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Analysis of Technology Adoption Rates in New Vehicles

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Abstract

This paper examines the pace at which manufacturers have added certain powertrain technology into new vehicles from model year 1975 to the present. Based on data from the EPA's Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends database [1], the analysis will focus on several key technologies that have either reached a high level of penetration in light duty vehicles, or whose use in the new vehicle fleet has been growing in recent years. The findings indicate that individual manufacturers have, at times, implemented new technology across major portions of their new vehicle offerings in only a few model years. This is an important clarification to prior EPA analysis that indicated much longer adoption times for the industry as a whole. This new analysis suggests a technology penetration paradigm where individual manufacturers have a much shorter technology penetration cycle than the overall industry, due to "sequencing" by individual manufacturers.

Introduction

Technology in new vehicles is continually changing and evolving. Innovative new technologies are regularly being introduced, replacing older and less effective technologies. This continuous cycle of improvement and re-invention has been a hallmark of the automotive industry. This paper provides a detailed look at the rate at which the automotive industry as a whole has adopted new technology, the rate at which individual manufacturers have adopted technology, and the differences between the overall industry and manufacturer adoption rates.

The focus of this paper is on "successful" technologies that have achieved widespread use by multiple manufacturers and, in some cases, by all or nearly all manufacturers. It does not look at "unsuccessful" technologies which never achieved widespread use. One consequence of a competitive and technology-driven enterprise like the automobile industry is that there will certainly be a number of unsuccessful technologies. This paper does not provide data on why technologies fail, but it does provide data on how quickly successful technologies can penetrate the marketplace.

How Technology Enters the Marketplace

Previous Literature on Technology Adoption in the Automotive Industry

The Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends (Trends) report [1] is the authoritative reference for carbon dioxide (CO_2) emissions, fuel economy, and powertrain technology trends for new vehicles in the United States. The report has been published annually since 1975, and relies on detailed data submitted to the U.S. Environmental Protection Agency (EPA) as part of EPA's regulatory programs. The Trends report has tracked industry-wide technology adoption trends for over 35 years. In particular, Figure 1, excerpted from the Trends report, has been widely cited [2, 4, and 6] for many years.

In recent years, several studies have examined technology penetration trends in the automotive industry, notably Argonne National Lab [2], MIT's Sloan Automotive Lab [3], EPA [5], and DeCicco [6].

Industry-Wide Technology Adoption Since 1975

Automotive technology has continually evolved since 1975, resulting in vehicles that have better fuel economy, more power, and more content. One of the most notable examples of this continual improvement is the evolution of fuel delivery in

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gasoline engines. Carburetors, the dominant fuel delivery system in the late 1970s and early 1980s, were replaced by throttle body fuel injection, then port fuel injection systems, which in turn are being replaced by direct injection systems. This trend, which has major implications for engine fuel economy and performance, is explored in Figures 1 and 2.

Figure 1 shows industry-wide adoption rates for five mature technologies in passenger cars that have achieved wide adoption across the entire industry. To provide a common scale, the adoption rates are plotted in terms of the number of years after the technology was first introduced into the market (in some cases very limited use of the technology may have occurred before being tracked in the Trends report). The five technologies included in Figure 1 are fuel injection (including throttle body, port, and direct injection), front wheel drive, multi-valve engines (i.e., engines with more than two valves per cylinder), engines with variable valve timing, and lockup automatic transmissions. For each of these technologies, it took at least a decade to attain an industry-wide production fraction of 60% after first use, and another five to ten years to reach maximum penetration. While some of these technologies may eventually be adopted in 100% of new vehicles, there may be design reasons that other technologies, like front-wheel drive, will likely never be adopted in all vehicles. Figure 1 shows that it has historically taken about 20 years to fully adopt a new technology industry-wide after it was first introduced into the marketplace.

