Automotive CO_2 Emissions Characterization by U.S. Light-Duty Vehicle Platform

Revised Manuscript for TRB, 15 November 2004

Feng An,[1] John DeCicco,[2*] and Huiming Gong[1]

[1]Energy and Transportation Technologies, LLC
42977 Ashbury Drive
Novi, MI 48375
248-347-9004
fengan@ameritech.net
hmgong@geichina.org

[2]Environmental Defense
6327 Todds Lane
Dexter, MI 48130
734-424-3742
jdecicco@edf.org

*corresponding author

ABSTRACT

Raising the fuel economy of automobiles to lower carbon dioxide (CO_2) emissions affects many aspects of vehicle design. Automakers organize their production using platforms, representing shared engineering across different models. A platform level of aggregation is therefore useful when examining the opportunities for and impacts of redesign. This paper explores the CO_2 emissions-related characteristics of major platforms in the U.S. market, using data for model year 2002.

The top 30 platforms were found to hold 69% of sales and emit 72% of the annualized CO_2 contribution of the model year 2002 new light vehicle fleet. Variations of up to 35% in vehicle weight were observed for models within a given platform. The within-platform variation of CO_2 emissions rate ranged up to 45% for all platforms among the top 30, except a platform including diesel engines, which had a 67% variation. Across major platforms, average CO_2 emissions rates varied by a factor of 2.3 from lowest to highest. Powertrain efficiency, as indicated by ton-miles per gallon, varied by 40% across platforms, with both the lowest and highest values being seen in truck platforms. This metric averaged barely 4% lower for truck compared to car platforms (statistically insignificant) and in fact, platform average ton-miles per gallon was uncorrelated with platform average weight.

Although examining CO_2 reduction potential was beyond the scope of this exploratory analysis, these results provide a foundation for performing such assessments at the platform level, which closely reflects how automotive product planning and production are organized.

INTRODUCTION

The need to improve light duty vehicle fuel economy is motivated by concerns about carbon dioxide (CO_2) emissions contributing to global climate change and petroleum demand contributing to economic and security risks. To minimize the costs of design changes that can improve fuel economy, technology improvements and related design changes are best made in line with ongoing product cycles. Although minor design refinements can be made on an ongoing basis, automakers organize their product development activities so as to stagger major engineering work, retooling investments, and supplier contracts across their vehicles lines. Therefore, understanding the potential for design change and its cost implications requires not only assessment of technologies in terms of their engineering, but also of how such changes would have to be implemented.

Well considered fuel economy improvement strategies should target the largest sources of fuel consumption and CO_2 emissions across the vehicle market. Cost and market acceptance considerations affect the degree of reduction achievable in different types of vehicles. A useful starting point for evaluation is a baseline characterization of vehicle fuel use and CO_2 emissions according to vehicle production platform, which is the motivation for the analysis reported here. Because CO_2 emissions are proportional to fuel consumption (the inverse of fuel economy) when holding the fuel fixed, analysis in terms of CO_2 emissions provides an appropriate picture of the vehicle market whether the main concern is global climate change or energy demand.

To date, published analyses addressing strategies for increasing fuel economy have examined individual technologies, groups of technologies, particular vehicles or classes of vehicles, or aggregations representing broadly defined fleets such as cars vs. light trucks or domestic vs. imported models *(1,2,3,4)*. A limitation of such analyses is that they do not represent how the industry actually organizes vehicle production. Automakers build most vehicles as variations of platforms that share major chassis and powertrain components. As flexible production methods advance and increasingly global firms balance scale economies with the competitive value of product differentiation, an analysis of CO_2 emissions linked to how production is organized may offer insights how technology can be changed for higher fuel economy and lower CO_2 emissions. Such analysis could also be useful for evaluating policies that apply to a subset of the market, such as California or groups of states, or that seek to subsidize technology change through tax credits or other mechanisms.

The Evolving Nature of Automotive Platforms

The concept of automotive platform cannot be defined precisely because it varies not only among firms, but even across products and through time in response to changing market conditions and changing approaches to manufacturing.

Although numerous cases could be given, a good example of an evolving high-volume platform application is that of Ford's F-150 pickup truck, which itself has been the top selling U.S. nameplate for many years running. The company introduced the Ford Expedition in 1996 and similar but more luxurious Lincoln Navigator in 1997 by building these large SUVs on the F-150 platform. However, market pressures led to the SUVs being redesigned in 2002, just over a year ahead of the F-150 redesign. Nevertheless, Ford is returning the vehicles to a common platform in model year (MY) 2007 in order to regain greater economies of scale *(5)*. As when the SUVs were first introduced, the vehicles will share many front-end components. But the SUVs will have an independent rear suspension for a softer ride, while the F-150 retains the solid real axle appropriate for a traditional pickup truck (among other differences). These vehicles also share major powertrain options, such as engine architectures; again, there can be variations in some aspects (such as valvetrain) while others elements (the basic blocks, pistons/cylinders, and displacements) are shared.

The basic notion of platform is that of commonality, generally covering shared parts and technologies but extending more broadly to cover any collection of a firm's assets that is shared among a set of its products *(6)*. Thus, the commonality of a platform can involve "soft" assets such as processes, knowledge, people, and relationships as well as "hard" items such as chassis or underbody components and other structural elements. At one time, a platform referred to a common chassis and body structural elements defined by the "hard points" for an assembly line. But flexible and robotic manufacturing techniques have long since superseded the traditionally constrained elements of a vehicle's structure that held a given platform to certain pre-defined dimensions. Similar principles of commonality also apply to sharing of engines or major engine components, as well as transmissions, electronics components, and other parts beyond those related to the chassis and body structure.

Today, increasing competition makes it difficult to profit from "cookie cutter" products produced with only relatively minor variations across many hundreds of thousands of units annually. A multiplicity of lower volume and niche models is much more important, as witnessed by the proliferation of nameplates that now exists in the market. Yet seeking underlying commonality is crucial for cost competitiveness. A key aspect of modern platform strategies is an organized degree of sharing for parts that are "hidden" in terms of customer impression and not important for brand identity *(7)*. Thus, some firms now shy away from using the term "platform," referring instead to use of a common "architecture" or even simply "shared technology" *(8)*. The key concept that remains is that of having a strategy to hold down costs through economies of scale while simultaneously reaping the marketing advantages of product differentiation. For convenience in this discussion, we retain use of the word platform as it is still commonly used by the industry and trade press to describe products sharing major elements.

Many of the technologies and techniques needed to improve fuel economy are applicable at the levels of commonality that correspond to both hard and soft assets shared within a platform. The flexibility and modularity now incorporated into platform strategies may enable cost-effective implementation of new designs for particular models or model variants within a platform, while leaving other models unchanged. On the other hand, more significant changes (such as major use of new structural materials and techniques) may only be cost-effectively implemented across an entire platform. The CO_2 emissions characterization by platform developed here can provide a foundation for "what if?" scenario analyses that explore such options.

METHODOLOGY

Characterization of CO_2 emissions by vehicle platform entails use of data on vehicle production and sales as well as fuel economy. This paper reports results for a single year, model year 2002, which is the most recent year for which finalized data were available from EPA and NHTSA as of the time of writing. Both average CO_2 emissions rates and aggregate annualized CO_2 emissions estimates are calculated. No existing data bases provide all of the information in one place, so a key aspect of the effort entails matching and cross-checking different sources of data. Given that automotive data have not been previously examined in this manner, it is not surprising that potential anomalies or inconsistencies may appear. We attempted to resolve these by comparing the 2002 data to that for previous years, but some issues remain unresolved and are left for future work.

Data Sources

Trade data, as given by *Automotive News* and Ward's, provide a source of information on the number of units built in North America for major platforms. However, these data do not include fuel economy or other technical parameters needed to characterize CO_2 emissions. Therefore, we turn to the EPA and NHTSA data bases used for CAFE compliance and related analysis. Although these government data bases term the annual volume number "production," what it really represents is U.S. sales during the model year.

