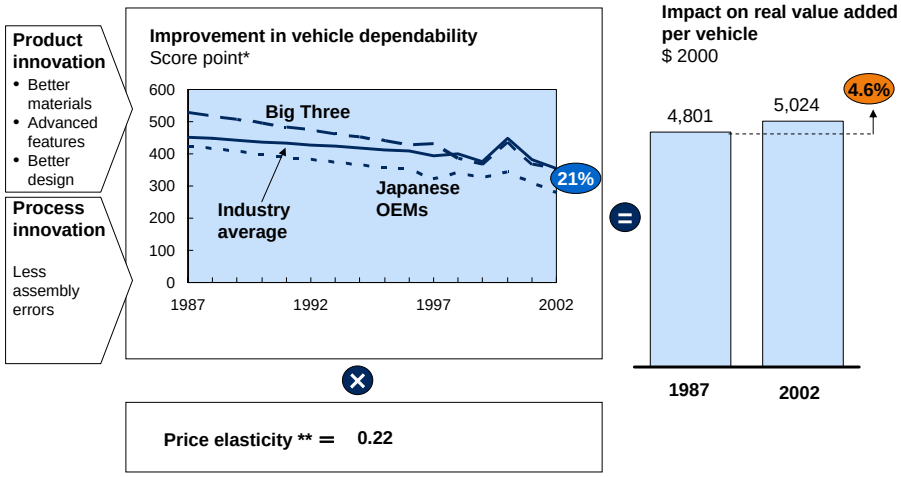
Source: Ward's; BEA; McKinsey analysis

QUALITY AND DURABILITY ANALYSIS

We estimated the impact of quality improvement on vehicle price in three steps. First, we estimated improvement in vehicle dependability. Second, we estimated the price elasticity of vehicle dependability. Finally, we used this elasticity to estimate the impact of dependability improvements on vehicle price. (Exhibit 15).

Exhibit 15

THE ISOLATED IMPACT OF IMPROVEMENTS IN VEHICLE DEPENDABILITY RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 5 PERCENT



* Includes initial quality and durability. Scores before 1996 were estimated based on improvement ratio from 1997-2002
** Models considered for price elasticity estimation were: Upper small cars (Ford Taurus, GM Impala, GM Grand Prix, Toyota Camry) and middle SUV (Ford Explorer, Chrysler Jeep Grand Cherokee, GM Blazer, Toyota 4 Runner)
Source: JD Power, Ward Automotive Yearbook, MGI

Estimating improvement in vehicle dependability

We used JD Power Vehicle Dependability Survey to understand how much improvement was made in vehicle dependability defined as long-term durability. Since the JD Power Survey started to use a different scale in 1996, we adjusted scores before 1996 based on improvement trajectory from 1997 to 2002. We used JD Power Vehicle Dependability data, not Initial Quality data, because long-term durability matters much more for price according to experts we interviewed.

Estimating the price elasticity

We estimated the price elasticity based on quality data by brand from JD Power Durability Survey and price data from Ward Automotive Yearbook:

- **Model selection**. We selected comparable models for two representative vehicle segments, which are, upper small cars and middle SUVs. Vehicles selected are Ford Taurus, GM Impala, GM Grand Prix, Toyota Camry for upper small cars and Ford Explorer, Chrysler Jeep Grand Cherokee, GM Blazer, Toyota 4 Runner for middle SUVs. In selecting the models, factors such as powertrain features are controlled for.

- **Elasticity estimation**. In estimating the price elasticity, we used the average vehicle dependability score for 1998-2002 and price data after incentives in 2002. We used the four-year average data in estimating quality performance given that price in a certain year reflects reputation built on quality performance for the past several years.

Estimating impact on real value added per vehicle

We estimated the impact of quality improvements on real value added by multiplying the average improvement rate from the vehicle dependability analysis with the estimated price elasticity.

ASSEMBLY EFFICIENCY IMPROVEMENT ANALYSIS

Data sources

We used hours information from the Harbour Report as our primary data source for analyzing OEM's manufacturing efficiency. We analyzed US-based plants only. Vehicle production in Mexico and Canada was excluded from the calculations. In addition, we used employment and hours worked in assembly, engine production and transmission production from BLS. We also referenced information from Global Insight on US-based plant production volumes.

Data adjustment

To create a consistent data set based for 1987-2002 based on Harbour report information, we had to make two primary assumptions. First, we needed to estimate hours per vehicle before 1987. Second, we needed to estimate efficiency data for 1987 and 1988 for the Big Three, and 1987-1991 for the transplants.

Performance definition adjustment: Before 1997 the Harbour Report measured manufacturing efficiency using workers per vehicle. In 1997, they switched to hours per vehicle. Both metrics were quoted on an annual production basis. To have a consistent time series, we estimated hours per-vehicle for the 1987-

1997 period. We first annualized the daily production volume for each plant reported by Harbour Report assuming 211 production days per year.[7] Next, we estimated total hours worked annually at each plant using data from the BLS which provides total hours worked and the total number of production workers for each sub sector in assembly, engine and transmission manufacturing. For each company, the sub-sector averages were adjusted based on the post-1997 company deviations from sub-sector averages. Finally, for each OEM, we divided total labor hours worked annually by total number of vehicles produced annually to estimate hours per vehicle for each company.

Time period adjustment: Harbour Report data on hours per vehicle for assembly plants is available on an annual basis beginning in 1989. Harbour also issued a report in 1979. For the Big Three, we assumed that manufacturing efficiency improved from 1987 to 1989 at the 1979-1989 improvement rate.

Complete data for transplants is available only after 1992, forcing us to use 1992 performance as a proxy for 1987 performance. We do not believe that this assumption has had a large impact mainly because Honda and Nissan held a combined production share of only 7% in 1987 (and Toyota did not start producing in the US until 1988), and were already very efficient in 1992. If there was a large increase in efficiency between 1987-1992, than our estimate of overall efficiency improvements constitute a lower bound.

The same procedure was used for engines and transmissions.

Other adjustments: We also made other small adjustments. For example, when data on particular plants were not available, we tried to estimate manufacturing efficiency performance for the plants based on Global Insight production volume data and the plant's manufacturing efficiency performance for the previous and next years. In addition, transplant's performance in early years was adjusted based on descriptions available in Harbour Report's footnotes.

7 Our estimate of 211 days is derived from Harbour Report capacity utilization analysis and also from comparison of daily production data from the Harbour Report and annual production data from Global Insight for representative plants

Execution of the manufacturing efficiency analysis

We have conducted three different sets of analysis using the adjusted manufacturing efficiency data. Industry average hours per vehicle can improve because more efficient producers increases their production share (mix effects), because of actual process improvements, and because of unintended efficiency impacts of changes in product mix (product innovation externalities, e.g., the shift to easier to produce light trucks). The mix effects were estimated at the industry level, while the process development and product mix effects were estimated based on a case study of GM.