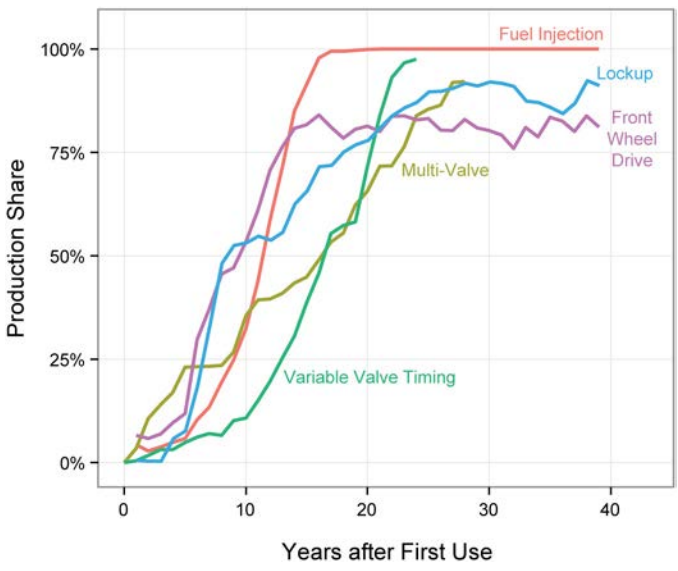

Figure 1. Industry-wide car technology penetration after first significant use.

One inherent limitation in using the Trends database to track the introduction of new technologies is that there is often a lag between the introduction of a new technology and the modifications to the formal EPA vehicle compliance information system that are necessary to ensure proper tracking of the new technology. Accordingly, for many of the technologies discussed in this paper, the Trends database did not begin tracking production share data until after the technologies had achieved some limited market share. For example, Trends did not begin to track multi-valve engine data until MY 1986 for cars and MY 2004 for trucks, and in both cases multi-valve engines had captured about 5% market share by that time. Likewise, turbochargers were not tracked in Trends until MY 1996 for cars and MY 2003 for trucks, and while turbochargers had less than a 1% market share in both cases at that time, it is likely that turbochargers had exceeded 1% market share in the late 1980s. Cylinder deactivation was utilized by at least one major manufacturer in the 1980s, well before being tracked by Trends.

Technology Adoption by Manufacturers

Industry-wide technology adoption rates, as shown in Figure 1, mask the actual speed at which individual manufacturers have adopted new technology. Manufacturer specific technology adoption rates can actually be much more rapid. The industry-wide technology adoption curves are aggregated from multiple manufacturers, each of which adopted the technology at a different rate, and at different times, resulting in the industry-wide curves. The distribution of manufacturers introducing new technologies over time is an important aspect of understanding the overall industry trend of technology adoption.

Figure 2 disaggregates the industry-wide trends shown in Figure 1 to examine how individual manufacturers have adopted new technologies. The first four technologies shown in Figure 2, which are also included in Figure 1, have reached (or are near) full market penetration for all manufacturers. Also included in Figure 2 are three additional technologies that are quickly increasing penetration in new vehicle production, and are projected to be installed on at least 15% of all MY 2013 vehicles. These technologies are advanced transmissions (transmissions with 6 or more speeds and CVTs), gasoline direct injection (GDI) fuel systems, and turbocharged gasoline engines. In both Figure 1 and 2, fuel injection includes GDI and other fuel injection systems. Front wheel drive is included in Figure 1, but not in Figure 2.

Figure 2 shows the percent penetration of each technology over time for the industry as a whole, and individually for the top seven manufacturers by sales. Figure 2 focuses on the length of time each manufacturer required to move from initial introduction to 80% penetration for each technology. After 80% penetration, the technology is assumed to be largely incorporated into the manufacturer's fleet and changes between 80% and 100% are not highlighted.

The technologies shown in Figure 2 vary widely in terms of complexity, application, and when they were introduced into the market. For each technology, there are clearly variations between manufacturers, both in terms of when they began to adopt a technology, and the rate with which they adopted the technology. The degree of variation between the manufacturers also varies by technology.