The two primary sources (trade data and government data) differ in several ways. The CAFE data are given by model year, a time period that can vary in beginning and ending date, as well as duration, from year to year and model to model. The trade data are given on a calendar year basis. The CAFE volumes represent sales in the United

States, including vehicles produced in North America as well as vehicles imported from other locales. Production data from trade sources include only vehicles with final assembly in North America (United States, Canada, and Mexico). The trade information also gives factory location, so it would be possible to break out U.S. production, but that is not of interest for this analysis. Calendar year sales data from trade sources provide another point of reference, which we used to cross-check in broad terms the government data. Model year data from EPA were used for the CO_2 emissions rates and carbon emissions totals reported here.

The first order of business is to identify nameplates that should be grouped together for platform-level analysis. *Automotive News (9)* and Ward's *(10)* give slightly different platform definitions, in terms of vehicles included; we used the automakers' platform codes as listed by Ward's to identify the major platforms in our tables. To develop our results, we used the trade data to assign each nameplate in the CAFE data base a platform code, enabling us to compute averages and other statistics by platform (regardless of the place of production).

Because we rely on the CAFE data, the population of vehicles analyzed includes only cars and light trucks up to 8,500 pounds gross vehicle weight (GVW). Both EPA and NHTSA work from data collected by EPA and then transmitted to NHTSA for purposes of CAFE calculations. EPA separately performs additional data clean-up and quality assurance for producing the agency's *Fuel Economy Trends* reports *(11)*. One difference between the EPA *Trends* data and NHTSA's official CAFE data is that the latter include regulatory adjustments, such as the dual-fuel vehicle credits. EPA's data, on the other hand, are designed to estimate a consistent time series of average fuel economy levels, excluding regulatory adjustments and therefore better suited for calculating CO_2 emissions. We therefore use the EPA version of the data for developing our platform-level fuel economy and CO_2 emissions statistics. However, EPA declined requests to share its complete data base, withholding in particular the weight (either curb or test) data. Because weight is important for exploring variations in CO_2 emissions, we rely on the NHTSA data for that portion of our analysis, back-adjusting the dual-fuel credits as needed.

Key Assumptions

We present results based on platform-average fuel economy and CO_2 emission rates, as well as annualized platform-based carbon emission contribution. To estimate annualized CO_2 emissions, assumptions are needed regarding vehicle usage, in-use fuel economy, and fuel characteristics. We adopt assumptions similar to those used in an earlier report characterizing "carbon burdens" (annualized aggregate CO_2 emissions reported on a carbon-mass basis) by firm and market segment *(12)*.

We assume annual vehicle usage of 12,000 miles per year; this value is a rounded average of recent household vehicle survey results (*13*, Table 8.11). It represents a lifetime average and so is lower than the 15,000 miles per year typical of new vehicles. Although light trucks historically have seen greater annual usage than cars, we did not assume different usage levels for car and truck platforms. Such an adjustment would further raise the estimated CO_2 emissions contribution of truck platforms.

We assume a CO_2 emissions factor of 8.8 kg/gallon, a nominal value for gasoline reflecting only direct emissions rather than full-fuel-cycle impacts. Per-vehicle rates are given in grams per kilometer (g/km) on a CO_2 mass basis. Aggregate emissions (carbon burdens) are reported in millions of metric tons on a carbon mass basis (MMTc), where one carbon mass unit equals 12/44 of a CO_2 mass unit. We assume a fuel economy shortfall of 15% for all vehicle types, corresponding to the average fuel economy label adjustment relative to laboratory test values. We apply this adjustment to the unadjusted 55% city, 45% highway composite fuel economy value reported for CAFE purposes. Although there is evidence that average shortfall is now higher than 15% and that it can vary by vehicle type, official updated adjustment factors are not yet available. Because the diesel share of the U.S. fleet under 8,500 pounds fleet is quite small -- only 0.1% of the market in MY2002 *(11)* -- we do not use a separate emissions factor for diesel vehicles. Alternative fuel use is negligible and so it is also ignored here.

PLATFORMS IN THE U.S. AUTO MARKET

At last count, 267 different nameplates were sold in the U.S. car and light truck market *(14)*. The term nameplate refers to the model name given to a vehicle by its manufacturer, not counting body style or trim variants. The proliferation of nameplates is driven by marketing considerations. The number of nameplates has doubled over the past three decades and growth can be rapid in popular market segments. For example, the number of SUV nameplates rose from 33 in 1997 to nearly 100 in 2004 *(14)*.

Manufacturing cost considerations, however, dictate that multiple nameplates be built on a single platform, or at least share many components, particularly for high-volume vehicles. Thus, the number of platforms is much smaller: 77 platforms underpin vehicles produced in North America (including Canada and Mexico) and account for the vast majority of sales in the U.S. market in 2002 *(9)*. Some global platforms have production in both North America and overseas and are therefore included among the 77 on which we focus here. A smaller number of distinct platforms produced overseas underpin additional sales; a tabulation of these platforms is not readily available in U.S. trade statistics and we did not include them in our analysis. As discussed below, an even smaller number of platforms accounts for a large fraction of sales. Indeed, the most extensive platform, that for GM's full-size pickup trucks and SUVs (GMT800), alone accounted for 10% of all North American light vehicle production and 8% of U.S. light vehicle sales in calendar year (CY) 2002 *(9, 15)*.

Caution is needed when making comparisons across firms, however, due to differences in platform definition. This issue is most significant for the full-size trucks, which are also among the highest volume platforms. GM and DaimlerChrysler do not make a platform distinction between the under-8,500 lb (Class 2A, ½ ton) and 8,500-10,000 lb (Class 2B, or ¾ and 1 ton) versions of their large pickup-based vehicles. These vehicles include the Chevy Silverado and GMC Sierra pickups plus the corresponding SUVs (Cadillac Escalade, Chevy Avalanche, Suburban, and Tahoe and GMC Yukon as of 2002). DaimlerChrysler does not offer an SUV based on its full-size pickup, the Dodge Ram, and its Class 2A and 2B versions of the Ram are counted on the same platform in the trade statistics. Ford, on the other hand, separated the Class 2B versions of its F-series vehicles beginning in 1996. Its light-duty platform (PN96) includes the F-150, the Ford Expedition, and Lincoln Navigator. Ford's super-duty platform (PHN131, not tallied here) includes the F-250 and F-350 pickups plus the Excursion SUV.

Table 1 lists the top 30 platforms in order by U.S. sales during model year 2002 based on the NHTSA and EPA data bases. Platform codes are those reported by Ward's *(10)*. Also listed are the nameplates (makes and models) associated with each platform and the North American production of vehicles using the platform during calendar year 2002 as reported by *Automotive News (9)*. Readers can reference this table to link platform codes used in subsequent tables and figures to particular makes and models. The top 30 platforms ranked by U.S. MY2002 sales accounted for 69% of total sales. The top 30 platforms ranked by production, which are not identical to the top 30 by sales, accounted for 81% of North American CY2002 production. Of the top 30 by sales, 16 are light truck platforms and 14 are car platforms. However, car platforms now include many vehicles classified as light trucks for purposes of CAFE regulation; examples include minivans and sport wagons (or "crossovers") such as Toyota's Sienna and RX300 derived from the Camry platform; Nissan Quest and Mercury Villager on the Altima platform; and DaimlerChrysler's PT Cruiser derived from the Neon.

Although the United State dominates the North American market, accounting for 86% of CY2002 sales *(10)*, the sales values in Table 1 may not closely correspond to the production numbers for a variety of reasons, including imports and exports as well as the fact that model year and calendar year do not match. For example, trade data give CY2002 U.S. sales of 17.1 million, compared to MY2002 sales of 16.1 million based on the NHTSA data. In many instances, particularly for U.S. automakers, sales (which are U.S.-only) are lower than production because of sales elsewhere in North America or overseas exports. For some Asian firms, North American production is lower than U.S. sales because some of the vehicles on the platform are imported.

Figure 1(a) shows the cumulative distribution of U.S. sales by platform, showing only the top 30 platforms, which each tallied close to 200,000 or more sales in 2002. As expected, high-volume platforms account for the bulk of sales; the top 20 all had sales of at least 250,000 units. Highlighted bars show that the top 5 account for 24% of sales, the top 10 for 38%, the top 20 for 56%, and the top 30 for 69% of sales based on MY2002 data.