Estimating the "mix-effect." We estimated the mix effect by averaging two approaches. The first approach assumed that production shares among the OEMs remained the same and only manufacturing efficiency changed over the period. This calculation isolates the amount of improvement that we can attributed to real process efficiency improvements. The residual is attributable to mix effects. The second approach holds manufacturing efficiency constant while allowing production shares to change, isolating the mix effect. The residual in this case is improvements from process efficiency.

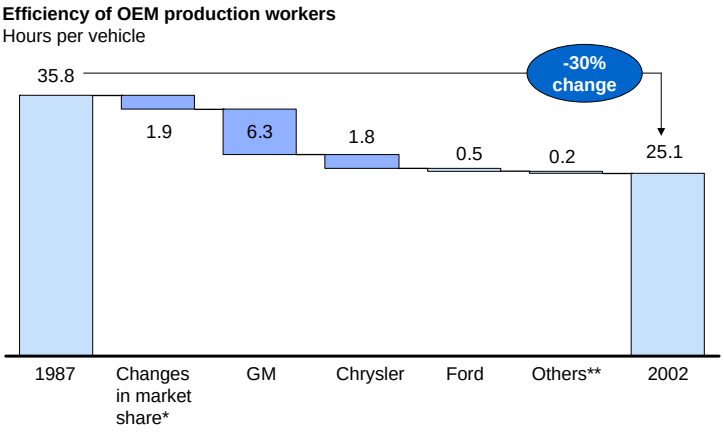
GM'S Efficiency Improvement Analysis

General Motors (GM) accounted for nearly 60 percent of the improvement in industry average manufacturing between 1987-2002 (Exhibit 16). Outside of plant closures, we isolated five factors driving this improvement: adoption of lean production techniques, outsourcing to suppliers, and product innovation externalities from new product introduction, common platforms and new and improved features (Exhibit 17).

Adoption of lean production techniques. To estimate the impact of GM's adoption of lean production techniques we began by building an understanding of the lean production diffusion rates among GM plants. We assumed that the penetration rate reached 100% in 2002. Harbour Report's plant descriptions provide explanations for changes in plant performance. We complemented this information with newspaper, industry and trade journal articles. Once we identified that a plant had begun to implement lean production, we assumed that efficiency improved at 2 percent annually through 1996 and at 5 percent annually thereafter. These improvement rates are based on expert input and analysis of

Exhibit 16

GM AND ACCOUNTED FOR 60% OF INCREASE IN OVERALL OEM EFFICIENCY

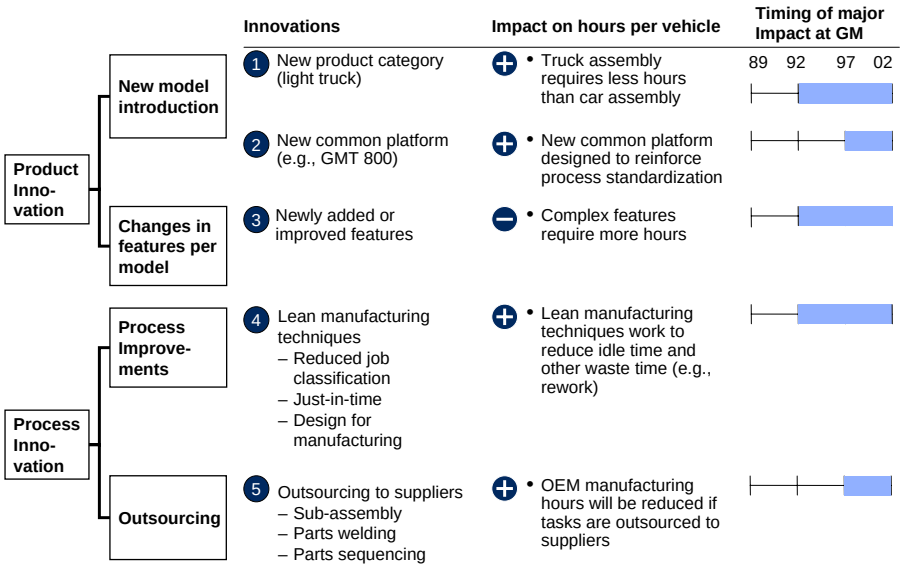


* Including the impact of new entrant (Toyota) and the impact of share changes among the existing OEM
** Nissan, Honda, NUMMI, AAI

Source: Harbour report, MGI Estimates

Exhibit 17

PRODUCT AND PROCESS INNOVATIONS DRIVE CHANGES IN EFFICIENCY AT GM

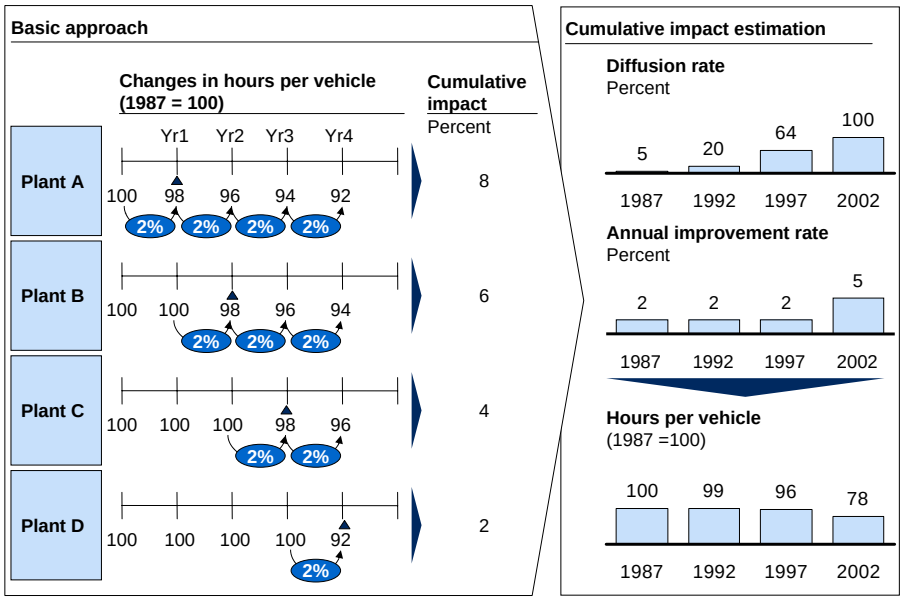


Source: Harbour report, News clippings, MGI Estimates

Harbour data.[8] (As a point of reference, our research indicates that Toyota Motors in Japan has improved at about 5 percent annually in manufacturing efficiency, excluding the impact of increased product complexity.) Combining our estimates of when individual plants began to adopt lean production with these improvement rates allowed us sum up the total impact of lean production adoption across all plants (Exhibit 18).

