Light-Duty Vehicle Cost Markup Analysis: Literature Review and Evaluation

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ACRONYMS

CAFE	corporate average fuel economy
EEA	Energy and Environmental Analysis, Inc.
EPA	United States Environmental Protection Agency
FEV	FEV Group
ICEV	internal combustion engine vehicle
ICM	indirect cost multiplier
HEV	hybrid electric vehicle
MFG	manufacturing
MSRP	manufacturer’s suggest retail price
NADA	National Automobile Dealers Association
NHTSA	United States National Highway Traffic and Safety Administration
NRC	National Research Council
OEM	original automotive equipment manufacturer
RPE	retail price equivalent
SAFE	Safer Affordable Fuel-Efficient
SUV	sport utility vehicle

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ABSTRACT

Knowledge of historical automotive manufacturing costs and intended sale prices of vehicles is important in understanding the costs and prices of current and emerging vehicle technologies, as well as the types of technology choices that original equipment manufacturers (OEMs) may make with their technology planning and vehicle deployment. Current practice is to translate available OEM manufacturing costs (or cost estimates) into likely sale prices by using a markup factor. This study examines the state of the literature as it pertains to light-duty vehicle cost markup factors to understand the foundation of available markup factor formulations and to describe how variations in assumptions may impact those factors. The study examines and evaluates literature to observe trends, such as markup factor variance and efforts to devise variable markup factors. It finds that there is consensus for a markup factor of 2.0 for vehicle parts produced by "in-house" and a factor of 1.5 for parts that are outsourced. There is wide acknowledgement that these values are not indicative of any specific part, or manufacturer. Rather, they highlight that over time the market has shown that it will, on average, across a manufacturer's entire fleet, allow the OEMs to set their prices such that their return is consistent with the markup factors presented. Some vehicles will have higher markup factors and they will thus subsidize vehicles with lower markup factors.

1 BACKGROUND AND MOTIVATION

Knowledge of historical OEM (original automotive equipment manufacturer) manufacturing costs and intended sale prices of vehicles is important in understanding the costs and prices of current and emerging vehicle technologies, as well as the types of technology choices that OEMs may make with their technology planning and vehicle deployment. Current practice is to translate available OEM manufacturing costs (or cost estimates) into likely sale prices by using a markup factor. The most commonly used factor is 1.5. Although a single linear markup may be appropriate for some estimates and analyses, there is concern that a singular markup factor may fail to capture the reality of OEM markups and may not provide the level of fidelity necessary for emerging vehicle technologies, which may be subject to different markup factors (e.g., batteries for battery electric vehicles) at different scales of technology deployment.

It has been often observed that OEMs gain more profit per vehicle for their truck and SUV (sport utility vehicle) sales than for their smaller cars. This leads some to suggest that markup factors may be different between these two vehicle classes, and specifically that the markup for trucks and SUVs may be higher than for compact cars. However, a linear markup factor could still be consistent with smaller cars having lower profit margins than trucks and SUVs simply because the former have lower manufacturing costs; thus, even a linear factor would suggest that trucks and SUVs obtain a higher profit margin. However, there is a widely held belief that profit margins vary in a complex fashion across an OEM's fleet. In fact, OEMs likely make detailed analyses of their fleet, vehicle manufacturing costs, market demands, and regulatory requirements in a coupled effort toward profit maximization, as opposed to using markup factors to set their sales price for a vehicle.

This study examines the state of the literature as it pertains to light-duty vehicle cost markup factors to understand the foundation of available markup factor formulations and to describe how variations in assumptions may impact those factors. The study examines and evaluates literature to observe trends, such as markup factor variance and efforts to devise variable markup factors. Estimates of markup factors informed by this literature and analysis will be presented, and some historical context provided. The mathematical formulation of markup factors will be examined to observe the likely variations in markup factors due to variation in the components that comprise it.

2 LITERATURE REVIEW

To study the relationship between light-duty vehicle manufacturing cost and vehicle "price" we must first consider how we define price. We could use the MSRP (manufacturer's suggested retail price); however, MSRP contains information and pricing strategies that are proprietary to each OEM, and further, consumers rarely pay the MSRP. Instead, consumers receive a variety of dealer incentives, discounts, rebates, and other tools that modify the MSRP. Thus, it is more common, though not universal, for researchers in this field to examine the RPE (retail price equivalent) associated with a vehicle. The RPE is the vehicle (or component) sales price needed in order for the producer to earn a competitive rate of return on their production investment (EPA and NHTSA 2018). In the following literature examination, we will clarify the price basis that the researchers reference; however, we will generally consider that RPE as the common basis currently used by most in the field.

2.1 Components of Cost

As an introduction to cost markup, we will describe a generalized framework for understanding the various cost components associated with vehicle production and sales. First, we understand that there is a direct cost of manufacturing a vehicle, which includes the cost of materials, labor, and energy directly involved in the part being produced. There are also manufacturing overhead costs, as well as corporate overhead costs that must be considered as a component of the vehicle's cost; each of these are viewed as indirect costs. Each of these can be further partitioned, as will be examined further in Section 2.1. There is also a cost associated with selling and dealerships. Finally, to determine an RPE, we must also consider a profit that will be earned with the vehicle's sale. Therefore, the RPE is the collection of all these costs (and profit) such that the OEM can recover all investment and earn money toward to continuation of its business. A diagram of these primary cost components is shown in Figure 1. We will examine these components in greater detail throughout this analysis and discuss the approach taken by other researchers in evaluating them.

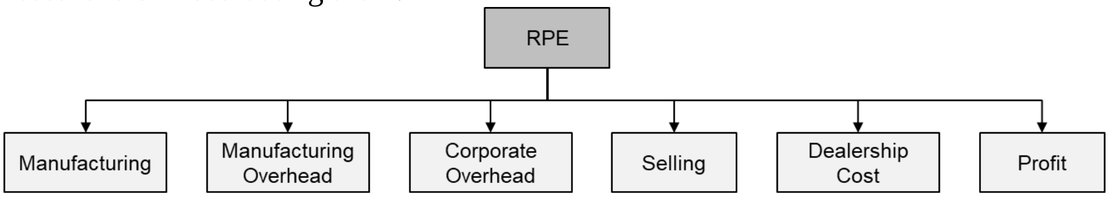

Figure 1: Primary components of vehicle RPE

We can decompose manufacturing costs into capital and operating expenses. These capital, or fixed (indirect), expenses are typically purchases of large and/or expensive items that must be amortized over time via the manufacture and sale of many parts that can justify such a large purchase (for example, a stamping press). Operating, or variable (direct), expenses are those costs incurred directly in the production or assembly of a part (for example, the electricity needed to operate the stamping press, or the labor paid for a stamping press operator) (National Research Council 2011).