CO_2 EMISSIONS CHARACTERIZATION BY PLATFORM

Table 2 lists key CO_2 emissions related statistics for the top 30 platforms. Platform-average fuel economy is shown (using unadjusted composite fuel economy values), along with the annualized CO_2 emissions ("carbon burden") of the platform as defined above. Also listed are cumulative sales shares (as shown in Figure 1a) and cumulative CO_2 emissions contributions.

Domestic truck platforms are among those having the highest volume overall. Because their fuel economy is lower than the overall light duty average, their positions in the top of the table push the cumulative CO_2 emissions distribution higher than the sales distribution as one goes through the list. These results are shown in Figure 1(b). The number one platform, GM's full-size trucks (GMT800) with their 8% sales share, has 10% CO_2 emissions share. Going down the list the cumulative CO_2 emissions contribution share exceeds the sales share by at least two percentage points; all in all, the top 30 platforms account for 69% of model year 2002 sales and 72% of the CO_2 emissions contribution. These statistics help underscore the fact that modest fuel economy improvements in high-volume, low-fuel-economy vehicles can have a significant impact in reducing fuel use.

Variability within a given platform

Parameters related to fuel consumption and CO_2 emissions can vary significantly among the vehicles built on a given platform. While numerous physical and engineering factors determine a vehicle's CO_2 emissions rate, some key parameters are engine displacement and vehicle weight. These parameters and a few other powertrain parameters are readily available and consistently measured, and so provide a first-order view of the extent to which models built on the same platform differ in this area of interest. Other characteristics, especially those that determine weight (such as materials use and packaging efficiency), are more difficult to analyze due to lack of data.

Table 3 lists basic statistics for engine displacement, vehicle weight (equivalent test weight, ETW), and CO_2 emissions for the vehicles in the top 30 platforms in model year 2002. The NHTSA version of the CAFE data base was used for this analysis because it is the only one that includes vehicle weight in addition to fuel economy, sales, and engine characteristics by make and model.

Some basic determinants of variability are number of different engines used across a platform and the number of different body styles. These tallies and the number of different models for each of the top 30 platforms are given in the first section of Table 3. For models, we simply count distinct nameplates, not distinguishing the trimlines of a given nameplate. For example, the Cadillac Escalade counts as one model; in MY2002 it was available in three trims (base, ESV, and EXT). For body style, we distinguish between sedans, coupes, hatchbacks, wagons, and minivans; we also distinguish pickups, SUVs, and "SUTs" (sport-utility trucks, having a fully enclosed rear cabin plus a small open bed). The Escalade, for example, came in two distinct body styles: SUV (the base and longer ESV versions) and SUT (the EXT version, similar to the Chevy Avalanche).

Given the company's history as an aggregation of many brands, GM's platforms stand out in terms of the number of models. Seven different models (nameplates) were built on the GMT800 platform in model year 2002; this was before GM added an eighth nameplate, the Hummer H2, to the platform in July 2002 as an early MY2003 model. (Table 1 lists the nameplates associated with each platform as of MY2002.) GMT800 also used the greatest number (5) of different engines.

Toyota's Camry platform -- an example of a base architecture which substantially extends the traditional notion of platform through the use of the company's very flexible yet highly rationalized manufacturing technique -- yields five models, including both car-based ("crossover") SUVs and a minivan. Yet Toyota used only two different base engines among these Camry-derived vehicles. A given base engine (common block and displacement) can be made with distinct performance characteristics through use of different valvetrains, manifolds, and other "hard" and "soft" differences in tuning. For example, Toyota's 3.0L V-6 was available in both 210 HP and 220 HP versions that year; the other engine used in Camry platform derived vehicles, a 2.4L I-4, had several horsepower ratings depending on the application.

Variability according to physical parameters

Both engine displacement and performance influence fuel economy and CO_2 emissions. Thus, the two-to-four different engines commonly available among vehicles within a platform can span a broad range of powertrain characteristics, even without considering the transmission, which was not covered in this analysis. Drive type (front, rear, four, or all-wheel drive) is another factor, also unexplored here. Of the top 30 platforms, 5 used just one engine. Within some platforms, however, the variations in engine displacement can be substantial; we characterize the variation as the range of displacements (maximum - minimum) divided by the sales-weighted mean. The Dakota/Durango platform (DCX HB/N2) has four engines ranging from a 2.4L I-4 to a 5.9L V-8, a 75% variation. On the other hand, the five different engines used in GMT800 vehicles have but a 33% variation in displacement. The median variation in engine displacement was 26% for the top 30 platforms.

The variation of vehicle weight within a given platform is notably less than that of engine displacement, and also less than that for CO_2 emissions rate (discussed next). The median variation in weight was 17% for models in the top 30 platforms. The largest variation was found in two Ford platforms, 35% for the company's full-size truck platform, which includes the F-150, Expedition and Navigator (but as noted earlier, excludes Ford's Super Duty full-size pickups and the Excursion), and 34% for Ford's compact pickup platform, which includes the Ranger and Mazda B-series pickups plus the 2-door Explorer Sport and Sport Trac. By 2002, Ford's Explorer SUV and its Mercury Mountaineer twin, which had originally been built on the Ranger platform, were put on a separate platform (U152), which now includes the 4-door versions of the SUV. The variation in weight within this platform is smaller (11%) because all models share a single SUV body style. Because the Explorer Sport SUV and the Sport Trac SUT remain on the Ranger platform (PN40), it carries three different body styles and has a notably larger variation in weight. Some high-volume platforms have little variation in weight. For instance, GM's W2 platform (Buick Regal, Chevy Impala, etc.) shows only a 4% variation across its models.

Numerous vehicle design factors contribute to fuel economy and CO_2 emissions. Therefore, the variation of CO_2 emissions rate might be expected to be larger than that for any individual factor. However, many factors correlate; for example, larger engines are more likely to be found on heavier vehicles. The median variation in CO_2 emissions rate is 20% for the top 30 platforms listed in Table 3, less than the 26% reflected for engine displacement. The highest variation in CO_2 emissions rate within a platform is 67% for the VW A4 (Jetta and New Beetle), which is the only one having a diesel engine option. Among the remaining platforms, it varied by up to 45%, with the largest variations being seen in the Big 3's compact pickup platforms. Interestingly, the CO_2 emissions rate variation across the GMT800 vehicles is only 23%, less than that of either engine displacement or vehicle weight for the models covered (only those under 8,500 lb GVW). The minimum variation in CO_2 emissions rate is 6% for the Honda CYR platform (Odyssey, Pilot, and Acura MDX), which has only one engine and only a 5% variation in weight across its models. Across the top 30 platforms, average CO_2 emissions rates varied by more than a factor of two from the lowest (Honda Civic) to highest (Dodge Ram). Truck platforms from among the top 30 had a CO_2 emissions rate averaging 44% higher than that of car platforms, somewhat more than the MY2002 market-wide comparison of 41% higher CO_2 emissions for light trucks *(11)*.

Comparisons to Federal classifications

The variations in CO_2 emissions rates for platforms can be compared to those within vehicles classes as defined in EPA's *Fuel Economy Trends* report *(11)*, for example. Although government classifications can poorly match market segmentations, they are a known point of reference. Also, EPA's nameplate lists (*11*, Appendix B) are useful for comparing similar offerings by different firms even though they are averaged across a nameplate.

Looking at large pickups (considering both 2- and 4-wheel drive models together), for example, EPA's MY2002 nameplate averages span a 42% range of CO_2 emissions rates (i.e., the emissions rate of the least fuel efficient nameplate is 42% greater than that of the most efficient). EPA classifies some versions of the Dodge Dakota and Nissan Frontier as large pickups even though they are commonly considered compact pickups; the variation in nameplate average CO_2 emissions rate for large pickups is reduced to 32% if these two models are excluded. Thus, variations within platforms are of a comparable magnitude to this number (32% for Dodge Ram platform, 35% for the Ford F-150 platform, but again, only 23% for the GMT800 family). For compact pickups (combining EPA's "small" and "midsize" pickup classes), the variation among nameplate average CO_2 emissions rates is 42%, comparing closely to 44%-45% variation seen in our analysis of GM's Chevy S-10, Ford's Ranger, and the Dodge Dakota based platforms. Thus, the within-platform variations identified in our analysis appear similar in magnitude to those derived from EPA's within-class nameplate listings.