Exhibit 18

ESTIMATING THE IMPACT OF LEAN MANUFACTURING DIFFUSION



Source: MGI

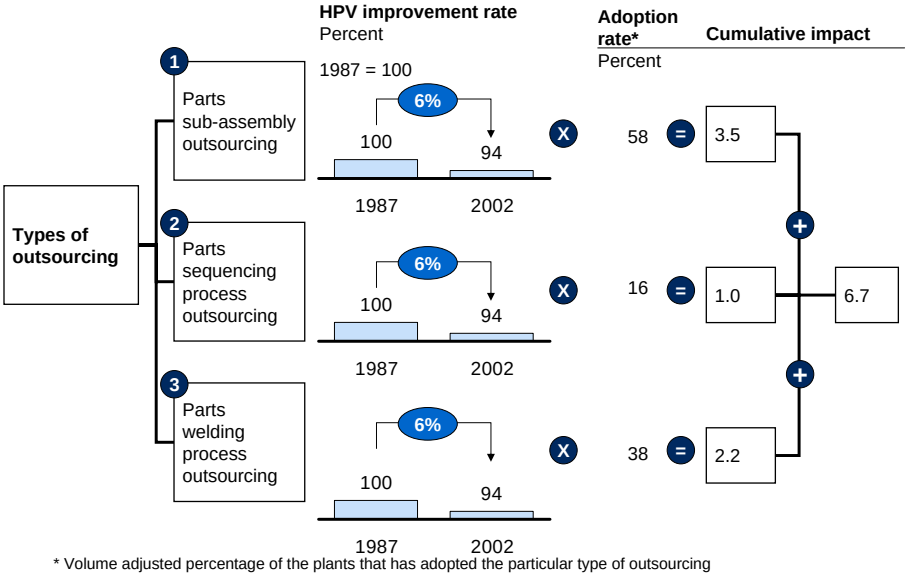
Plant closures effect: GM's average manufacturing efficiency improved partly because it closed inefficient plants. We estimated the plant closure effect by estimating the average 1987 performance for continuing plants only. We classified the plant closure effect as the performance gap between the average 1987 performance for the continuing plants and the average 1987 performance for all plants including both closed and continuing plants. Since all of the closed plants were relatively inefficient, the average 1987 performance for continuing plants only is higher than the average 1987 performance for all plants.

8 We estimated the average improvement rate for selected plants for particular years in which they had no major improvement efforts other than process improvement using lean production techniques

Outsourcing to suppliers. We identified three important types of outsourcing by OEMs to suppliers: sub-assembly, sequencing, and welding. To estimate the impact of these outsourcing activities, we depended on Harbour Report descriptions of plant performance. We compared the performance of plants in the year that outsourcing occurred to the previous and subsequent years performance. We paid particularly close attention to the plant for which outsourcing was a primary driver of improvement to eliminate the impact from other improvement efforts. Rates of efficiency improvement due to outsourcing were then combined with plant-based outsourcing adoption rates to calculate the cumulative impact (Exhibit 19).

Exhibit 19

ESTIMATING THE IMPACT OF OUTSOURCING



* Volume adjusted percentage of the plants that has adopted the particular type of outsourcing

Source: Harbour Report, MGI

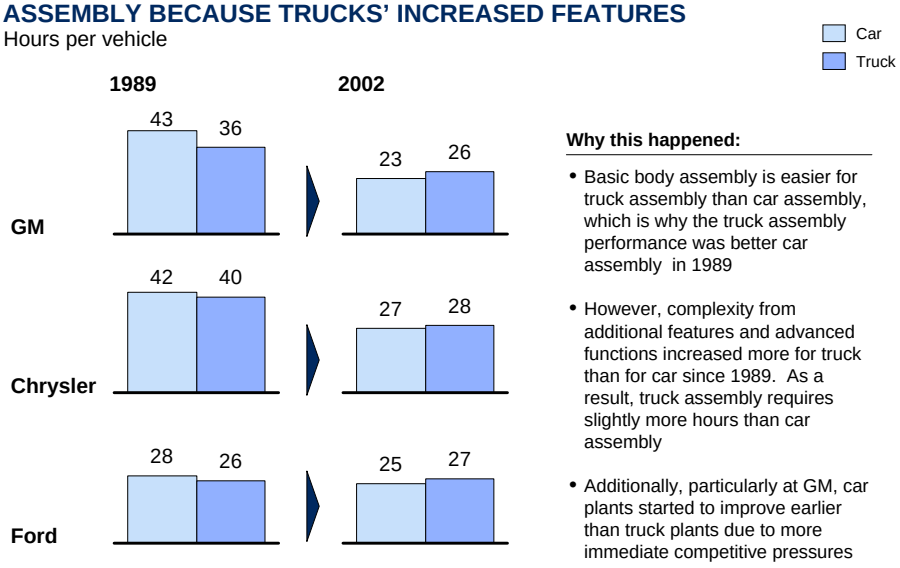
New product introduction: A light truck based on "body-on-frame" technology is easier to assemble than a car (or car-based truck such as a minivan) based on unibody construction. The shift to light trucks should have a positive impact on hours per vehicle if everything else was held constant. We estimated the performance gap between car assembly and truck assembly from the 1989 Harbour data and then multiplied the gap by the increase in the share of light trucks to estimate how much the average hours per vehicle improved.

By 2002, truck assembly on average requires more time than car assembly. This happened because the hours required to add increased luxury features outweighed savings in body manufacturing (Exhibit 20). We account for these increase in hours due to increased complexity separately as the impact of newly added or improved features.

Exhibit 20

TRUCK ASSEMBLY NOW REQUIRES MORE HOURS THAN CAR ASSEMBLY BECAUSE TRUCKS' INCREASED FEATURES

Hours per vehicle



Source: Harbour report, Expert interview

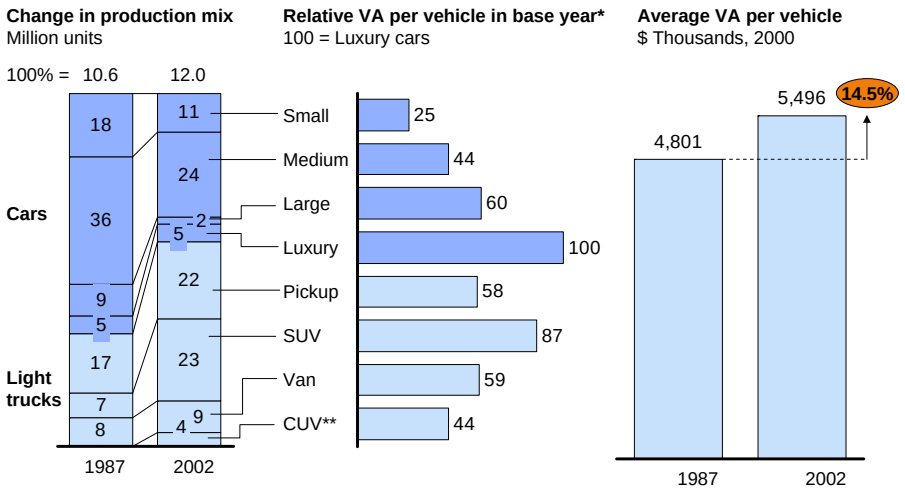
New common platform: Platform commonization should also reduce hours per vehicle. We estimated the impact from the platform commonization in the same way we estimated the impact of outsourcing. First, we identified names of plants that introduced common platforms such as GMT800 and when they did so. We then tracked plant performance to estimate the unique contribution from the commonization efforts, controlling for the impact from annual process improvement and outsourcing.