Manufacturing overhead consists of those cost components related to the production of the vehicle that are not tied to the act of making the part. This includes maintenance, repairs and operations, research, development and engineering, and product warranty. Some researchers include depreciation and amortization in production overhead, while others place it with the cost of manufacturing. This obviously creates a potential conflict in determining a markup factor for the RPE if some researchers include amortization and depreciation as an indirect manufacturing cost and others do not. In particular, Vyas, Santini, and Cuenca (2000) did not include the indirect (fixed) cost of manufacturing in their influential evaluation of markup factors. Instead, they use the variable costs (material, labor, energy, etc.) as the cost of manufacturing. Others (Energy and Environmental Analysis, Inc., Borroni-Bird) did not follow the same approach (Vyas, Santini, and Cuenca 2000). However, for this analysis, we will focus on the cost of manufacture as the direct (variable) costs noted above to be consistent with the majority of the literature. Note, however, that many estimates of vehicle and part costs include the amortization and depreciation (fixed) costs within their manufacturing cost estimates. Care must thus be taken when applying an RPE markup factor to an estimated vehicle manufacturing cost.

Corporate overhead considers those components of operating the OEMs business that are outside the direct purview of the product itself. These include costs such as administrative, health care, retirement, and other considerations.

The cost of *selling* includes all costs borne by the OEM that are associated with selling the vehicle. Some researchers include dealerships within the cost of selling, while others do not. We keep them separate here to be inclusive of both approaches. Selling costs include marketing, transportation, and distribution.

Dealership costs include labor, materials, and capital costs at the dealership. These costs are not usually closely examined by the RPE research, but they make up a component of total vehicle cost that cannot be neglected.

Profit is simply the money earned by the OEM from selling the vehicle. Net income can also be referred to as profit.

The collection of these different cost components comprises the total RPE of the vehicle. Thus, if we divide that RPE by the cost of manufacturing, then we can determine the markup factor for these vehicles. As we will discuss further, the “cost of manufacturing” can be viewed in different ways depending upon how a vehicle’s parts are acquired.

2.2 Prior Examinations of Cost Markup

Vyas, Santini, and Cuenca (2000) compared cost multipliers and found consistency between their internal approach and those of two other researchers. Vyas, Santini, and Cuenca compared these cost multipliers for vehicle parts that were directly made by the OEM and for those parts made externally, for example, by Tier 1 suppliers. They had previously conducted an analysis that evaluated the production costs of electric and hybrid electric vehicles and used this as their basis for evaluating cost markups (Cuenca, Gaines, and Vyas 2000). Vyas, Santini, and Cuenca (2000) compared their own markup factors (and methodology) with those by Borroni-Bird (1996) and the Energy and Environmental Analysis, Inc. (EEA). As noted, Vyas, Santini, and Cuenca were interested in two different markup factors. First, they considered parts that were produced in-house, by the OEM. In that formulation, the only costs considered were the variable manufacturing costs. Second, they considered parts that were purchased from outside sources. In that case, Vyas, Santini, and Cuenca included additional costs incurred by the supplying manufacturer, namely that of production overhead, as cost components of vehicle manufacturing.

In Table 1 we reproduce the cost components described by Vyas, Santini, and Cuenca (2000). Note that Vyas, Santini, and Cuenca and Borroni-Bird used MSRP as their sum of all costs plus profit, while EEA uses the RPE term. Vyas, Santini, and Cuenca do not detail the differences between MSRP and RPE; however, as we noted before, the RPE is more commonly used in current studies. Using Table 1, Vyas, Santini, and Cuenca calculate the markup factors for components made internally by the OEM as the total contributions to MSRP divided by the cost of manufacture, which is equal to 2.00:

$$Internal\ components\ = \frac{100}{50}\ =\ 2. \qquad \text{Equation 1}$$

Next, they determined the markup factor for components that were outsourced as the total contributions to MSRP divided by the sum of the cost of manufacture and production overhead, which is equal to 1.50.

Markup factors for outsourced components = 100/(50 + 6.5 + 5.5 + 5) = 1.50:

$$Outsourced\ components\ = \frac{100}{50 + 6.5 + 5.5 + 5}\ =\ 1.50. \qquad \text{Equation 2}$$

What this means, essentially, is that Vyas, Santini, and Cuenca consider the direct cost borne by the OEM to be the component cost, or the cost to manufacture.

Table 1: Contributors to MSRP as described in and reproduced from Vyas, Santini, and Cuenca (2000).

Cost Category	Cost Contributor	Relative to Cost of Vehicle Manufacturing	Share of MSRP (%)
Vehicle Manufacturing	Cost of Manufacture	1.00	50.0
Production Overhead	Warranty	0.10	5.0
	R&D/Engineering	0.13	6.5
	Depreciation and Amortization	0.11	5.5
Corporate Overhead	Corporate Overhead, Retirement, and Health	0.14	7.0
Selling	Distribution, Marketing, Dealer Support, and Dealer Discount	0.47	23.5
Sum of Costs		1.95	97.5
Profit	Profit	0.05	2.5
Total Contribution to MSRP		**2.00**	**100.0**

Vyas, Santini, and Cuenca go on to compare their results to those of Borroni-Bird and EEA, each of which is discussed below briefly. First, they evaluated Borroni-Bird's work using the information reproduced in Table 2. From this, we can see that they find that their internal determination of markup factor for in-house parts was 2.05:

$$Internal\ components\ = \frac{100}{42.5 + 6.5}\ =\ 2.05. \qquad \text{Equation 3}$$

However, for outsourced components, they have to determine what portion of the fixed manufacturing costs will be included in the cost borne by the OEM. They chose to include the transportation/warranty aspect while including half of the remaining portion. This leads to a markup factor of 1.56 for the outsourced vehicle components:

$$Outsourced\ components\ = \frac{100}{42.5 + 6.5 + 4.5 + 10.75}\ =\ 1.56. \qquad \text{Equation 4}$$

Table 2: Contributors to MSRP from Borroni-Bird as described in and reproduced from Vyas, Santini, and Cuenca (2000).