The variability in CO_2 emissions rate within a platform can in one way be interpreted as indicating the flexibility to reduce CO_2 emissions by shifting the mix of models within the platform, perhaps to models using the most fuel-efficient powertrains in the platform. Such an approach may seem to violate the principle of transparency, entailing a potential trade-off of consumer utility. However, this need not be the case if it is accomplished over a period of years spanning a platform generation (between major redesign), during which the model mix is likely to be shifting anyway. Given an ongoing technical efficiency improvement trend (see *11*), a modest reduction in CO_2 emissions rate might be realized by emphasizing the more fuel efficient variants of a platform. All models are otherwise likely to become more capable (in power or size) than they were in a previous generation if powertrain, materials, and packaging efficiency improvements follow recent trends. This platform-based view of CO_2 reduction potential is analogous to a best-in-class assessment, except that it is based on variations within a firm's platform rather than variations across models of all makes within a pre-defined class.

Significant technology application in one or a few models can produce a greater variation of a platform's CO_2 emissions rate, suggesting the potential to reduce emissions via greater diffusion of the improved technology across the platform. Such a situation is seen for the diesel engine used in the Volkswagen platform. None of the top 30 MY2002 platforms had hybrid-electric options (the Honda Civic Hybrid was a MY2003 model even though sales started in March 2002), but that technology could provide a similar example. Analogous explorations might also identify a reduction potential based on the use of more advanced conventional engine technologies in certain models of a platform. Such investigations are left for future work.

Engine characteristics and powertrain efficiency comparisons

Table 4 lists sales-weighted, platform-average engine size, peak power, and specific power (peak power per unit of engine displacement), as well as platform-average vehicle equivalent test weight (ETW), CO_2 emission rate, and ton-mpg (test weight times mpg). As expected, average engine size and peak power vary greatly from platform to platform: while the number one platform GMT800 has the highest average engine size (5.2 Liter [L]) and rated power (281 HP), the Honda Civic platform has the smallest average engine size (1.7L) but the GM Saturn S platform has the smallest average power (111 HP). At the bottom of the table are the separate car/truck averages for the top 30 platforms, followed for comparison by the overall car and light truck fleet averages from EPA *(11)*.

Figure 2(a) plots average engine peak power as a function of engine size for the top 30 platforms. Five out of seven top GM platforms have average engine sizes over 3.5L, as do four DCX platforms. Reflecting the breadth of its lineup, GM also has two platforms from among the top 30 with average engine sizes under 2.5L. A fitted trend line is also shown for reference. GM's lineup also shows some of the greatest offsets both above and below the trend line. The engines used in the GMT352 vehicles (S-10, etc.) fell well below the line, averaging 3.8L and 45 HP/L; these engines have since been replaced, as have the compact pickups themselves when the Chevy Colorado and GMC Canyon were introduced in MY2004. The only engine (4.2L) used in GMT360 vehicles (Trailblazer, etc.) is notably above the line and produces 65 HP/L. This engine (GM's Vortec 4200 inline six) has 4-valves per cylinder and double overhead cams with variable cam phasing. Most of the non-Big-3 platforms (from among the top 30 shown here) are near or above the trend, reflecting their generally high degree of refinement as well. Analyses by EPA *(11)*, among others, have reported on such technology trends, so we do not examine them further beyond this characterization of variability exhibited at the platform level.

Specific power (HP/L) is a common index related to an engine's efficiency and performance; it is plotted here in Figure 2(b). Although some GM engines have relatively high specific power and their platform averages are above the trend, a number of U.S. truck-based platforms had average specific power only in high 40's to low 50's range as of MY2002. Japanese car-based platforms (including car-based SUVs and minivans) have engine specific powers near 70 HP/L, as does the VW platform; the Honda Civic platform had the highest at 72 HP/L. Japanese pickup platforms, however, averaged in the low 50's HP/L, similar to a number of their Big 3 counterparts. The majority of Big 3 platforms have engine specific powers in the 50-60 HP/L range, although several are notably higher, such as the DCX JR/FJ (Stratus, Sebring) at 69 HP/L and the Ford U204 (Escape) at 67 HP/L.

The downward trend of specific power with engine size Figure 2(b) reflects the significant non-zero intercept of the power vs. displacement relationship of Figure 2(a). We do not show a trend fit in Figure 2(b); more pertinent would be the residuals from fits like that of Figure 2(a). Such analysis is better done at the engine rather than platform level and again because this issue has been studied elsewhere it is not pursued further here.

The platform average vehicle test weight varies from about 2,700 lbs for GM's Saturn S to more than 5,500 lbs for the GMT800. Platform-average CO_2 emission rates vary greatly as well, from about 140 g/km for Honda Civic to 320 g/km for the Dodge Ram. Generally speaking, there is a good correlation between CO_2 emissions vs. engine size and vs. vehicle weight. However, deviations from weight-based trends exist and can be seen by examining vehicle powertrain efficiency indices.

Ton-miles per gallon (ton-mpg) is a good, although not perfect, index for powertrain efficiency *(16)*. Ton-mpg is the reciprocal of fuel consumption normalized by vehicle mass, and so isolates the non-mass-related aspects of a vehicle's technical energy efficiency. It is dominated by the powertrain, but the ton-mpg metric also reflects differences in rolling and aerodynamic resistances. That is to say, lowering these resistances will serve to increase ton-mpg even if powertrain efficiency is fixed. Nor does it account for vehicle acceleration performance, often characterized by power/weight ratios (not examined here).

The last column in Table 4 shows that vehicle ton-mpg values vary from 36 for the DCX KJ (Jeep Liberty) platform to 50 for Honda CYR platform (Odyssey, Pilot, MDX). Thus, among the top 30 platforms examined here, the most efficient rates 40% higher than the least efficient. The average truck platforms among the top 30 are barely 4% less efficient than the car platforms, an insignificant gap similar to the 5% difference seen in the overall market (bottom lines of Table 4). Some truck platforms, such as those of the Chevy Silverado and Dodge Caravan rate well by this metric, while some car platforms, such as those of the Chevy Cavalier and Dodge Neon, rate poorly.

Figure 3(a) plots the average ton-mpg from the highest to the lowest for the top 30 platforms. After the Honda CYR platform, the next highest ratings were those of the Honda Civic and GMT250 (Aztek, Rendevous) platforms. The Toyota Camry, GMT800 (Silverado), and DaimlerChrysler's minivan platform (Dodge Caravan and siblings) ranked 4th–6th while two DCX other platforms (Liberty and Grand Cherokee) ranked last. Also ranked relatively low are GM's J2 platform (Chevy Cavalier) and DaimlerChrysler's PL2 platform (Neon, PT Cruiser). In contrast, Ford's compact car platform, CW170 (Focus), has a ton-mpg rating 10% higher than those of its domestic competitors. This situation reflects the fact that in MY2002, Focus was a relatively fresh design, while Neon and Cavalier were relatively dated. Similarly, the S-10 and Ranger, as well as the Nissan Frontier/Xterra, compact pickup-based platforms were also relatively dated in comparison to the new or recently redesigned platforms on the market. For example, GM's newer full-size pickup platform (GMT800, Silverado) has a ton-mpg metric 16% higher than its compact pickup platform (GMT352, S-10). On the other hand, Ford's full-size light trucks (PN96, F-150, etc.), which average 43.8 ton-mpg, were only 8% higher than its Ranger-based platform (PN40); MY2002 was late in the F-150's model cycle (it was updated in MY2004).

Another view of the variation is Figure 3(b), which plots ton-mpg against vehicle weight. The scatter is pronounced, with average powertrain efficiency showing no correlation to average platform test weight (r = -0.04). There are wide differences among trucks, reflecting some of the comparisons pointed out above. This spread is notable in that it reflects truck-to-truck, rather than truck-to-car, platform comparisons. The most efficient truck platform--and also the most efficient overall in terms of ton-mpg--was the Honda CYR (Odyssey), with a powertrain efficiency 40% higher than that of the least efficient platform, the DCX KJ (Jeep Liberty). It was 24% higher than that of the similar weight Ford U152 (Explorer) platform while including a competing mid-size SUV (Pilot) and a luxury SUV (Acura MDX). Such variations in ton-mpg ratings suggest a CO_2 emissions reduction opportunity based on the potential to bring less efficient platforms up to the level of higher rated platforms.