Newly added or improved features: Increasing complexity of vehicles can have negative impact on hours per vehicle. We estimated the negative impact as a residual of total improvement minus contributions from the other factors.

Estimating relative impacts: We added up these independent estimates to estimate the relative impact of each factor. We did not normalize the impact given that the impact of newly added or improved features was estimated as a residual (Exhibit 21).

Exhibit 21

SHIFT TO LIGHT TRUCKS RAISED AVERAGE VALUE ADDED PER VEHICLE BY NEARLY 15 PERCENT



* Relative magnitudes estimated based on 1999 reference year
** Cross-utility vehicle assumed to have VA per vehicle of a small SUV
Source: Ward's Automotive yearbook; Goldman Sachs; BEA; MGI Analysis

PARTS EFFICIENCY IMPROVEMENT ANALYSIS

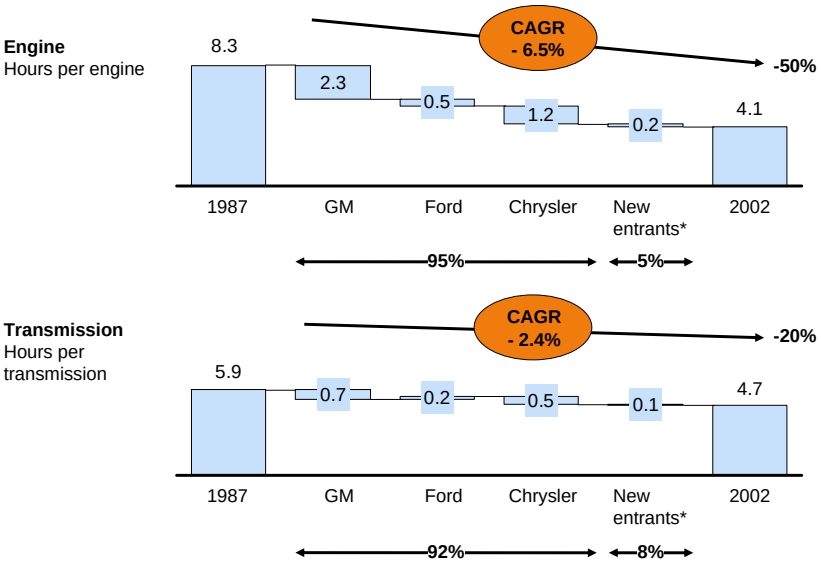
Coverage of measurement. The parts manufacturing efficiency analysis includes process improvements for both in-house parts production at OEMs and other parts manufactured by parts suppliers. In accordance with the BEA, in-house parts manufacturing is classified as part of the parts sector, not the assembly sector. Given the fragmented nature of the parts industry and data limitations, we were only able to independently analyze in-house parts production of engines and transmissions. These two sub-sectors consistently accounted for 25 percent of parts sector employment between 1987-2002. Furthermore, some of the improvements in hours for the parts industry could have come about because of shifting jobs out of the US, primarily to Mexico. It has not been possible to obtain quantitative estimates of this activity, although the qualitative evidence suggests that a large portion of parts imports are destined for the aftermarket not new vehical production.

Estimating the mix effect. For Engine and Transmission, the mix is primarily due to shift of production to more efficient producers (Toyota, Honda and Nissan). We estimated the impact from the production share shift for in-house engine and transmission production by using the same method that we used to calculate the mix effect for assembly process improvements. The production share shift impact we estimated as 5 percent for engine and 8 percent for transmission (Exhibit 22). For other parts, we assumed 5 percent based on the engine analysis. The remainder of the efficiency improvements are attributable to process improvements. To estimate the cumulative impact of mix and process improvements, we calculated the weighted average based on employment shares of these three segments, which are, 13 percent for Engine, 12 percent for Transmission and 75 percent for other parts (Exhibit 23).

Product innovation externalities. The mix effect for parts manufacturing did not include product innovation externalities for parts manufacturing. Although we estimated that about 30 percent of improvements for the in-house engine production came from new model introduction, we believe the impact should be classified as efficiency improvements as these new models were introduced for production volume consolidation. In addition, the impact of changes in feature complexity as another source of product innovation externalities is difficult to measure for parts manufacturing. In understanding "parts hours" per vehicle, we need to consider both the positive impact from design simplification and reduced hours for rework (by-product of technology advancement and direct material cost reduction efforts by OEMs), as well as the negative impact from the increasing number of added features, which should offset each other to some extent. We were unable to derive estimates for these effects, so we do not independently quantify the contribution from product innovation externalities in the mix effects for parts manufacturing.

Exhibit 22

MANUFACTURING EFFICIENCY IMPROVEMENT FOR IN-HOUSE PARTS



* Toyota, Honda, Nissan

Source: Harbor Report

Exhibit 23

BOTTOM-UP APPROACH TO ESTIMATE THE CONTRIBUTION FROM THE CONTINUING OPERATION (a + b)

Percent

	Segment share of employment	Improvement rate in process efficiency*		Within : mix ratio		
		Total	CAGR	Within		Mix
Other	75	-26.0	-2.0	95	:	5
Transmission	12	-20.0	-2.4	92	:	8
Engine	13	-50.0	-6.5	95	:	5
Weighted average		**-28.4**		95	:	5

Reference information

- Changes the share in over time have been small
- 5% is Toyota's annual improvement rate at their best effort
- Parts had supposedly smaller impact from the market share change to transplant suppliers

* Hours per unit (e.g., hours per engine, hours per transmission)