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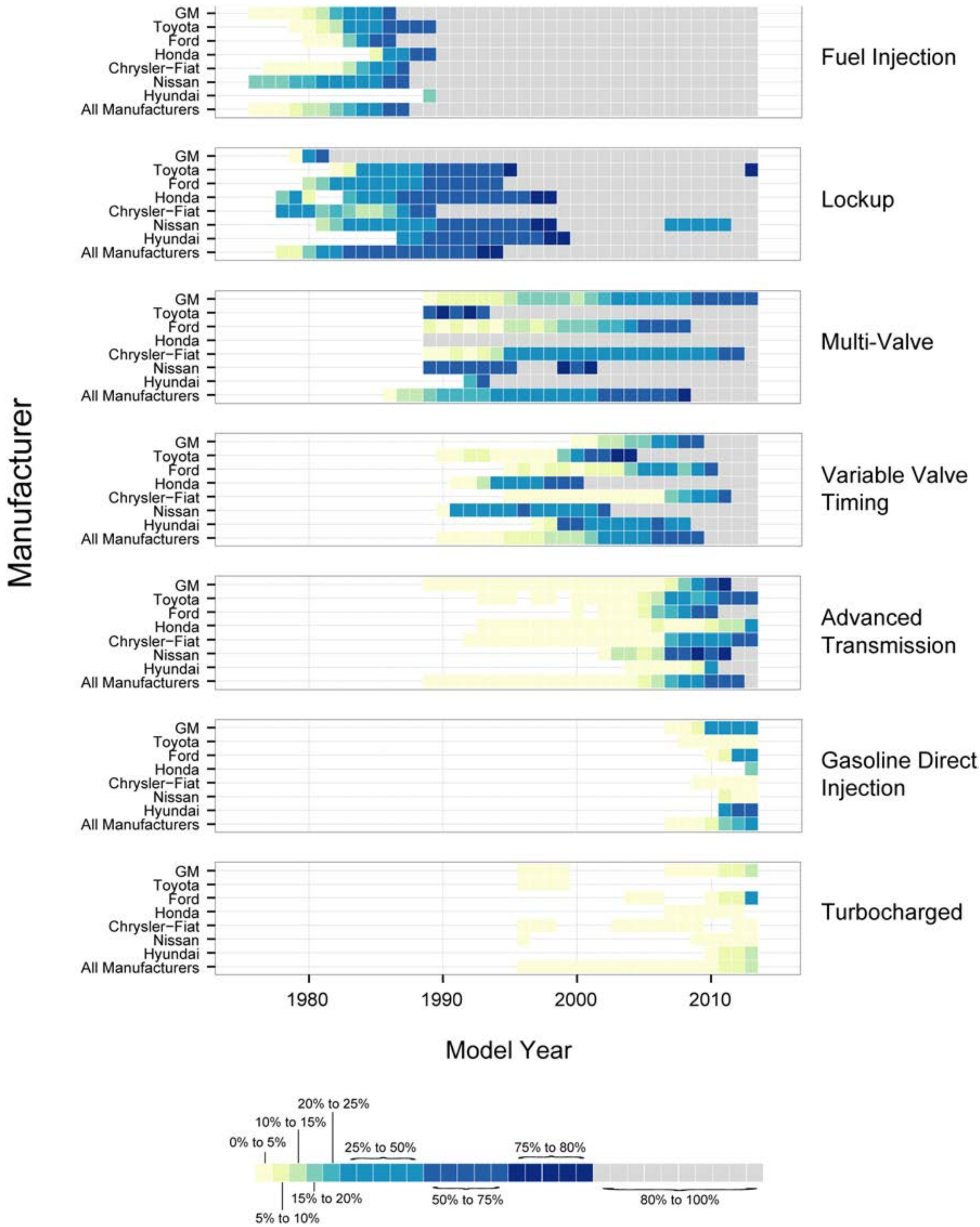

Figure 2. Manufacturer specific and industry-wide technology adoption over time for key technologies

The data for variable valve timing (VVT), for example, shows that several manufacturers were able to adopt the technology much faster than the overall industry rate might suggest. As shown in Figure 1, it took a little over 20 years for VVT to reach 80% penetration across the industry as a whole. However, Figure 2 shows that of the top seven manufacturers (by MY 2012 sales), several were able to implement at least 80% VVT in significantly less time than the overall industry. Therefore, it was not the rate of manufacturer specific technology adoption, but rather the staggered implementation between manufacturers that resulted in the longer industry average. This is an important distinction to draw when making observations about overall industry trends on technology uptake.

Fuel injection systems show the least amount of variation in initial adoption timing between manufacturers, which when combined with the rapid rates of adoption resulted in a faster adoption by the industry overall (see Figure 1) than technologies like VVT. Advanced transmissions, and turbocharged engines, have been available in small numbers for some time, but have rapidly increased market penetration in recent years. Turbocharged engines and GDI fuel systems are

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only recently beginning to reach significant parts of the market, and while both technologies are showing variation in adoption between manufacturers, it is too early to tell how, and if, they will ultimately be adopted widely by the industry.