CONCLUSION

Examining vehicle characteristics by platform offers a new approach for looking at the factors that determine automobile CO_2 emissions. Because platforms represent the way vehicle production is organized, it provides a basis for examining design changes at a level related to industry's redesign process. The variability both within and across platforms hints at ways to estimate potential CO_2 emissions reductions.

Developing a data base for platform-based analysis is relatively straightforward but tedious, because it involves matching data collected by the government for CAFE purposes with the separate production and sales data reported by the industry through trade channels. This task was carried out for model year 2002, the most recent year for which sufficiently complete data were publicly available. It was possible to examine key powertrain parameters within and across platforms; however, readily available data do not allow examination of other important variables, such as those related to materials use or packaging efficiency (as related to vehicle weight), size and other utility metrics, or technical parameters such as tire rolling resistance, aerodynamic attributes, and so on.

The highest volume platforms in the U.S. market contribute, by a modest margin, disproportionately to CO_2 emissions. This observation is consistent with the fact that pickup trucks and their related SUVs are among the vehicles produced in the highest volumes on a given platform. Thus, the top 5 platforms accounted for 24% of sales and 26% of the annualized CO_2 emissions contribution; the top 30 platforms accounted for 69% of sales and 72% of the CO_2 emissions for model year 2002. There is significant variability among the number of models, as well as distinct engines and body styles, linked to a single platform.

The largest platform in the market, that of GM's full-size pickups and their related SUVs, offered 7 different models in 2002, using 5 different engines and employed in vehicles of 3 different body styles. This platform alone accounted for 10% of the model year 2002 annualized CO_2 emissions contribution ("carbon burden"). However, we also found that this platform was one of the more efficient, as assessed when comparing both CO_2 emissions rate relative to engine displacement and average powertrain efficiency as measured by ton-mpg. Some platforms are much more restricted in variation among models; for example, the most efficient platform overall was the Honda CYR, using one engine for a minivan and two SUV models. The least efficient platforms were those of compact pickup trucks. On average among the top 30 platforms, however, trucks had an average ton-mpg rating only slightly lower than that of cars. This is explained by the fact that some high-volume truck platforms were among the more efficient (e.g., GM full-size pickups, DaimlerChrysler minivans) while some high-volume car platforms were relatively inefficient (GM and DaimlerChrysler compact cars).

Within platforms (examining the only top 30, high-volume platforms), vehicle weight was found to vary by as much as 35% (between the lightest and heaviest models on the platform, relative to the platform's sales-weighted mean weight). The median variation in weight was 17%. Engine displacement varied as much as 75%, with a median 26% variation within a platform. Vehicle CO_2 emissions rates varied by a median 31% within platforms, ranging up to 55% for all but one platform. The VW Jetta/New Beetle platform exhibited a 67% variation in CO_2 emissions rate among models because it includes diesel engine versions.

This initial exploration of platform-level CO_2 emissions related characteristics did not attempt the more detailed technology assessment needed to analyze how platforms might evolve. It does, however, provide a baseline for such analysis as well as suggest new techniques for technology assessment that more closely match how auto manufacturing is organized than those that have been commonly reported to date.

ACKNOWLEDGMENTS

The authors are grateful to Freda Fung, John German, Robert Heavenrich, and anonymous reviewers for comments and suggestions, and to the Energy Foundation by which this work was supported in part. The authors remain wholly responsible for the content and conclusions.

REFERENCES

1. Documentation of Attributes of Technologies to Improve Automotive Fuel Economy. Report prepared for Martin Marietta Energy Systems. Arlington, VA: Energy and Environmental Analysis, Inc. October 1991.
2. An, F., J. DeCicco, and M. Ross. Assessing the Fuel Economy Potential of Light-Duty Vehicles. SAE Paper No. 2001-01FTT-31. Warrendale, PA: Society of Automotive Engineers, 2001.
3. Teotia, A., A. Vyas, R. Cuenca, F. Stodolsky, J. Eberhardt. CAFE compliance by light trucks: economic impacts of clean diesel engines. Energy Policy 27: 889-900, 1999.
4. National Research Council. Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. Washington, DC: National Academy Press, 2002.
5. Wilson, A. Ford truck plan is mixed bag for suppliers. *Automotive News,* June 21, 2004.
6. Hodges, P. Issues in Automotive Platform Strategies. SAE Paper No. 2004-01-0483. Warrendale, PA: Society of Automotive Engineers, 2004.
7. Birch, S. Not so easily diesel. *Automotive Engineering* 111(12): 80-82, December 2003.
8. Carney, D. Platform Flexibility. *Automotive Engineering* 112(2): 147-149, February 2004.
9. North American Car and Truck Production, calendar year 2002 report. *Automotive News* (www.automotivenews.com, accessed January 10, 2003).
10. U.S. Domestic Car and U.S. Domestic Light Truck Platform Designations, *2003 Ward's Automotive Yearbook,* p. 163. Troy, MI: Ward's Automotive, 2003.
11. Hellman, K.H., and Heavenrich, R.M. Light-Duty Automotive Technology and Fuel Economy Trends, 1975 through 2003. Report EPA 420R-03-006. Ann Arbor, MI: U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Advanced Technology Division. April 2003.
12. DeCicco, J., and F. An. Automakers' Corporate Carbon Burdens: Reframing Public Policy on Automobiles, Oil and Climate. New York, NY: Environmental Defense, July 2002.
13. Davis, S.C., and S.W. Diegel. Transportation Energy Data Book: Edition 23. Report ORNL-6970. Oak Ridge, TN: Oak Ridge National Laboratory. October 2003.
14. Stein, J. So many nameplates. *Automotive News,* May 17, 2004.
15. U.S. Passenger Car Sales and U.S. Light Truck Sales, December and YTD, calendar year 2002 reports. Automotive News (www.automotivenews.com, accessed January 3, 2003).
16. An, F., and D. Santini. Mass Impacts on Fuel Economies of Conventional vs. Hybrid Electric Vehicles. SAE Paper No. 2004-01-0572. Warrendale, PA: Society of Automotive Engineers, 2004.

List of Tables and Figures

Table 1. Top 30 North American platforms ranked by U.S. sales in MY2002

Rank	Platform Designation	Firm and Nameplates	MY2002 U.S. Sales	CY2002 Production
1	GM GMT800	Chevrolet Avalanche, Silverado, Suburban, Tahoe; Cadillac Escalade; GMC Sierra, Yukon; Hummer H2	1,221,120	1,698,211
2	Toyota Camry	Lexus RX 330; Toyota Avalon, Camry, Solara, Sienna	808,798	523,605
3	Ford PN96	Ford F-150, Expedition; Lincoln Navigator	613,885	812,204
4	GM W2	Buick Century, Regal; Chevrolet Impala, Monte Carlo; Pontiac Grand Prix	595,633	702,738
5	Ford DN101	Ford Taurus, Windstar; Mercury Sable	573,245	692,914
6	Ford U152	Ford Explorer, Mercury Mountaineer	540,918	466,353
7	Honda CYR2	Honda Accord; Acura CL, TL	486,007	446,937
8	GM GMT360	Buick Rainier; Chevrolet TrailBlazer; GMC Envoy; Isuzu Ascender; Oldsmobile Bravada	427,314	446,138
9	DCX RS	Chrysler Town & Country, Voyager; Dodge Caravan	413,986	519,565
10	GM X130	Chevrolet Malibu; Oldsmobile Alero; Pontiac Grand Am	378,625	504,356
11	Ford PN40	Ford Ranger, Explorer Sport Trac, Mazda B series pickup	360,169	330,411
12	GM G	Buick LeSabre, Park Avenue; Cadillac DeVilIe, Seville; Oldsmobile Aurora; Pontiac Bonneville	339,360	331,088
13	GM J2	Chevrolet Cavalier; Pontiac Sunfire	338,706	404,735
14	Honda Civic	Acura EL; Honda Civic	329,778	392,006
15	Nissan FFL	Nissan Altima, Maxima, Quest; Mercury Villager	299,836	235,445
16	DCX PL2	Chrysler Neon, PT Cruiser; Dodge Neon	288,836	342,699
17	DCX DR	Dodge Ram pickup	287,513	465,925
18	GM T352	Chevrolet Blazer, S10; GMC Jimmy, Sonoma	285,062	288,081
19	DCX HB/N2	Dodge Dakota, Durango	257,534	284,088
20	Ford CW-170	Ford Focus	252,987	344,928
21	GM GMT250	Buick Rendezvous; Chevrolet Venture; Oldsmobile Silhouette; Pontiac Aztek, Montana	248,996	352,287
22	VW A4	Volkswagen Jetta, New Beetle, Cabrio	212,584	308,469
23	DCX WJ	Jeep Grand Cherokee	211,786	253,237
24	Ford U204	Ford Escape; Mazda Tribute	208,883	264,083
25	DCX KJ	Jeep Liberty	207,991	225,714
26	Honda CYR	Acura MDX; Honda Odyssey, Pilot	197,855	299,774
27	DCX JR/FJ	Chrysler Sebring; Dodge Stratus	196,165	249,672
28	Toyota Tundra	Toyota Sequoia, Tundra	193,008	186,507
29	GM Saturn S	Saturn SC, SL	191,727	110,968
30	Nissan PU98	Nissan Frontier pickup, Xterra	190,851	204,665

Source: compiled from *Automotive News (9, 15)* and Ward's *(10)*.