Cost Category	Cost Contributor	Relative to Cost of Vehicle Manufacturing	Share of MSRP (%)
Vehicle Manufacturing	Material Cost	0.87	42.50
	Assembly Labor and Other Manufacturing	0.13	6.50
Fixed Costs	Transportation/Warranty	0.09	4.50
	Amortization and Depreciation, Engineering R&D, Pension and Health Care, Advertising and Overhead	0.44	21.50
Selling	Price Discounts	0.10	5.00
	Dealer Markup	0.36	17.50
Sum of Costs		1.99	97.50
Profit	Automobile Profit	0.06	2.50
Total Contribution to MSRP		**2.05**	**100.00**

Next, they evaluated EEA's work using the information reproduced in Table 3. From this, we see that they determined the markup factor for in-house parts to be 2.14:

$$Internal\ components\ = \frac{100}{33.7 + 6.7 + 6.5}\ =\ 2.14. \qquad \text{Equation 5}$$

And then, again, Vyas, Santini, and Cuenca needed to decompose EEA's Overhead costs to fit their approach to calculate the manufacturing costs of an outsourced component borne by the OEM. To do this, they included the engineering, tooling, and facilities costs, while including only half of the manufacturing overhead costs. The resulting markup factor was 1.56:

$$Outsourced\ components\ = \frac{100}{33.7 + 6.7 + 6.5 + 5.05 + 12}\ =\ 1.56. \qquad \text{Equation 6}$$

Table 3: Contributors to RPE from EEA as described in and reproduced from Vyas, Santini, and Cuenca (2000).

Cost Category	Cost Contributor	Relative to Cost of Vehicle Manufacturing	Share of MSRP (%)
Vehicle Manufacturing	Division Cost	0.72	33.70
	Division Overhead	0.14	6.70
	Assembly Labor and Other Manufacturing	0.14	6.50
Overhead	Manufacturing Overhead	0.22	10.10
	Engineering, Tooling, and Facilities Expenses	0.26	12.00
Selling	Dealer Margin	0.49	22.90
Sum of Costs		1.97	91.90
Profit	Manufacturing Profit	0.17	8.10
Total Contribution to RPE		**2.14**	**100.00**

The markup factors from those three studies, as harmonized by Vyas, Santini, and Cuenca, are presented together in Table 4. We note that despite the claim that these values are harmonized onto a common basis, the National Research Council (NRC) conducted an analysis that included an evaluation of Vyas, Santini, and Cuenca and highlighted that these choices drive the final markup factors of the compared studies (National Research Council 2011). That NRC report goes on to provide a final recommendation that closely mirrors the findings of Vyas, Santini, and Cuenca, suggesting that average RPE markup values for in-house and outsourced components are 2.0 and 1.5, respectively. Again, note that the cost-basis of the outsourced component includes aspects of production overhead in addition to direct manufacturing expenses, whereas the basis for the in-house component is on the direct manufacturing expenses (National Research Council 2011).

Table 4: RPE by component provenance across studies.

Multiplier	Argonne (Vyas 2000)	Borroni-Bird	EEA
In-House Components	2.00	2.05	2.14
Outsourced Components	1.50	1.56	1.56

The Vyas, Santini, and Cuenca study and its associated estimate of cost markup have provided an important basis that other researchers considered, but several other research efforts attempted to evaluate cost markup factors. Roy, Souchoroukov, and Shehab highlighted the need for detailed bottom-up information for automotive cost modeling (2011). Lipman and Delucchi utilized their own estimates of vehicle cost markups to estimate the costs of electrified vehicles and conventional vehicles (2006), and they derived their data based on their own prior work (Delucchi et al. 2000). They provided cost estimates based on numerous part groups and used these data to indicate a detailed estimate of vehicle cost. They suggested that markup factors are highly nuanced. Therefore, they did not indicate a factor that could apply to all types of vehicle parts. We reproduce Table 7 from Lipman and Delucchi (2006) and calculate a multiplier (or markup multiplier) associated with the ICEV (internal combustion engine vehicle) and HEV (hybrid electric vehicle) cost components as shown in our Table 5. Lyons (2008) used a markup factor of approximately 2.0, but was not specific about the cost components included in the estimate to which this factor was applied.

Table 5: Contributions to vehicle cost from Lipman and Delucchi (2006) and inferred multipliers of manufacturing cost.

	Multiplier of MFG Cost	
Cost	**ICEV**	**HEV**
Total manufacturing cost	**1.000**	**1. 000**
Division costs (engineering, testing, advertising)	0.655	0.544
Corporate costs (executives, capital, research and development)	0.387	0.303
Corporate cost of money	0.030	0.027
Corporate TRUE profit (taken as fraction of factory invoice)	0.064	0.058
Factory invoice (price to dealer)	2.136	1.932
Dealer costs	0.354	0.296
Manufacturer suggested retail price (MSRP)	**2.490**	**2.228**
Shipping cost (destination charge)	0.064	0.050
3% tax	0.077	0.068
Retail cost to consumer (includes shipping cost and 3% tax)	2.630	2.346
Inferred Markup (derived here)	**2.49**	**2.23**

Rogozhin, Gallaher, and McManus developed an approach for estimating the cost of adding new technologies to automobiles in response to regulatory changes (Rogozhin, Gallaher, and McManus 2009). They note that RPE relates direct manufacturing costs to all other costs reflected in the final price of vehicle, but that in regulatory analyses associated with fuel economy improvements some indirect cost components of RPE (fixed depreciation, health care for retirees, pensions, etc.) may not be affected by vehicle changes from regulations (Rogozhin, Gallaher, and McManus 2009; Rogozhin et al. 2010). In response to this, they developed indirect cost multipliers (ICMs) that specifically apply to those aspects of indirect cost likely to be affected by vehicle modifications that are associated with environmental regulations, and these ICMs are associated with those technology components, not necessarily the whole vehicle. These serve as modifiers to individual elements of RPE associated with specific vehicle components, and their unified effect modifies the overall RPE. They suggest that

RPE = (direct + indirect costs + profit) / (direct manufacturing costs),

while

ICM = (incremental direct + indirect costs) / (incremental direct manufacturing costs).

They developed ICM for low, medium, and high levels of technology complexity for both short-term and long-term effects for use in EPA (U.S. Environmental Protection Agency) calculations. They indicated that using these multiple levels of complexity and time scales allows for a more accurate estimate of the change in the OEM's indirect costs associated with changes in direct manufacturing costs under these scenarios. Those values are presented in Table 6. However, a report by the NRC of the National Academies indicates that these values neglect to include profit, which they indicate is methodologically incorrect (National Research Council 2011). Rogozhin, Gallaher, and McManus acknowledge this in a later publication and suggest that adding 0.06 to the values in Table 6 resolves the issue of neglected profit (or return on capital) (Rogozhin et al. 2010). Thus, we estimate that the smallest ICM would be 1.08, and the largest would be 1.51 across all ICM cases presented in Table 6.

Table 6: ICM values reproduced from Rogozhin, Gallaher, and McManus (2009).