A different way to look at technology adoption patterns is to look at the maximum rate of adoption that manufacturers have been able to achieve for each technology. Figure 3 uses this approach to look at technology adoption for the same manufacturers and technologies examined in Figure 2. For each technology and manufacturer, Figure 3 shows the maximum change in technology penetration that each manufacturer achieved over any three year and five year period.

Figure 3 shows that there have been many examples of manufacturers applying a new technology to a large percentage of their fleet in 5 years (or less). For example, each of the seven manufacturers was able to increase the percentage of their new vehicles with fuel injection systems by over 50% in five years, and three were able to increase the penetration of VVT by more than 85% in that time. For VVT, all seven manufacturers achieved close to or above a 70% penetration increase in a five year period, but the industry as a whole only achieved a maximum of a 40% change over any five years. This data reinforces the conclusion that the staggered timing of VVT adoption by individual manufacturers resulted in an overall industry adoption period that is considerably longer than actually required by many (if not most) manufacturers.

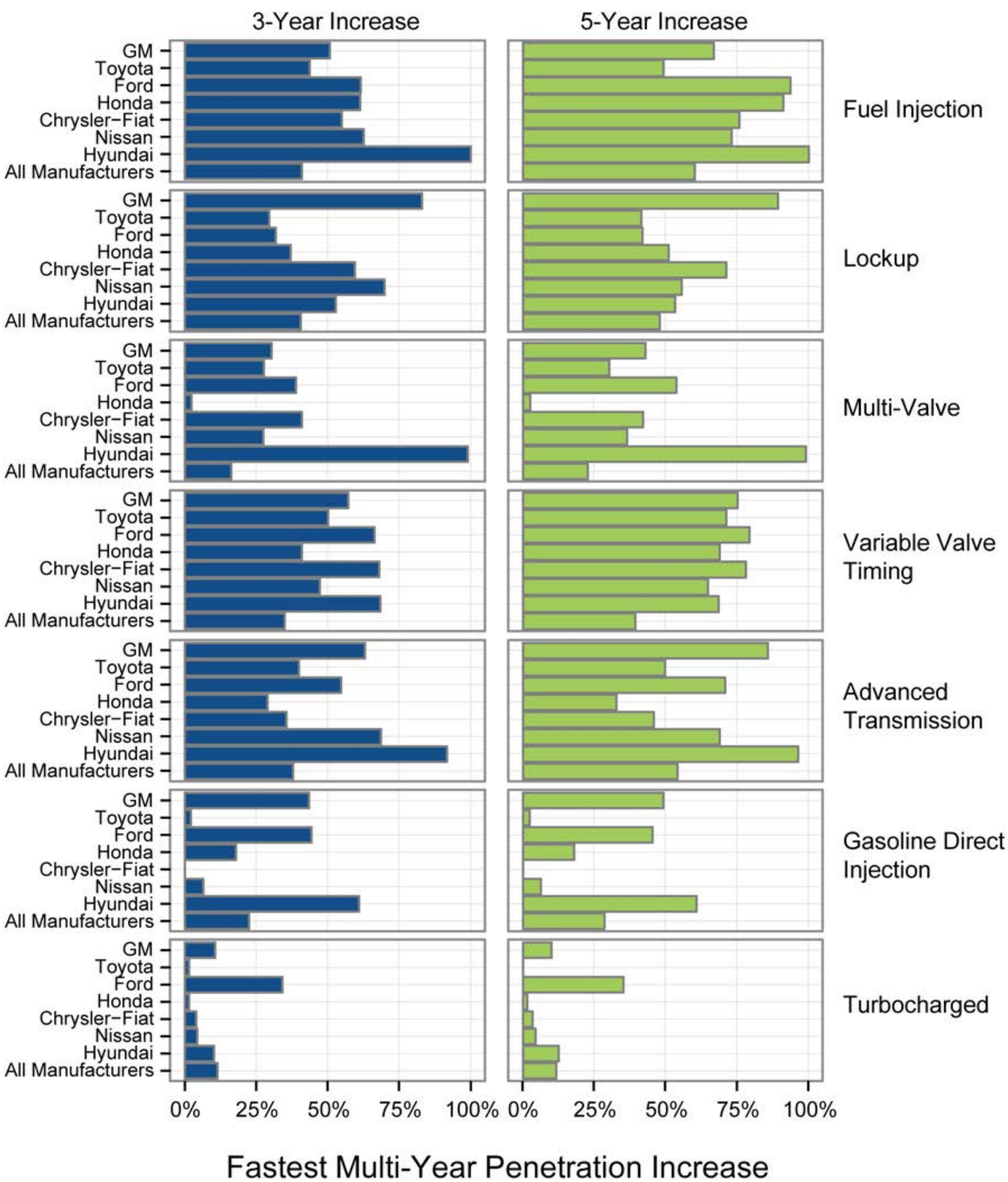

Figure 3. Maximum three and five year increases in adoption for key technologies

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One important note for Figure 3 is that, in some cases, the penetration increases may actually be artificially low, if manufacturers either entered the U.S. market with high technology penetration rates, or if they achieved high penetration rates before the Trends report began to collect data for that technology (for example, Honda was using multi-valve engines throughout its fleet when EPA starting monitoring multi-valve data in the mid-1980s).