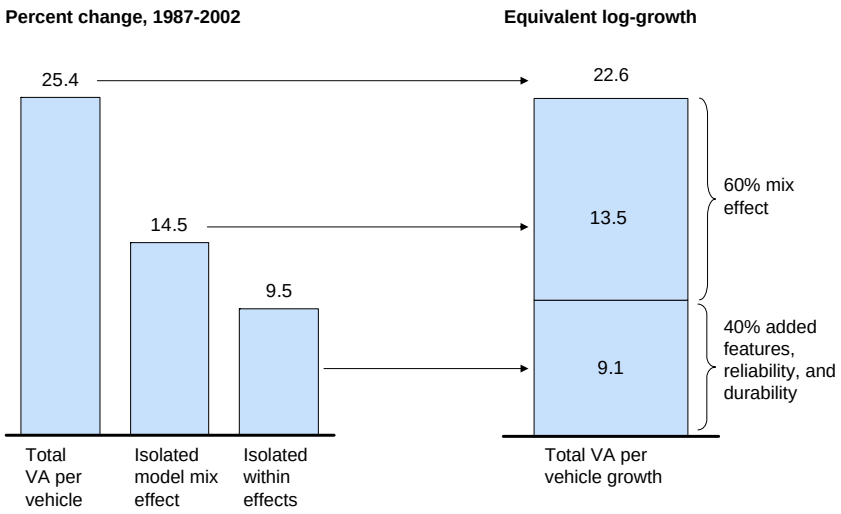
COMBINING MICRO-LEVEL INSIGHTS WITH AGGREGATE PRODUCTIVITY DECOMPOSITION

Our micro-level analysis allowed us identifying the impact of changes in firm behavior on productivity growth.

Decomposing value added per vehicle. As discussed above, the contribution of growth in value added per vehicle to productivity growth was driven by changes in model mix, added features, and improved quality and durability (see Exhibit 10). Expressing the growth in value added driven by these changes in terms of contributions to growth, we find that approximately 60 percent of the total change in value added per vehicle can be attributed to mix effects, and the remaining 40 percent to changes in features, reliability, and durability (Exhibit 24).

Exhibit 24

USING LOGARITHMIC GROWTH RATES, THE RELATIVE CONTRIBUTION OF MODEL MIX VS. WITHIN EFFECTS CAN BE QUANTIFIED AS 60/40



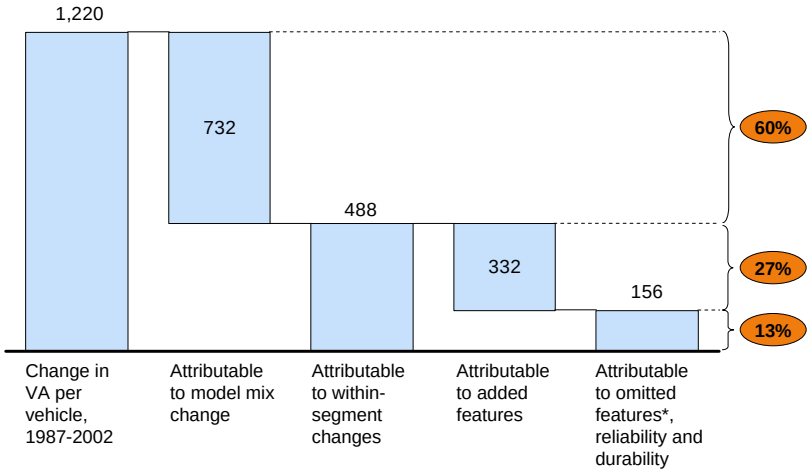
Source: Ward's Automotive yearbook; Goldman Sachs; BEA

Similarly, the 40 percent contribution can be further decomposed using our estimate of the growth in value added per vehicle driven by added features (Exhibit 25). This decomposition suggests that 68 percent of the growth in value added per vehicle outside of mix effects has come from added features, with increases in quality and durability accounting for the remaining 32 percent. The results are similar if we combine the impact of our independent estimates of added features with our independent estimates of reliability and durability (see Exhibits 8, 9). Assuming that these two elements account for all the growth in value added per vehicle outside of mix effects implies that 60 percent of this growth comes from added features and 40 percent from increases in quality and durability. Averaging these two estimates and rounding to the nearest number divisible by 5 yields our full decomposition of value added per vehicle growth (Exhibits 26, 27).

Exhibit 25

IN CONJUNCTION WITH THE PREVIOUSLY-DERIVED CONTRIBUTION OF ADDED FEATURES AND MODEL MIX CHANGE, THE CONTRIBUTION OF RELIABILITY CAN BE AT BEST 13%

$ 2000



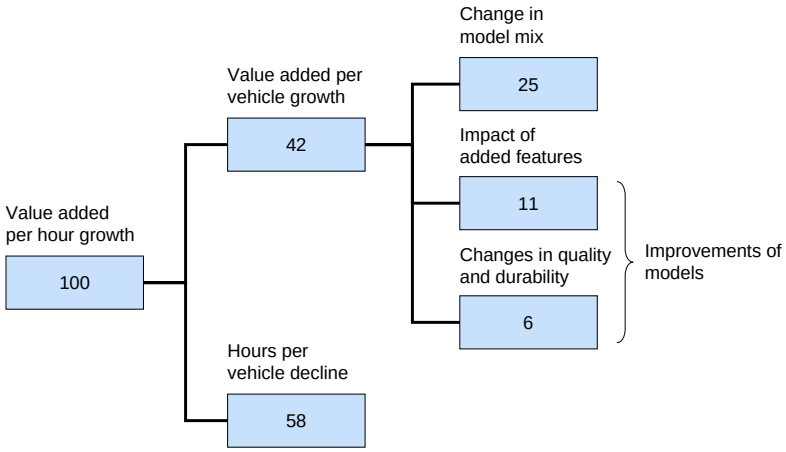
* E.g., increased engine size

Source: McKinsey analysis

Exhibit 26

DECOMPOSITION OF GROWTH IN VALUE ADDED PER VEHICLE

Contributions to productivity growth
Index, 100 = 1987-2002 growth in value added per hour

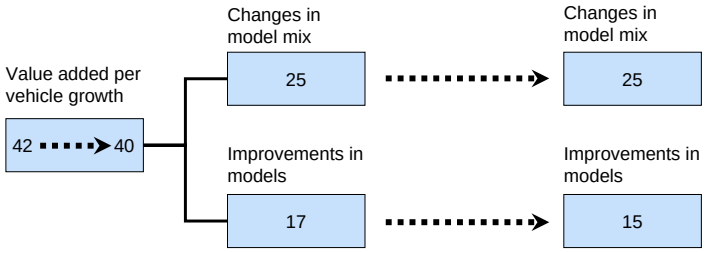


Source: BEA; BLS; MGI estimates

Exhibit 27

ROUNDING TO THE NEAREST NUMBER DIVISIBLE BY 5 YIELDS THE FINAL DECOMPOSITION

Contributions to productivity growth
Index, 100 = 1987-2002 growth in value added per hour