Table 2. CO2 emissions related statistics for the top 30 platforms in MY2002

Sales rank	Platform Designation	MY2000 Sales	Sales share	Cumulative sales share	Average MPG*	Carbon burden**	CO_2 share	Cumulative CO_2 share
1	GMT800 (Silverado)	**1,221,120**	**7.6%**	**8%**	**18.5**	**2.2**	**10%**	**10%**
2	Toyota Camry	808,798	5.0%	13%	27.6	1.0	4%	14%
3	Ford PN96 (F-150)	613,885	3.8%	16%	18.8	1.1	5%	19%
4	GM W2 (Impala)	595,633	3.7%	20%	27.7	0.7	3%	23%
5	Ford DN101 (Taurus)	**573,245**	**3.6%**	**24%**	**25.5**	**0.8**	**3%**	**26%**
6	Ford U152 (Explorer)	540,918	3.4%	27%	19.4	0.9	4%	30%
7	Honda CYR2 (Accord)	486,007	3.0%	30%	28.8	0.6	3%	33%
8	GMT360 (Trailblazer)	427,314	2.6%	33%	20.1	0.7	3%	36%
9	DCX RS (Caravan)	413,986	2.6%	35%	24.5	0.6	3%	39%
10	GM GMX130 (Malibu)	**378,625**	**2.3%**	**38%**	**28.5**	**0.4**	**2%**	**41%**
11	Ford PN40 (Ranger)	360,169	2.2%	40%	22.4	0.5	2%	43%
12	GM G (LeSabre)	339,360	2.1%	42%	25.6	0.4	2%	45%
13	GM J2 (Cavalier)	338,706	2.1%	44%	31.3	0.4	2%	47%
14	Honda Civic	329,778	2.0%	46%	39.0	0.3	1%	48%
15	Nissan FFL (Altima)	299,836	1.9%	48%	27.3	0.4	2%	50%
16	DCX PL2 (Neon)	288,836	1.8%	50%	27.8	0.4	2%	51%
17	DCX DR (Dodge Ram)	287,513	1.8%	51%	17.3	0.6	3%	54%
18	GMT352 (S-10)	285,062	1.8%	53%	21.6	0.4	2%	56%
19	DCX HB/N2 (Dakota)	257,534	1.6%	55%	18.7	0.5	2%	58%
20	Ford CW-170 (Focus)	**252,987**	**1.6%**	**56%**	**32.3**	**0.3**	**1%**	**59%**
21	GMT250 (Rendezvous)	248,996	1.5%	58%	25.1	0.3	2%	60%
22	VW A4 (Jetta)	212,584	1.3%	59%	31.3	0.2	1%	62%
23	DCX WJ (Grand Cherokee)	211,786	1.3%	61%	19.3	0.4	2%	63%
24	Ford U204 (Escape)	208,883	1.3%	62%	24.4	0.3	1%	64%
25	DCX KJ (Liberty)	207,991	1.3%	63%	20.3	0.3	2%	66%
26	Honda CYR (Odyssey)	197,855	1.2%	64%	23.8	0.3	1%	67%
27	DCX JR/FJ (Stratus)	196,165	1.2%	66%	27.2	0.2	1%	68%
28	Toyota Tundra	193,008	1.2%	67%	18.5	0.4	2%	70%
29	GM Saturn S	191,727	1.2%	68%	35.5	0.2	1%	71%
30	Nissan PU98 (Frontier)	**190,851**	**1.2%**	**69%**	**21.0**	**0.3**	**1%**	**72%**

*Average MPG is based on unadjusted CAFE values. **Carbon burden is annualized 10^6 metric tons/year (MMTc).
Source: authors' calculations using EPA data.

Table 3. Variability of CO_2 emissions related parameters within the top 30 platforms

				Engine displacement (L)				Weight (ETW, lbs)				CO_2 emissions rate (g/km)			
Platform	Models	Engines	Body styles	Min	Max	Mean	Vari*	Min	Max	Mean	Vari*	Min	Max	Mean	Vari*
GMT800 (Silverado)	7	5	3	4.3	6.0	5.2	33%	4,500	6,000	5,516	26%	268	336	298	23%
Toyota Camry	5	2	4	2.4	3.0	2.7	22%	3,500	4,250	3,774	20%	170	236	198	33%
Ford PN96 (F-150)	3	3	2	4.2	5.4	4.9	24%	4,250	6,000	5,013	35%	254	357	294	35%
GM W2 (Impala)	5	3	1	3.1	3.8	3.5	20%	3,625	3,750	3,707	4%	191	214	203	12%
Ford DN101 (Taurus)	3	2	3	3.0	3.8	3.2	25%	3,625	4,500	3,877	23%	206	239	218	15%
Ford U152 (Explorer)	2	2	1	4.0	4.6	4.1	14%	4,250	4,750	4,493	11%	253	302	282	17%
Honda CYR2 (Accord)	2	3	1	2.3	3.2	2.7	34%	3,250	3,750	3,522	14%	167	206	192	20%
GMT360 (Trailblazer)	3	1	2	4.2	4.2	4.2	0%	4,750	5,250	4,848	10%	263	286	273	9%
DCX RS (Caravan)	3	3	1	2.4	3.8	3.4	42%	4,250	4,750	4,382	11%	212	252	234	17%
GM GMX130 (Malibu)	3	3	1	2.2	3.4	2.9	41%	3,250	3,500	3,364	6%	163	196	191	17%
Ford PN40 (Ranger)	4	4	3	2.3	4.0	3.3	51%	3,375	4,750	3,991	34%	179	289	251	44%
GM G (LeSabre)	6	4	1	3.5	4.6	4.1	27%	3,625	4,250	3,990	16%	207	233	214	12%
GM J2 (Cavalier)	2	2	1	2.2	2.4	2.2	9%	3,000	3,250	3,036	8%	163	198	177	20%
Honda Civic	1	2	2	1.7	2.0	1.7	18%	2,750	3,000	2,856	9%	118	169	140	36%
Nissan FFL (Altima)	3	3	2	2.5	3.5	3.0	34%	3,375	4,250	3,538	25%	181	243	200	31%
DCX PL2 (Neon)	2	2	2	2.0	2.4	2.2	18%	3,000	3,500	3,284	15%	156	215	195	30%
DCX DR (Dodge Ram)	1	4	1	3.7	5.9	5.0	44%	4,500	5,500	5,270	19%	269	372	320	32%
GMT352 (S-10)	3	2	2	2.2	4.3	3.9	55%	3,500	4,500	4,088	26%	193	306	252	45%
DCX HB/N2 (Dakota)	2	4	2	2.5	5.9	4.6	75%	3,750	5,250	4,801	31%	216	348	297	45%
Ford CW-170 (Focus)	1	1	2	2.0	2.0	2.0	0%	3,000	3,875	3,063	29%	149	207	164	35%
GMT250 (Rendezvous)	5	1	2	3.4	3.4	3.4	0%	4,000	4,750	4,285	18%	212	232	224	9%
VW A4 (Jetta)	3	4	3	1.8	2.8	2.0	51%	3,000	3,625	3,248	19%	103	221	175	67%
DCX WJ (Grand Cherokee)	1	2	1	4.0	4.7	4.3	16%	4,000	4,500	4,287	12%	269	304	287	12%
Ford U204 (Escape)	2	2	1	2.0	3.0	2.9	34%	3,375	3,750	3,682	10%	188	232	224	20%
DCX KJ (Liberty)	1	2	1	2.4	3.7	3.7	35%	3,625	3,875	3,817	7%	217	269	267	20%
Honda CYR (Odyssey)	2	1	1	3.5	3.5	3.5	0%	4,500	4,750	4,563	5%	228	242	231	6%
DCX JR/FJ (Stratus)	2	3	2	2.4	3.0	2.6	23%	3,375	3,750	3,611	10%	193	216	206	11%
Toyota Tundra	2	2	2	3.4	4.7	4.5	29%	4,500	5,500	5,114	20%	265	307	296	14%
GM Saturn S	2	1	1	1.9	1.9	1.9	0%	2,625	2,875	2,742	9%	142	161	154	12%
Nissan PU98 (Frontier)	2	2	2	2.4	3.3	3.1	29%	3,500	4,500	4,210	24%	197	288	260	35%