	Technology Complexity		
Time Frame	**Low**	**Medium**	**High**
Short-term effects	1.05	1.2	1.45
Long-term effects	1.02	1.05	1.26

Rogozhin, Gallaher, and McManus also conducted an industry wide evaluation of company specific RPE multipliers using information obtained from publicly available information regarding the OEMs financial performance, like their required 10-K reports from the Securities and Exchange Commission (Rogozhin, Gallaher, and McManus 2009). They used and augmented these reports with numerous other studies that informed levels for appropriate cost components for health care and other costs. They report that the range of RPE values varies between 1.42 and 1.49, with an industry average of 1.46. We depict these data in Figure 2 to highlight their main cost component categories. We see that there is variation within categories across the different OEM firms. The NRC evaluated this and contends that these values neglect to include legacy health care cost and this, in turn, reduced the estimates by 1 to 2%, thus bringing them closer to 1.5 (National Research Council 2011).

Rogozhin, Gallaher, and McManus's (2009) formulation of ICMs was used in the EPA's greenhouse gas regulations to determine vehicle technology costs, which has made this formulation both influential and controversial. The EPA and NHTSA (National Highway Traffic and Safety Administration) regulations for greenhouse gas and fuel economy, respectively, used Rogozhin, Gallaher, and McManus's (2009) approach in their regulatory analyses (EPA and NHTSA 2010; 2012). Vehicle teardown and redesign studies from NHTSA have also used results from Rogozhin, Gallaher, and McManus (2009) to determine cost markup values for their own studies that consider efforts to reduce vehicle mass through component redesign (Singh 2012). In the NHTSA (National Highway Traffic and Safety Administration) study, researchers conducted a teardown study of a Honda Accord. They used an RPE multiplier of 1.47, consistent with Rogozhin, Gallaher, and McManus (Singh 2012; Rogozhin, Gallaher, and McManus 2009). A study from FEV (FEV Group) and the EPA acknowledges Rogozhin, Gallaher, and McManus (2009), but suggest that such implementation is outside the scope of their analysis (U.S. Environmental Protection Agency 2012).

The NRC has been critical of Rogozhin, Gallaher, and McManus (2009), but also provides additional context and reviews several other analyses that evaluate RPE multipliers (2011). As noted, the NRC contends that Rogozhin, Gallaher, and McManus (2009) neglected to include profit in their formulation. It also states that the resulting RPE's associated with Rogozhin, Gallaher, and McManus's multipliers range from 1.02 to 1.45, spanning the short and long run, implying that none of the fuel economy technologies would cause an increase above the industry average indirect costs as the Rogozhin, Gallaher, and McManus report suggested. This then suggests that additional regulatory requirements would serve to lower the overall industry RPE. It is unlikely that additional regulations would reduce indirect costs. The NRC goes on to highlight additional markup literature, showing that factors of 1.5 were used in the NHTSA fuel economy ruling (DOT/NHTSA 2009), 1.4 was used by the NRC itself in 2002 by a representative of the California Air Resources Board, and the EPA used a value of 1.26 in 2008. They further highlight that their interactions with experts yielded markup predictions from those experts of 1.96 or 2.08 depending on analytical approach for the same data, and a suggestion of a factor of 2.22 to 2.51 for markup over variable, and 1.65–1.73 for markup over Tier 1. Finally, the NRC committee contracted with IBIS associates to analyze markup factors for the model year 2009 Honda Accord and Ford F-150, and IBIS reported RPE markup factors of 1.39 and 1.52 for the Accord and F-150, respectively. The NRC goes on to recommend that RPE factors of 1.5 and 2.0 are appropriate as averages for outsourced and in-house components, but that markups for specific technologies will vary by circumstance. They state that complexity influences variability in RPE factors, but that until a rigorous estimation method is available to indicate such variability, they could not recommend such an approach.