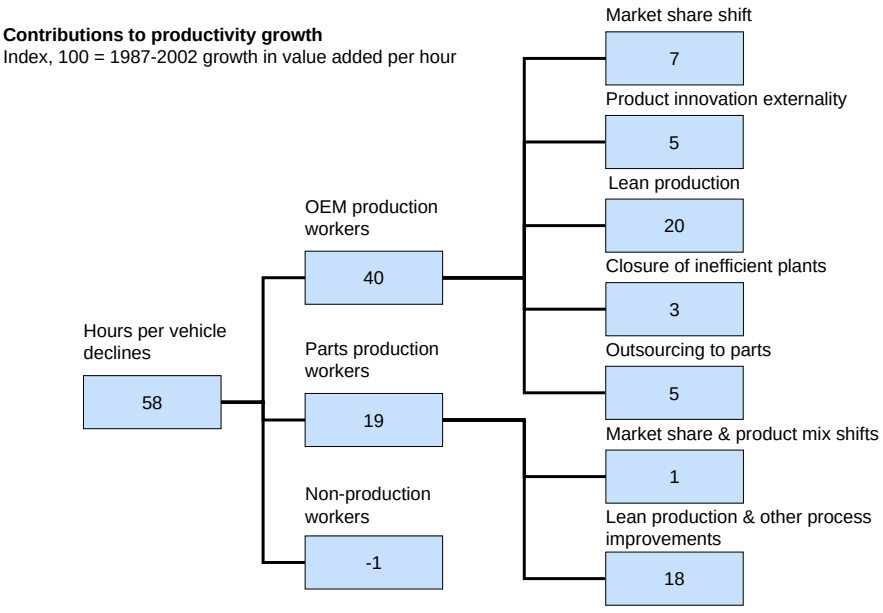


Source: BEA; BLS; MGI estimates

Decomposing hours per vehicle. We analyzed the efficiency improvements for OEMs and parts manufactures separately. For OEMs, market share shifts accounted for 18 percent of the total change of hours per vehicle between 1987-2002 (see Exhibit 18). The remaining 82 percent was driven by adoption of lean production techniques, product innovation externalities, plant closures, and outsourcing of activities to parts suppliers. We derived estimates of the relative importance of these components above (see Exhibit 19). For parts, we also derived estimates of market share shifts and process improvements (see Exhibit 22). Using these estimates, we can decompose the change in hours per vehicle (Exhibit 28).[9] Improvements that were driven by outsourcing to parts suppliers by OEMs was attributed to the parts suppliers (Exhibit 29). Finally, combing OEMs and parts and rounding to the nearest number divisible by 5 yields our full decomposition of declines in hours per vehicle (Exhibit 30).

Exhibit 28

DECOMPOSITION OF CHANGES IN HOURS PER VEHICLE



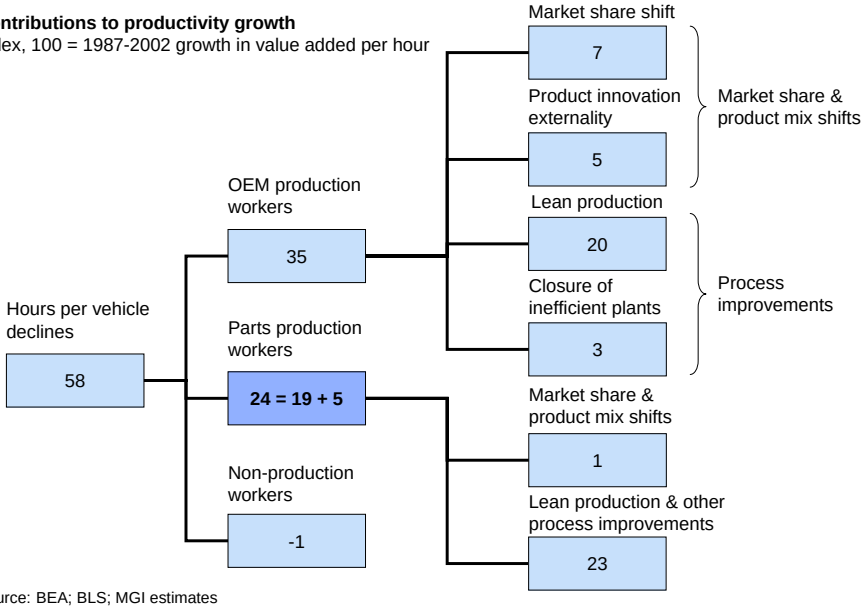
Source: BEA; BLS; MGI estimates

9 For example, adoption of lean production by OEMs was responsible for 20 percent of the change in value added per vehicle since 20 = 40 x 0.82 x 0.6.

Exhibit 29

CONTRIBUTION OF HOURS FROM OUTSOURCING IS ATTRIBUTED TO THE PARTS SECTOR

Contributions to productivity growth
Index, 100 = 1987-2002 growth in value added per hour

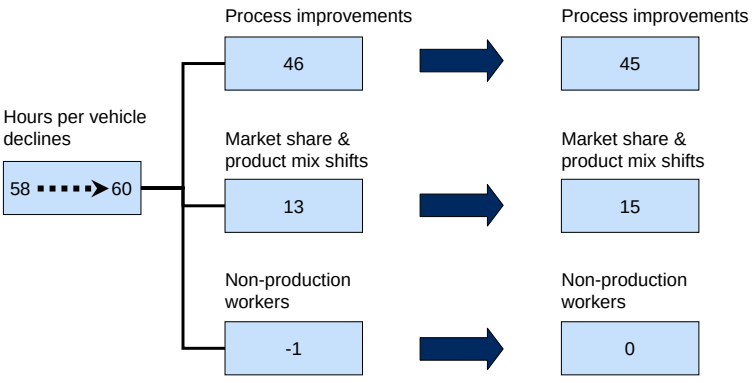


Source: BEA; BLS; MGI estimates

Exhibit 30

COMBINING OEMS AND PARTS AND ROUNDING TO THE NEAREST NUMBER DIVISIBLE BY 5 YIELDS THE FINAL DECOMPOSITION

Contributions to productivity growth
Index, 100 = 1987-2002 growth in value added per hour



Source: BEA; BLS; MGI estimates

Bibliography

Abernathy, William J. 1978. *The productivity dilemma: roadblock to innovation in the automobile industry*. Baltimore, MD: The Johns Hopkins University Press.

Ahn, Sanghoon. June 2001. "Firm dynamics and productivity growth; a review of micro evidence from OECD countries." OECD Economics Department Working Papers, Working Paper No. 297.

Baily, Martin N. 2004. "Recent productivity growth: the role of information technology and other innovations." *Federal Reserve Bank of San Francisco Economic Review 2004* 35-42

Baldwin, John R., and Wulong Gu. September 2004. "Innovation, survival and performance of Canadian manufacturing plants."

Bartelsman, Eric, Stefano Scarpetta, and Fabiano Schivardi. January 2003. "Comparative analysis of firm demographics and survival: micro-level evidence for the OECD countries." OECD Economics Department Working Papers, Working Paper No. 348.

Bartelsman, Eric J., and Mark Doms. September 2000. "Understanding productivity: lessons from longitudinal microdata." *Journal of Economic Literature*. 38: 569-94.