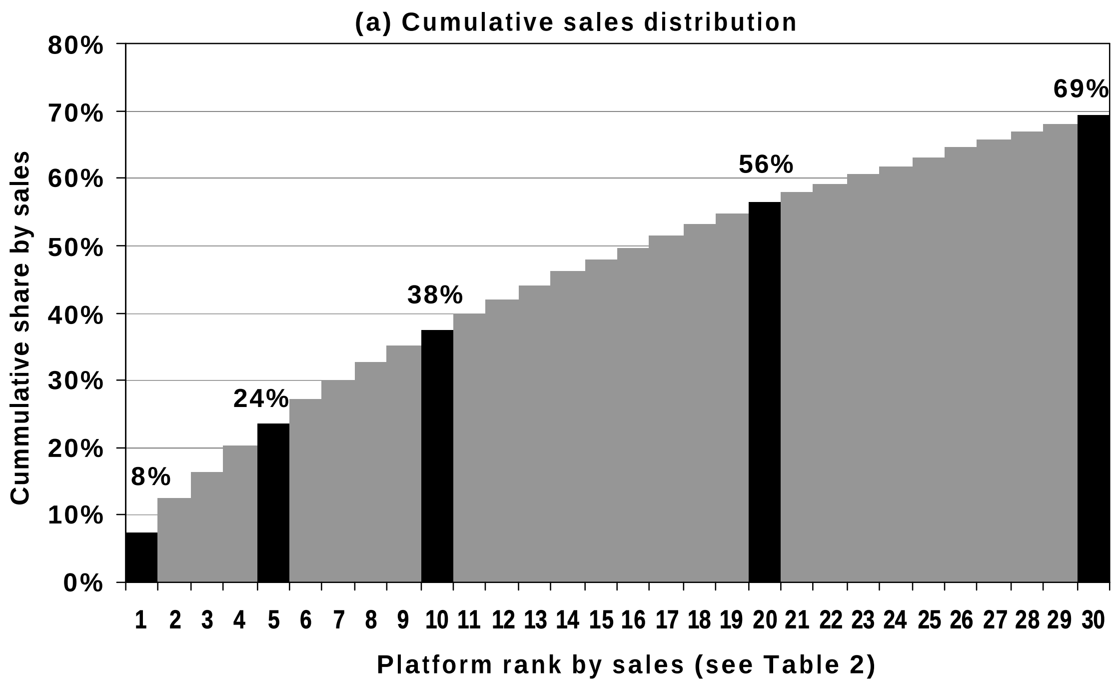
Source: Authors' calculations using NHTSA data for MY2002. *Variation within platform is calculated as (Max-Min)/Mean; Mean is sales-weighted.

Table 4. Average engine and vehicle characteristics for top 30 platforms in MY2002

Sales rank	Platform	Type	Engine Characteristics Liters	HP	HP/L	Vehicle Characteristics ETW (lb)	CO_2 (g/km)	ton-mpg
1	GMT800 (Silverado)	Truck	5.2	281	54	5,516	298	47.9
2	Toyota Camry	Car	2.7	185	68	3,774	198	48.1
3	Ford PN96 (F-150)	Truck	4.9	245	50	5,013	294	43.8
4	GM W2 (Impala)	Car	3.5	187	53	3,707	203	45.9
5	Ford DN101 (Taurus)	Car	3.2	175	55	3,877	218	45.1
6	Ford U152 (Explorer)	Truck	4.1	216	52	4,493	282	40.7
7	Honda CYR2 (Accord)	Car	2.6	174	68	3,522	192	46.2
8	GMT360 (Trailblazer)	Truck	4.2	270	65	4,848	273	45.6
9	DCX RS (Caravan)	Truck	3.3	187	56	4,382	234	47.8
10	GM GMX130 (Malibu)	Car	3.1	166	54	3,364	191	44.4
11	Ford PN40 (Ranger)	Truck	3.3	174	53	3,991	251	40.5
12	GM G (LeSabre)	Car	4.0	230	57	3,990	214	46.9
13	GM J2 (Cavalier)	Car	2.2	136	62	3,036	177	41.7
14	Honda Civic	Car	1.7	122	72	2,856	140	49.3
15	Nissan FFL (Altima)	Car	3.0	207	70	3,538	200	44.2
16	DCX PL2 (Neon)	Car	2.3	143	63	3,284	195	42.0
17	DCX DR (Dodge Ram)	Truck	5.0	236	48	5,270	320	42.7
18	GMT352 (S-10)	Truck	3.8	174	45	4,088	252	41.2
19	DCX HB/N2 (Dakota)	Truck	4.6	219	48	4,801	297	41.5
20	Ford CW-170 (Focus)	Car	2.0	120	61	3,063	164	46.2
21	GMT250 (Rendezvous)	Truck	3.4	185	55	4,285	224	48.8
22	VW A4 (Jetta)	Car	2.0	131	67	3,248	175	47.1
23	DCX WJ (Grand Cherokee)	Truck	4.2	222	52	4,287	287	37.9
24	Ford U204 (Escape)	Truck	2.9	197	67	3,682	224	41.3
25	DCX KJ (Liberty)	Truck	3.7	210	57	3,817	267	36.0
26	Honda CYR (Odyssey)	Truck	3.5	240	69	4,563	231	50.4
27	DCX JR/FJ (Stratus)	Car	2.6	179	69	3,611	206	43.8
28	Toyota Tundra	Truck	4.5	233	52	5,114	296	44.5
29	GM Saturn S	Car	1.9	111	59	2,831	154	45.2
30	Nissan PU98 (Frontier)	Truck	3.1	168	54	4,210	260	41.2
	Top 30 platform averages:	Cars	2.8	168	62	3,496	192	45.7
		Trucks	4.2	229	54	4,724	275	44.1
	Fleetwide averages:	Cars	2.8	175	65	3,405	191	41.7
		Trucks	4.0	219	56	4,556	269	39.7

Source: sales-weighted platform averages calculated from NHTSA data; fleetwide averages from *(11)*.