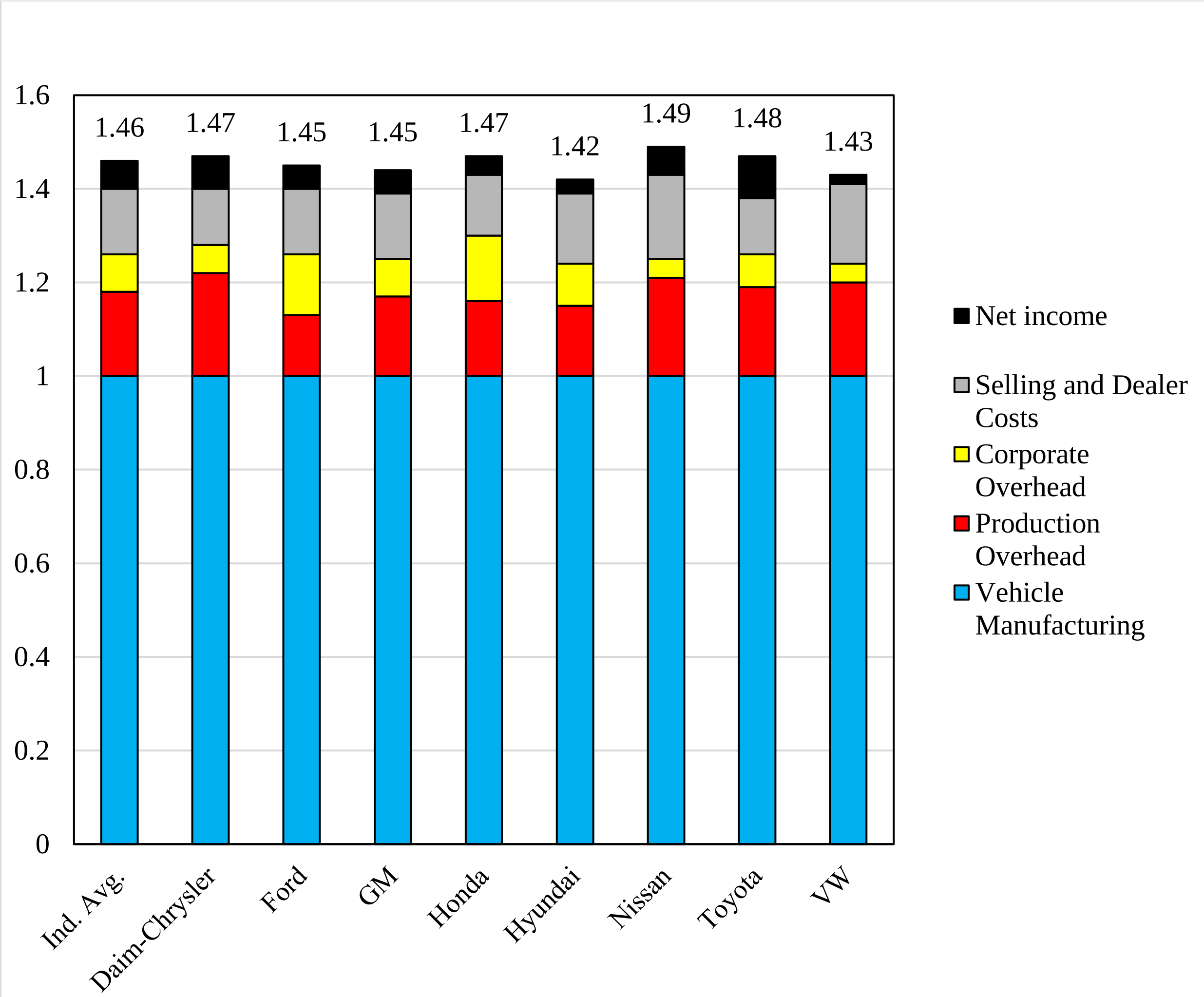

Figure 2: RPE Multiplier components and values for different OEMs for model year 2007 vehicles, developed using data from Rogozhin, Gallaher, and McManus (2009).

In a critique of CAFE (corporate average fuel economy) and greenhouse gas regulations from 2012, the National Automobile Dealers Association (NADA) was highly critical of the new regulation and primarily focused on the ICM basis for the regulation's technology cost components (Whinihan, Drake, and Aldorfer 2012). Its comments provide an industry perspective on the new regulation and concerns about the potential for mischaracterizing the costs the OEMs incur in technology development. It further suggests that the review conducted by the NRC, which proposed that multipliers of 1.5 and 2.0 for outsourced and in-house components, respectively, were low estimates from the NRC's available data. It indicated that these estimates are low for four reasons: the estimates neglect the cost of prematurely obsolete capital equipment; they neglect the cost of retraining dealer and service center staff; they exclude product and marketing plan disruptions; and they exclude certain opportunity costs of diverting staff away from market-driven technologies toward regulatory compliance technology.

Finally, the new SAFE (Safer Affordable Fuel-Efficient) Regulatory Impact Analysis recommends the use of a 1.5 RPE multiplier (EPA and NHTSA 2018). In their determination of this recommendation, EPA and NHTSA studied prior research, including those cited within the present article. Although they promote a multiplier of 1.5 in their official recommendation, they also conduct analyses of RPE multipliers modified for learning effects. One of the motivations for recommending the 1.5 multiplier derives from their evaluation of more than 30 years of RPEs for manufacturers. They note that these average values have been remarkably consistent during that time frame, with a value of roughly 1.5, illustrating the stable relationship between vehicle retail prices and direct manufacturing costs. The RPEs that they present never exceeded 1.6 nor were they below 1.4.

In the SAFE Regulatory Impact Analysis, EPA and NHTSA state:

> *"An RPE of 1.5 does not imply that manufacturers automatically markup each vehicle by exactly 50%. Rather, it means that, over time, consumer, market, and investor demand enabled manufacturers to set prices across their entire fleets at this level. It is the level of markup the competitive marketplace has produced, and which has enabled the industry to collect a profitable return that will attract enough investment capital to keep them operating as a viable business. Prices for any individual model may be marked up at a higher or lower rate depending on market demand. The consumer, who buys a popular vehicle, may subsidize the installation of a new technology in a less marketable vehicle. But, on average, the retail price to consumers has risen by $1.50 for each dollar of direct costs incurred by manufacturers."*

This is an important acknowledgement of the value of the RPE, highlighting that it is an "average" and that there is variability across the market. They go on to state that, although the value has averaged ~1.5 throughout the lifetime of the technology (vehicle), the average RPE for that technology would be lower in its earlier years and, due to learning effects on direct costs, it would be higher in later years. As noted, they augment their study and develop ICM for model year 2017–2025 analysis using modified Delphi ICM values that ranged from 1.24 for short-term, low-complexity technologies to 1.77 for high-complexity technology; these values were 1.19 and 1.50 for long-term low and high complexity, respectively. Ultimately, they do not use the ICM method in the SAFE regulation, but employ the RPE approach using a 1.5 multiplier while exploring a range from 1.1 to 2.0.

Overall, the literature suggests a range between approximately 1.3 and 2.5 for RPE markup factors. Further, there is general agreement that a value of 1.5 is appropriate for outsourced components, while a value of 2.0 should be used for in-house parts. There is also wide acknowledgement that variations exist within RPE values due to technology maturity, learning by doing, and variations between OEMs strategic marketing efforts. In the next section, we examine the sensitivity of some of these markup formulations to their various components.

3 EVALUATION OF SELECT LITERATURE MARKUP FACTORS

We use selections from the literature above to better understand the components of markup factors along with drivers of their sensitivity. In this evaluation, we examine the work by Vyas, Santini, and Cuenca and Rogozhin, Gallaher, and McManus in order to visualize their detailed preparations of RPE components (Vyas, Santini, and Cuenca 2000; Rogozhin et al. 2010). We then we explore each group's RPE formulation more deeply to observe how sensitive the overall RPE values are to variations in different cost components.

3.1 Vyas, Santini, and Cuenca (2000)

3.1.1 Description of Component Costs

The cost components for OEM-produced parts described by Vyas, Santini, and Cuenca (2000) are visually presented in Figure 3. We see that the MSRP is composed of costs associated with manufacturing (MFG), production overhead, corporate overhead, and selling along with profit. Production overhead costs include costs associated with warranty, R&D and engineering, and depreciation and amortization, while corporate overhead costs include costs associated with corporate overhead, retirement and healthcare, and selling costs include costs associated with distribution, marketing, dealer support, and dealer discounts. Thus, their MSRP formulation would be

$$MSRP = Profit + Selling + MFG + Corporate\ Overhead + Production\ Overhead.$$

Equation 7

In the Vyas, Santini, and Cuenca (2000) formulation of an MSRP multiplier, which we can treat as a proxy here for RPE, they indicate that all cost components listed would be included in the cost of the product, and that, for parts produced by the OEM, their direct manufacturing costs would be the only costs associated with production. Consequently, their markup factor for OEM, or internally, produced parts would be

$$MarkupFactor_{internal} = \frac{Profit+Selling+MFG+Corporate\ Overhead+Production\ Overhead}{MFG}.$$

Equation 8

$$MarkupFactor_{outsourced} = \frac{Profit+Selling+MFG+Corporate\ Overhead+Production\ Overhead}{MFG+Production\ Overhead}.$$

Equation 9

Within Figure 3, all cost components shown below MSRP are included in the total cost, or the numerator, in Equation 8. We indicate that only the manufacturing cost is a part of the denominator by highlighting it. However, in Figure 4, we show the cost components associated with outsourced components as described in Vyas, Santini, and Cuenca (2000). Again, all cost components below MSRP are included in the numerator of Equation 9, while highlighted components, manufacturing and production overhead costs, are within the denominator.