Figure 4 takes a more detailed look at the introduction of VVT by manufacturers by combining aspects of both Figure 2 and Figure 3. For each manufacturer, Figure 4 shows the actual percent penetration of VVT over time for the individual manufacturer (solid red line) versus the average penetration for all manufacturers (dotted grey line), and compared to the maximum penetration by any manufacturer (solid grey line) over time. Figure 4 also shows when the largest increase in VVT penetration occurred over any one, three, and five year period as green, orange, and yellow boxes, respectively.

As shown in Figure 2, each manufacturer clearly followed a unique trajectory to adopt VVT. It took over 20 years for nearly all new vehicles to adopt VVT; however it is also very clear that individual manufacturers were able to adopt VVT across their own vehicle offerings much faster. All of the manufacturers shown in Figure 4 were able to adopt VVT across the vast majority of their new vehicle offerings in under 15 years, and many accomplished that feat in under 10 years. Figure 3 showed that all seven manufacturers achieved close to or above a 70% VVT penetration increase in a five year period, which is also highlighted in Figure 4 by the yellow rectangles. While reinforcing the fact that each manufacturer was able to quickly adopt VVT over a large portion of their fleet, Figure 4 also makes it apparent that the maximum adoption time period was in fact very different for each of the manufacturers, and that every manufacturer shown was able to adopt VVT into new vehicles at a rate faster than the overall industry data would imply. As noted earlier, the industry average represents both the rate that manufacturers adopted VVT and the effect of manufacturers adopting the technology at different times. Accordingly, the industry average shown in Figure 1 and Figure 4 does not represent the average pace at which individual manufacturers adopted VVT, which is considerably faster.