Battisti, Giuliana, and Paul Stoneman. 2003. "Inter- and intra-firm effects in the diffusion of new process technology." *Research Policy* 32: 1641-55.

Battisti, Giuliana, and Paul Stoneman. December 2004. "The intra-firm diffusion of new process technologies."

Berkovec, James. Summer 1985. "New car sales and used car stocks: a model of the automobile market." *Rand Journal of Economics* 16 (2).

Berry, Steven, Samuel Kortum, and Ariel Pakes. September 1996. "Environmental change and hedonic cost functions for automobiles." NBER Working Paper Series, Working Paper 5746.

Berry, Steven, James Levinsohn, and Ariel Pakes. July 1995. "Automobile prices in market equilibrium." *Econometrica*. 63 (4): 841-90.

Berry, Steven, James Levinsohn, and Ariel Pakes. June 1999. "Voluntary export restraints on automobiles: evaluating a trade policy." *The American Economic Review.* 89 (3): 400-31.

Berry, Steven, James Levinsohn, and Ariel Pakes. February 2003. "Differentiated products demand systems from a combination of micro and macro data: the new car market."

Bils, Mark. June 2004. "Measuring growth from better and better goods." NBER Working Paper Series, Working Paper 10606.

Bils, Mark, and Peter J. Klenow. September 2001. "Quantifying quality growth." *The American Economic Review*. 91 (4): 1006-30.

Boone, Jan. Autumn 2000. "Competitive pressure: the effects on investments in product and process innovation." *Rand Journal of Economics* 31 (3): 549-69.

Bresnahan, Timothy F. 1981. "Departures from marginal-cost pricing in the American automobile industry." *Journal of Econometrics* 17: 201-27.

Bresnahan, Timothy F. June 1987. "Competition and collusion in the American automobile industry: the 1955 price war." *The Journal of Industrial Economics* 35 (4).

Cheung, Yin-Wong, and Antonio Garcia Pascual. September 2004. "Market structure, technology spillovers, and persistence in productivity differentials." *International Journal of Applied Economics*. 1 (1): 1-23.

Chrysler. 1987, 1995. *Annual Report*.

Clark, Kim B., and Takahiro Fujimoto. 1991. *Product development performance: strategy, organization, and management in the world auto industry*. Boston, MA: Harvard Business School Press.

Cobet, Aaron E., and Gregory A. Wilson. June 2002. "Comparing 50 years of labor productivity in U.S. and foreign manufacturing." *Monthly Labor Review*.

Cohen, Wesley M., and Steven Klepper. 1996. "Firm size and the nature of innovation within industries: the case of process and product r&d." *Review of Economics and Statistics* 78 (2): 232-43.

Cusumano, Michael A., and Kentaro Nobeoka. 1998. *Thinking beyond lean: how multi-project management is transforming product development at Toyota and other companies*. New York: The Free Press.

Daimler Chrysler. 1999, 2002. *Annual Report*.

Dargay, Joyce, and Dermot Gately. 1999. "Income's effect on car and vehicle ownership, worldwide: 1960-2015." *Transportation Research Part A* 33: 101-38.

Dean, Edwin R., Michael J. Harper, and Mark S. Sherwood. May 1996. "Productivity measurement with changing-weight indexes of outputs and inputs." *U.S. Department of Labor: Bureau of Labor Statistics*.

Deutsche Bank Alex. Brown. August 2001. "Why GM's and Ford's auto businesses may not stay profitable for long."

Dorfman, Jeffrey H., and Gary Koop. 2004. "Current developments in productivity and efficiency measurement." *Journal of Econometrics* 126: 233-40.

Dyler, Jeffrey H. July 1996. "How Chrysler created an American keiretsu." *Harvard Business Review*.

Ford. 1995, 1999, 2002. *Annual Report*.

Foster, Lucia, John Haltiwanger, and C.J. Krizan. November 1998. "Aggregate productivity growth: lessons from microeconomic evidence." NBER Working Paper Series, Working Paper 6803.

Freyssenet, Michel, Andrew Mair, Koichi Shimizu, and Giuseppe Volpato, eds. 1998. *One best way?: trajectories and industrial models of the world's automobile producers*. New York: Oxford University Press, Inc.

Fujimoto, Takahiro. 2003. "Capability building competition (*Nouryo Kochiku Kyousou*)." Chuo Koron.

General Motors. 1987, 1991. *Annual Report*.

Goldman Sachs. November 2000. "Automobiles: United States." Global Equity Research.

Goldman Sachs. September 2002. "Identifying the long-term global winners." Global Equity Research.

Griliches, Zvi. 1961. "Hedonic price indexes for automobiles: an econometric analysis of quality change." *The Price Statistics of the Federal Government.* General Series No. 73. New York: National Bureau of Economic Research.

Groningen Growth and Development Centre. October 2004. "Data sources and methodology of the 60-industry database of the Groningen growth and development centre."

Guellec, Dominique, and Bruno van Pottelsberge de la Potterie. 2001. "R&D and productivity growth: panel data analysis of 16 OECD countries." *OECD Economic Studies*.

Gullickson, William. July 1995. "Measurement of productivity growth in U.S. manufacturing." *Monthly Labor Review*.

Hall, Bronwyn H. January 2004. "Innovation and Diffusion." NBER Working Paper Series, Working Paper 10212.

Hall, Bronwyn H., and Beethika Khan. May 2003. "Adoption of New Technology." NBER Working Paper Series, Working Paper 9730.

Harbour Consulting. 1989-2003. *The Harbour Report North America*.

Helper, Susan. May 1997. "Complementarity and cost reduction: evidence from the auto supply industry." NBER Working Paper Series, Working Paper 6033.

Hulten, Charles R. January 2000. "Total factor productivity: a short biography." NBER Working Paper Series, Working Paper 7471.

Hulten, Charles R., Edwin R. Dean, and Michael J. Harper, eds. 2001. *New developments in productivity analysis*. Chicago: The University of Chicago Press.

Jensen, J. Bradford, Robert H. McGuckin, and Kevin J. Stiroh. February 2000. "The impact of vintage and survival on productivity: evidence from cohorts of U.S. manufacturing plants."

Jones, Benjamin F. May 2005. "The burden of knowledge and the 'death of the renaissance man': is innovation getting harder?" NBER Working Paper Series, Working Paper 11360.

Keller, Maryann. 1989. *Rude awakening: the rise, fall, and struggle for recovery of General Motors.* New York: Harper Collins.

Kennedy, Michael N. 2003. *Product development for the lean enterprise: why Toyota's system is four times more productive and how you can implement it.* Richmond, VA: The Oaklee Press.

Kenney, Martin, and Richard Florida, eds. 2004. *Locating global advantage: industry dynamics in the international economy*. Stanford, CA: Stanford University Press.