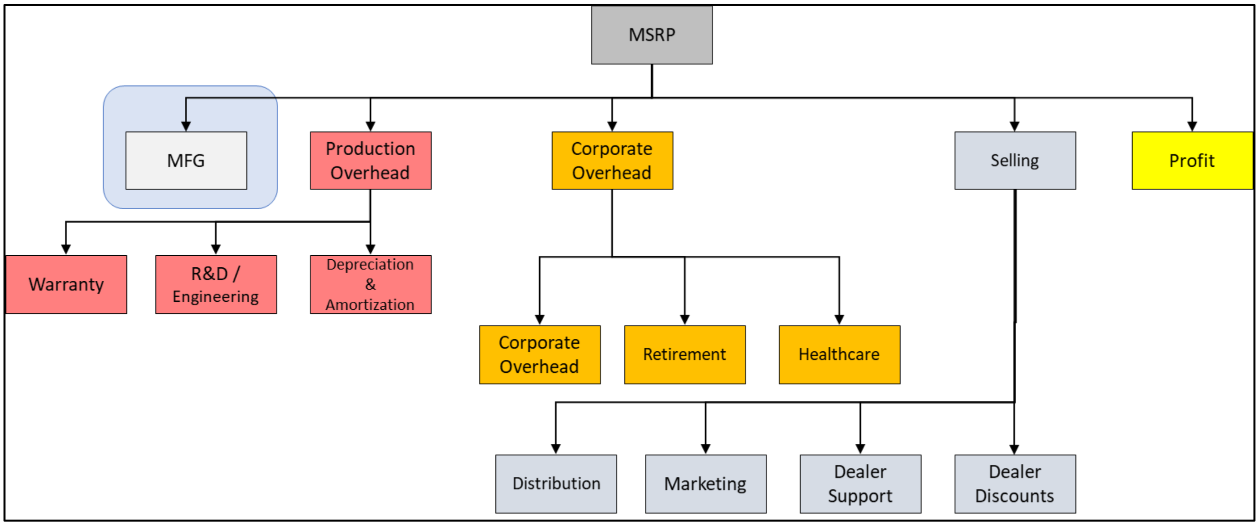

Figure 3: Cost components described in Vyas, Santini, and Cuenca (2000) for internally produced parts; the blue box highlights cost components in the denominator of Equation 8.

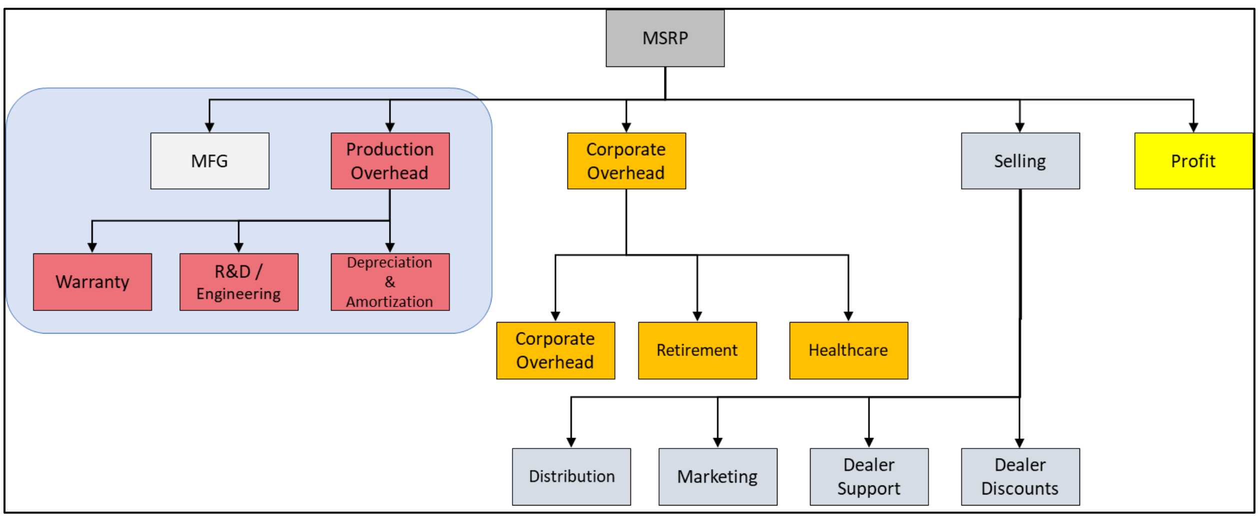

Figure 4: Cost components described in Vyas, Santini, and Cuenca (2000) for outsourced parts; the blue box highlights cost components in the denominator of Equation 9.

3.1.2 Sensitivity Analysis

Using the information presented regarding the mathematical formulation of vehicle part cost in the previous section along with data found in Table 1, we conducted a sensitivity analysis of the internal and outsourced component cost markup factors considering variations in different cost components. In this analysis, we varied the quantity of the cost components selling, corporate overhead, production overhead, and manufacturing in the absence of changes to any other components. We varied costs by 25% for each of these categories to observe the impacts such a change would have on the markup factor. We present these results by showing the percent change these variations imparted upon the markup factor. By observing the formulation of the markup factor in Equation 8, we see that the selling, corporate overhead, and production overhead components of cost are directly proportional to the markup factor. The manufacturing component of cost has both an inverse relationship to the markup factor. Examining this further in Figure 5, we see that this relationship holds, that the markup factor is most sensitive to the cost of manufacturing, and that the relationship is inverse such that a 25% reduction in cost leads to a 17% increase in markup factor. We also see that, among the directly proportional relationships, the markup factor is most sensitive to the cost of selling, such that a 25% increase or decrease leads to a 6% increase or decrease, respectively.

We conducted the same type of sensitivity analysis for the relationship between cost components and markup factors considering outsourced vehicle parts. We again varied costs by 25% for each of the noted categories to observe the impact on markup factor. By observing the formulation of markup factor in Equation 9, we see that the selling and corporate overhead components of cost are directly proportional to the markup factor. The manufacturing and production overhead components of cost have both an inverse relationship to the markup factor. Examining this further in Figure 6, we see that this relationship holds, and that the markup factor is most sensitive to the cost of manufacturing or selling, depending on the direction of the sensitivity. We further see that that the relationship is inverse for manufacturing and production overhead such that a 25% reduction in manufacturing cost leads to a 7% increase in markup factor, while a 25% reduction in production overhead costs yields a 2% increase in the markup factor. We also see that, among the directly proportional relationships, the markup factor is most sensitive to the cost of selling, such that a 25% increase or decrease leads to a 6% increase or decrease, respectively.