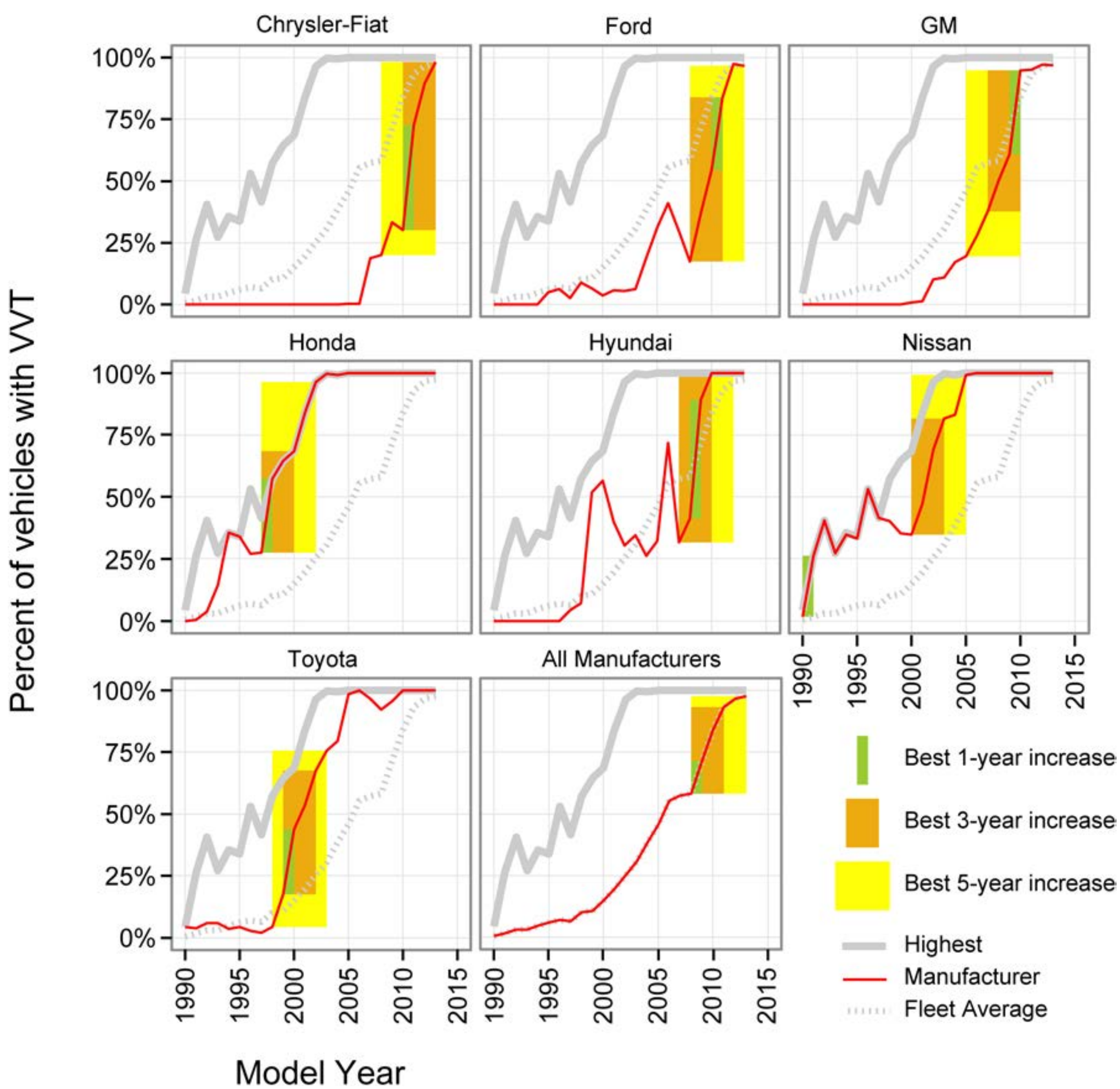

Figure 4. VVT adoption rates by manufacturer

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Figures 2, 3, 4 examine manufacturer specific technology adoption in different ways, but all three clearly support the conclusion that some manufacturers have been able to adopt technology much faster than industry-wide data suggests, and that there is significant variation in how individual manufacturers have adopted technology.

Technology Adoption in the Last 5 Years

Over the last five years, engines and transmissions have continued to evolve and incorporate new technologies. Figure 5 shows the penetration of several key technologies in MY 2008 and the projected penetration for each technology in MY 2013 vehicles. Over that five year span, VVT increases almost 40%, GDI by almost 30%, and 6 speed transmissions by over 40% across the entire industry. These are large changes taking place over a relatively short time. As shown in Figures 2 and 3, some individual manufacturers are adopting these technologies faster than the industry as a whole.

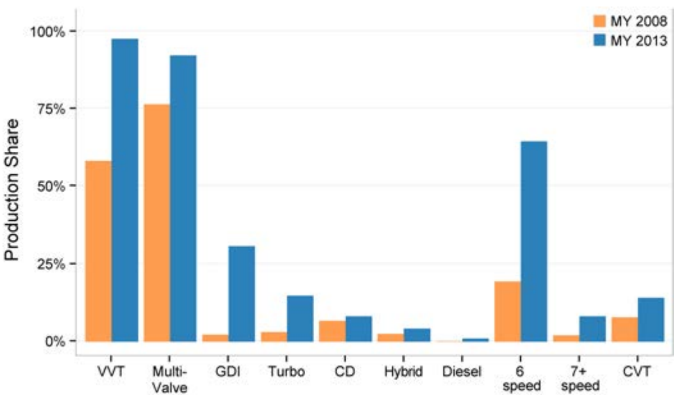

Figure 5. Five year change in light-duty vehicle technology penetration share

Conclusions

Individual manufacturers have been able to adopt new technologies at faster rates than previous industry-wide analyses have shown. Additionally, any variation between manufacturers for given technologies can be masked when only evaluating industry-wide trends. As the data in this paper suggests, adoption by individual manufactures is generally more rapid than has previously been reported for the overall industry, and it is clear that the penetration of important technologies has grown significantly over the last 5 years.

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Definitions/Abbreviations

CVT - continuously variable transmission

EPA - Environmental Protection Agency

GDI - gasoline direct injection.

VVT - variable valve timing

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