Kochan, Thomas A., Russell D. Lansbury, and John Paul MacDuffie. 1997. *After lean production: evolving employment practices in the world auto industry*. Ithaca, NY: Cornell University Press.

Landefeld, J. Steven, Brent R. Moulton, and Cindy M. Vojtech. November 2003. "Chained-dollar indexes: issues, tips on their use, and upcoming changes." *Survey of Current Business* 83 (11).

Landefeld, J. Steven, and Robert P. Parker. July 1995. "Preview of the comprehensive revision of the national income and product accounts: BEA's new featured measures of output and prices." *Survey of Current Business*.

Lawson, Ann M., Brian C. Moyer, Sumiye Okubo, and Mark A. Planting. March 2005. "Integrating industry and national economic accounts: first steps and future improvements." NBER Working Paper Series, Working Paper 11187.

Lieberman, Marvin B., and Rajeev Dhawan. September 2000. "Assessing the resource base of US and Japanese auto producers: a stochastic frontier production function approach."

Macroeconomic Advisers. May 2000. "Technical note: Fisher aggregation and subtraction."

Maddison, Angus. November 1997. "Causal influences on productivity performance 1820-1992: a global perspective." *Journal of Productivity Analysis* 325-60.

Mairesse, Jacques, and Pierre Mohnen. 2002. "Accounting for innovation and measuring innovativeness: an illustrative framework and an application." *American Economic Review* 92 (2): 226-30.

Malerba, Franco, and Luigi Orsenigo. 1995. "Schumpeterian patterns of innovation." *Cambridge Journal of Economics* 19: 47-65.

Mansfield, Edwin. October 1961. "Technical change and the rate of imitation." *Econometrica* 29 (4).

Maynard, Micheline. 2003. *The end of Detroit: how the big three lost their grip on America's car markets*. New York: Currency Books.

McAlinden, Sean P., David J. Andrea. November 2002. *Estimating the new automotive value chain: a study prepared for Accenture*. Altarum Institute, Center for Automotive Research.

McKinsey Global Institute

1993 "Manufacturing productivity."

2001 "U.S. productivity growth: understanding the contribution of information technology relative to other factors."

2002 "How IT enables productivity growth."

2002 "Reaching higher productivity growth in France and Germany."

2003 "New Horizons: Multinational Investment in Developing Countries."

Moulton, Brent R., and Eugene P. Seskin. October 1999. "A preview of the 1999 comprehensive revision of the national income and product accounts: statistical changes." *Survey of Current Business*.

Moyer, Brian C., Mark A. Planting, Paul V. Kern, and Abigail M. Kish. June 2004. "Improved annual industry accounts for 1998-2003: integrated annual input-output accounts and gross-domestic-product-by-industry accounts." *Survey of Current Business* 84 (6).

Murray, Jonathan, and Nicholas Sarantis. 1999. "Price-quality relations and hedonic price indexes for cars in the United Kingdom." *International Journal of the Economics of Business* 6 (1): 5-27.

Murray, Jonathan, and Nicholas Sarantis. 1999. "Quality, user cost, forward-looking behavior, and the demand for cars in the U.K." *Journal of Economics and Business* 51: 237-58.

Nadiri, M. Ishaq. December 1970. "Some approaches to the theory and measurement of total factor productivity: a survey." *Journal of Economic Literature* 8 (4): 1137-77.

Nelson, Douglas R. May 1994. "The political economy of U.S. automobile protection." NBER Working Paper Series, Working Paper 4746.

Nelson, Richard B. September 1981. "Research on productivity growth and productivity differences: dead ends and new departures." *Journal of Economic Literature* 19: 1029-64.

OECD. 2001. "Measuring productivity: measurement of aggregate and industry-level productivity growth."

Pakes, Ariel. 2003. "A reconsideration of hedonic price indexes with an application to PC's." *American Economic Review* 93 (5): 1578-96.

Peters, Thomas J., and Robert H. Waterman, Jr. 1982. *In search of excellence: lessons from America's best-run companies*. New York: Warner Books.

Reinsdorf, Marshall B., W. Erwin Diewert, and Christian Ehemann. 2002. "Additive decompositions for Fisher, Törnqvist and geometric mean indexes." *Journal of Economic and Social Measurement* 28: 51-61.

Romeo, Anthony A. 2001. "The rate of imitation of a capital-embodied process innovation." *Economica* 44: 63-69.

Rosenberg, Nathan. Fall 1972. "Factors affecting the diffusion of technology." *Explorations in Economic History* 10 (1): 3-33.

Schreyer, Paul, and Dirk Pilat. 2001. "Measuring productivity." *OECD Economic Studies* 33.

Shin, Taeyoung. July 2003. "Innovation behaviors of Korea's manufacturing firms: some empirical evidences based on the Korean innovation survey (KIS) dataset." *United Nations On Line* (UNPAN).

Sperling, Daniel, et al. June 2004. "Analysis of auto industry and consumer response to regulations and technological change, and customization of consumer response models in support of AB 1493 rulemaking." Institute of Transportation Studies, Davis, CA.

Syrneonidis, George. 1996. "Innovation, firm size and market structure: Schumpeterian hypotheses and some new themes." *OECD Economic Studies* 27: 35-65.

Triplett, Jack. October 2004. "Handbook on hedonic indexes and quality adjustments in price indexes: special application to information technology products." OECD STI Working Papers, Working Paper No. 2004/9.

Triplett, Jack E., and Barry P. Bosworth. September 2003. "Productivity measurement issues in services industries: 'Baumol's disease' has been cured." *Economic Policy Review* 9 (3): 23-33.

Triplett, Jack E., and Barry P. Bosworth. 2004. *Productivity in the U.S. services sector: new sources of economic growth*. Washington, DC: Brookings Institution Press.

Van Biesebroeck, Johannes. October 2003. "Revisiting some productivity debates." NBER Working Paper Series, Working Paper 10065.

Van Biesebroeck, Johannes. 2003. "Productivity dynamics with technology choice: an application to automobile assembly." *Review of Economic Studies* 70: 167-98.

Ward's Communications, Inc. 1978, 1988, 1998, 2003, 2004. Ward's Automotive Yearbook. Detroit, MI: *Ward's Communications*, Inc.

Whelan, Karl. June 2000. "A guide to the use of chain aggregated NIPA data." *Board of Governors of the Federal Reserve System* Finance and Economics Discussion Series 2000-35.

Womack, James P., Daniel T. Jones, and Daniel Roos. 1990. *The machine that changed the world*. New York: Simon and Schuster.

Yuskavage, Robert E. March 1998. "Gross product by industry price measures, 1977-96." *Survey of Current Business*.

McKinsey Global Institute
05/11/11
Copyright © McKinsey & Company
www.mckinsey.com/knowledge/mgi
Design by New Media, McKinsey & Company, Sydney

McKinsey&Company