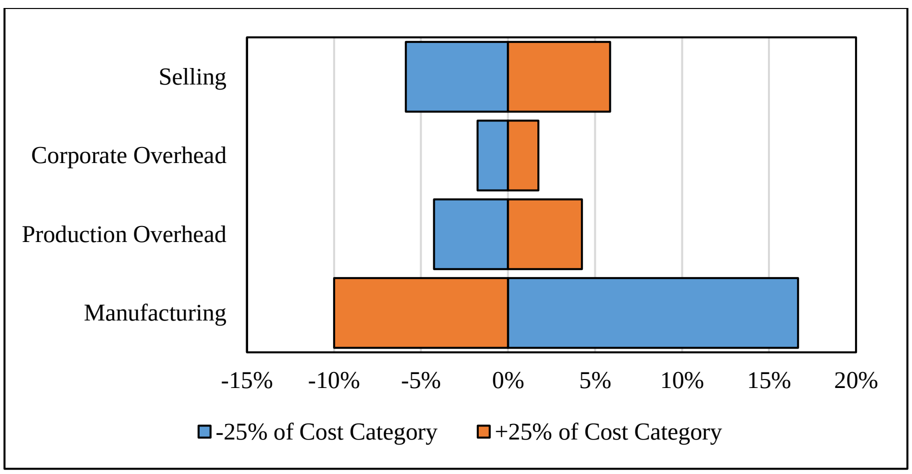

Figure 5: Sensitivity of the internal product part's markup factor from Vyas, Santini, and Cuenca (2000) due to a 25% variation in the listed components of cost.

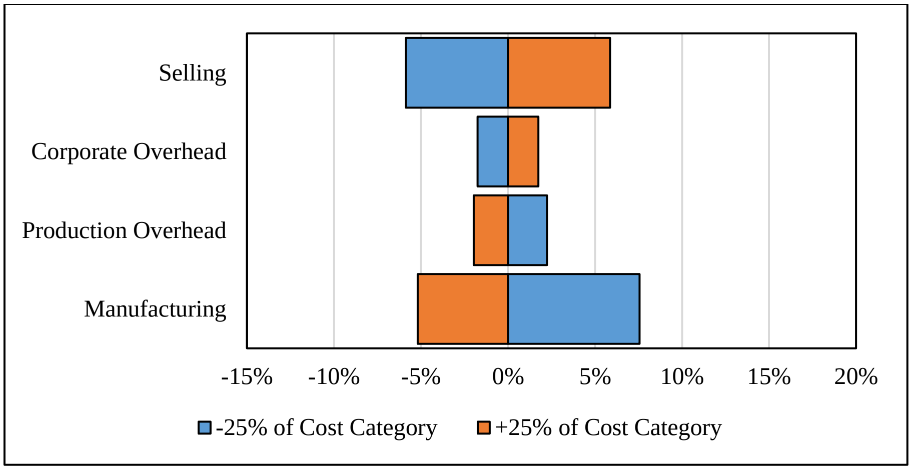

Figure 6: Sensitivity of the outsourced part's markup factor from Vyas, Santini, and Cuenca (2000) due to a 25% variation in the listed components of cost.

This sensitivity analysis helps us observe the effect of the components of cost on vehicle cost markup factors based on Vyas, Santini, and Cuenca (2000). We also present the resultant markup factors associated with these percent variations in Figure 7 and Figure 8. These figures allow us to better see the large impact of the manufacturing cost in both the internal and outsourced scenarios while further highlighting the proportional and inverse relationships associated with the different cost components.

This examination does not purport to indicate that the in-component mathematical formulation of cost is a simple linear matter. We know, for instance, that production volume has a distinctly nonlinear relationship with cost. This sensitivity analysis bounds the effects for the equations posited by Vyas, Santini, and Cuenca There may be, in fact, some interplay between the components of cost that are more complex than what they suggest, and we, again, do not purport to suggest that a more complex relationship does not exist; we only suggest that, given the formulations as stated, we can observe changes to the cost markup factor based changes to the components of costs.

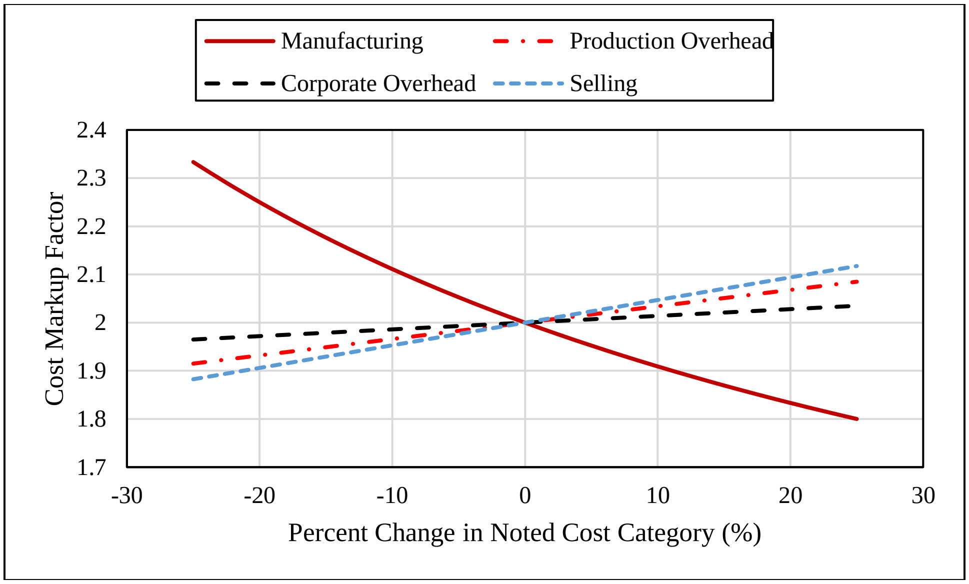

Figure 7: Sensitivity of the internally produced part's markup factor from Vyas, Santini, and Cuenca (2000) due to variation in the listed components of cost.