Figure 1. Sales and Carbon Emissions Contributions for Top 30 Platforms



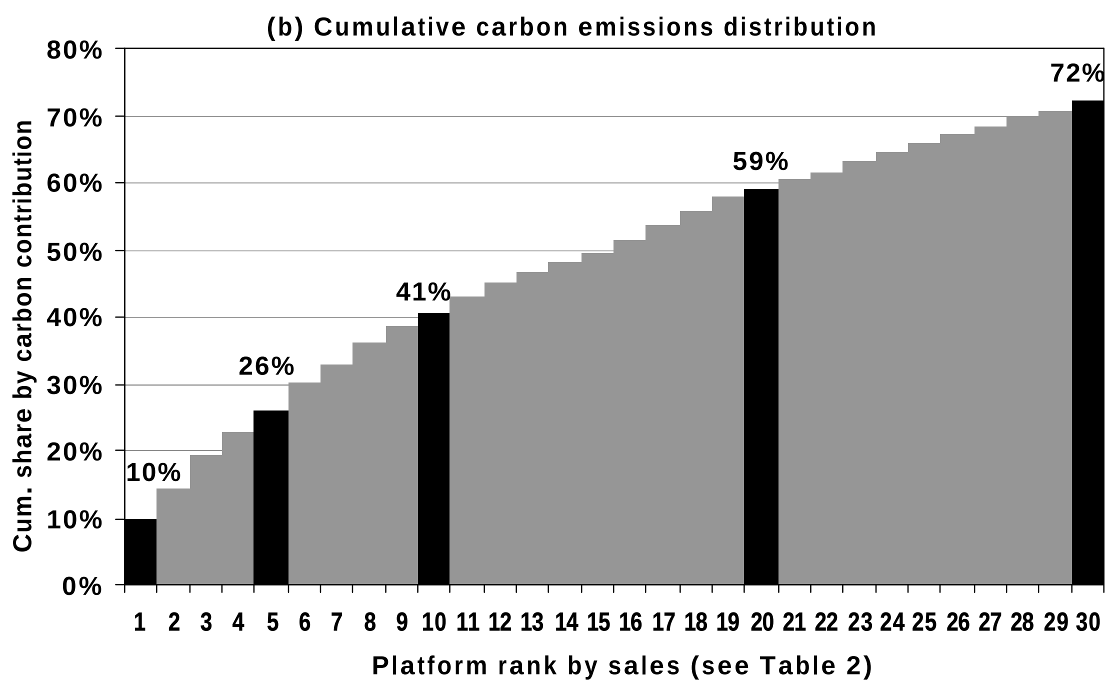
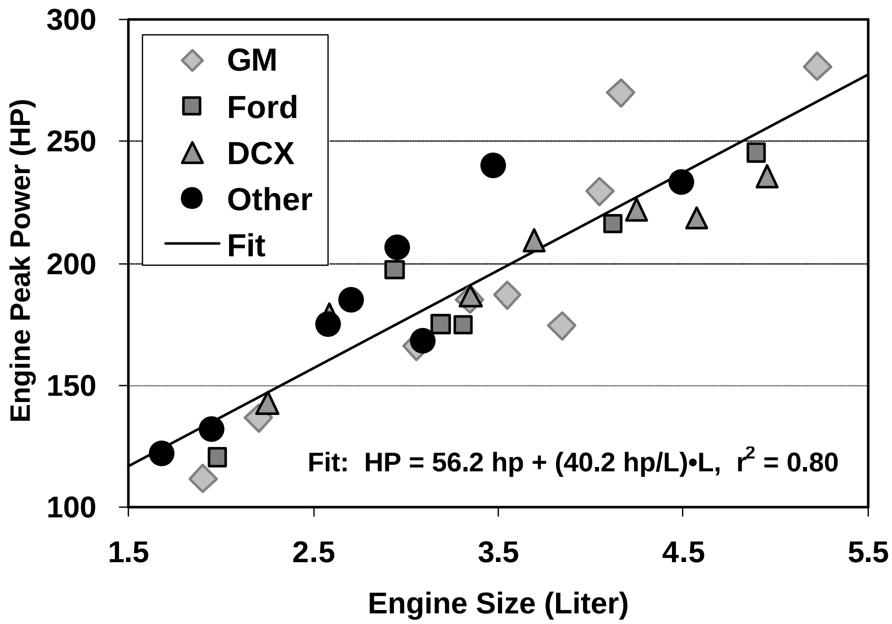


Figure 2. Average engine charactersitics for the top 30 platforms in MY2002

(a) Platform average peak power vs. engine size



(b) Platform average specific power vs. engine size

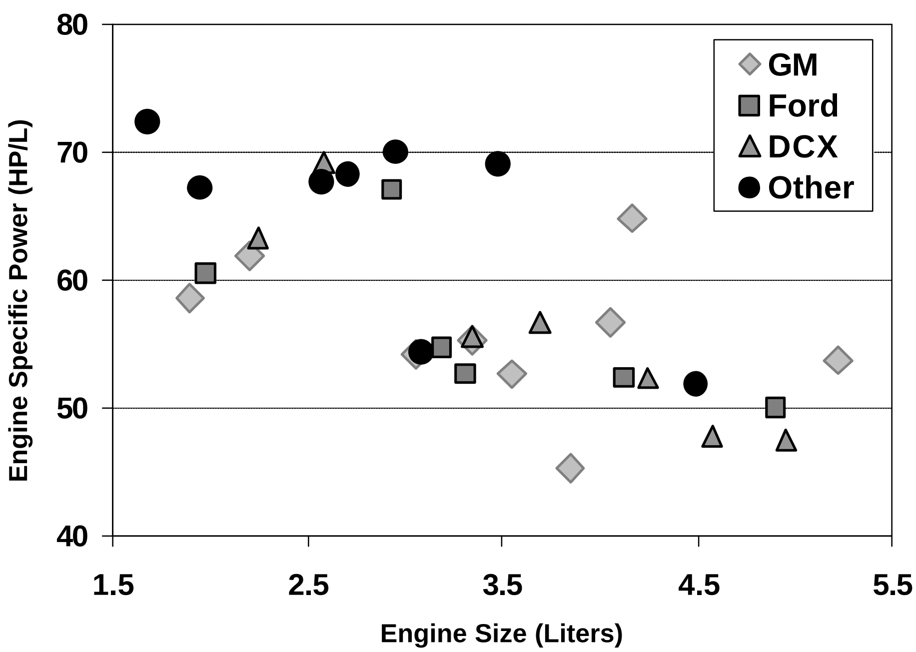
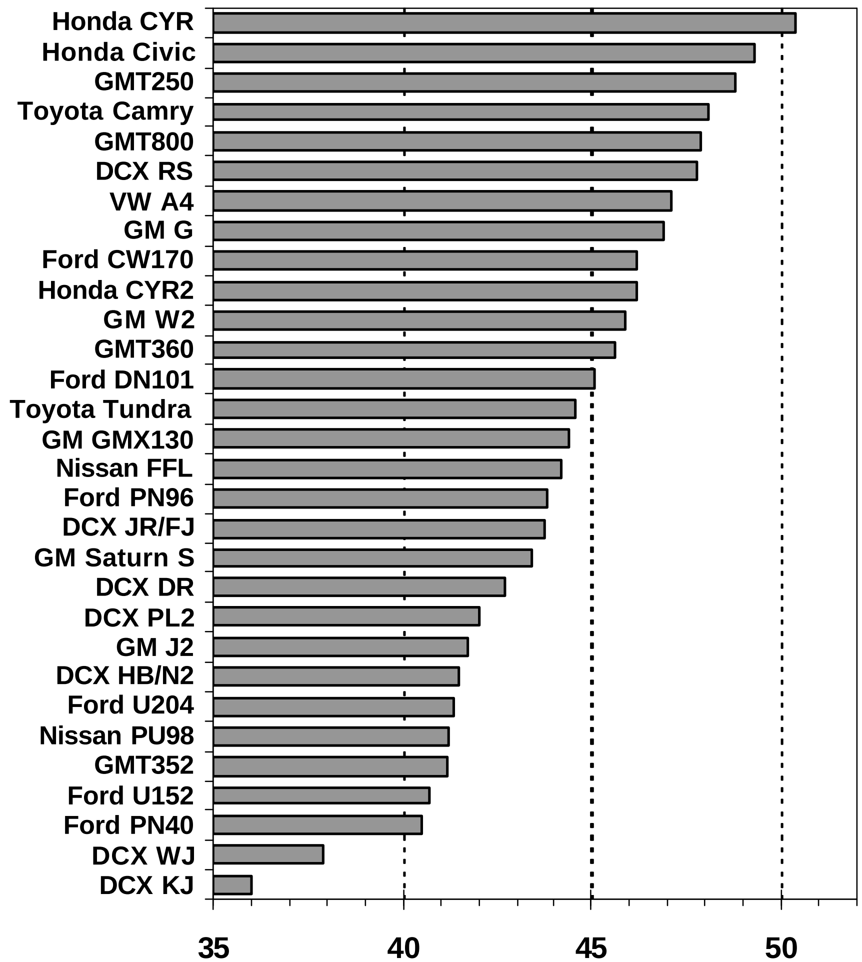


Figure 3. Powertrain efficiency indices for top 30 platforms in MY2002

(a) Platforms ranked by efficiency index (ton-mpg)



(b) Efficiency index vs. average vehicle weight