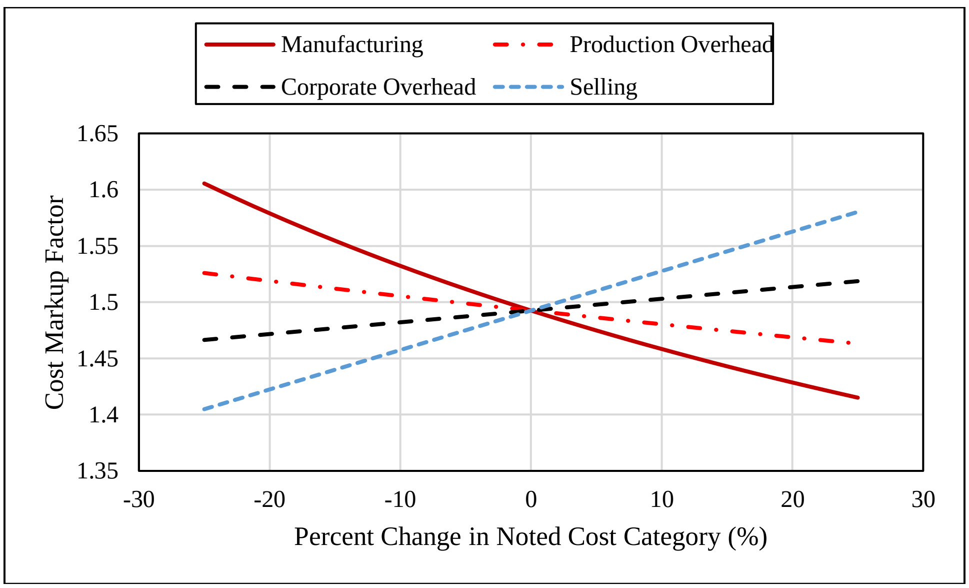

Figure 8: Sensitivity of the outsourced part's markup factor from Vyas, Santini, and Cuenca (2000) due to variation in the listed components of cost.

3.2 Rogozhin, Gallaher, and McManus (2009)

3.2.1 Description of Component Costs

The cost components for multiple vehicle OEMs as described by Rogozhin, Gallaher, and McManus (2009), for the year 2007, are visually presented in Figure 9. We see that RPE is composed of costs associated with manufacturing (MFG), production overhead, corporate overhead, selling, and dealers, along with net income. Production overhead costs includes costs associated with warranty, R&D and engineering, depreciation and amortization, and maintenance, repairs and operations, while corporate overhead costs include costs associated with general administration, retirement, and healthcare, while selling costs include costs associated with transportation and marketing, and dealers costs include costs associated with new vehicle selling costs and new vehicle net profit. Thus, the Rogozhin, Gallaher, and McManus (2009) RPE formulation would be

$$RPE = Net\ Inc + Selling + MFG + Corp\ Ovrhd + Prod\ Ovrhd + Dealers.$$

Equation 10

In their formulation of an RPE multiplier, they indicate that all cost components listed would be included in the RPE, and that only manufacturing costs would be the only costs associated with production. Consequently, their markup factor would be

$$MarkupFactor = \frac{Net\ Inc + Selling + MFG + Corp\ Ovrhd + Prod\ Ovrhd + Dealers}{MFG}.$$

Equation 11

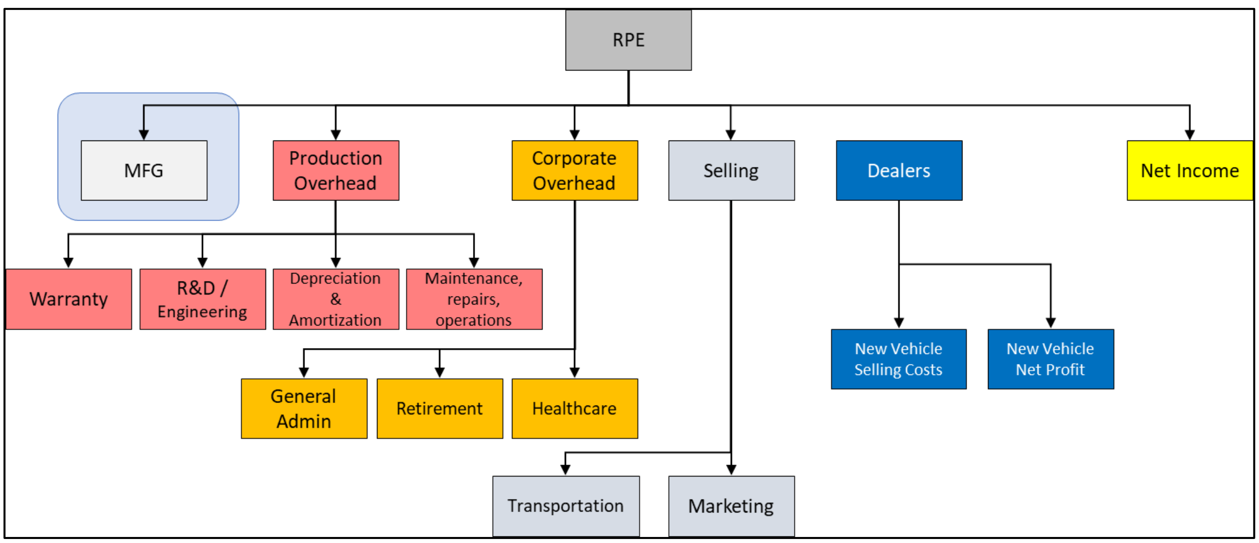

Figure 9: Vehicle OEM cost components described in Rogozhin, Gallaher, and McManus (2009); the blue box highlights cost components in the denominator of Equation 11.

3.2.2 Sensitivity Analysis

As in Section 3.1.2, we use the information presented regarding the mathematical formulation of vehicle part cost in the previous section along with data found in (Rogozhin, Gallaher, and McManus 2009). We conducted a sensitivity analysis of RPE markup factors considering variations in different cost components. Here we varied the quantity of the cost components selling, corporate overhead, production overhead, and manufacturing in the absence of changes to any other components. We varied costs by 25% for each of these categories to observe the impacts that such a change would have on the markup factor; we present these results by showing the percent change that these variations imparted upon the RPE markup factor. By observing the formulation of markup factor in Equation 11, we can see that the selling, corporate overhead, and production overhead components of cost are directly proportional to the markup factor, while the manufacturing component of cost has a relationship that is both inversely and directly proportional to the markup factor. Examining this further in Figure 10, we see both that this relationship holds, and that its impact varies depending upon the OEM. The markup factor is most sensitive to the cost of manufacturing. The overall relationship is inverse such that a 25% reduction in manufacturing cost leads to an increase between 9.9 and 10.8% in markup factor depending upon the OEM, and a 25% increase in manufacturing cost yields a reduction in markup factor between -5.9 and -6.6%, depending on the OEM. We see that, among the directly proportional relationships, the markup factor tends to be most sensitive to the cost of production overhead for the OEMs, such that a 25% increase or decrease leads to an increase or decrease, respectively, between 2.6 and 3.7%, depending on the OEM.

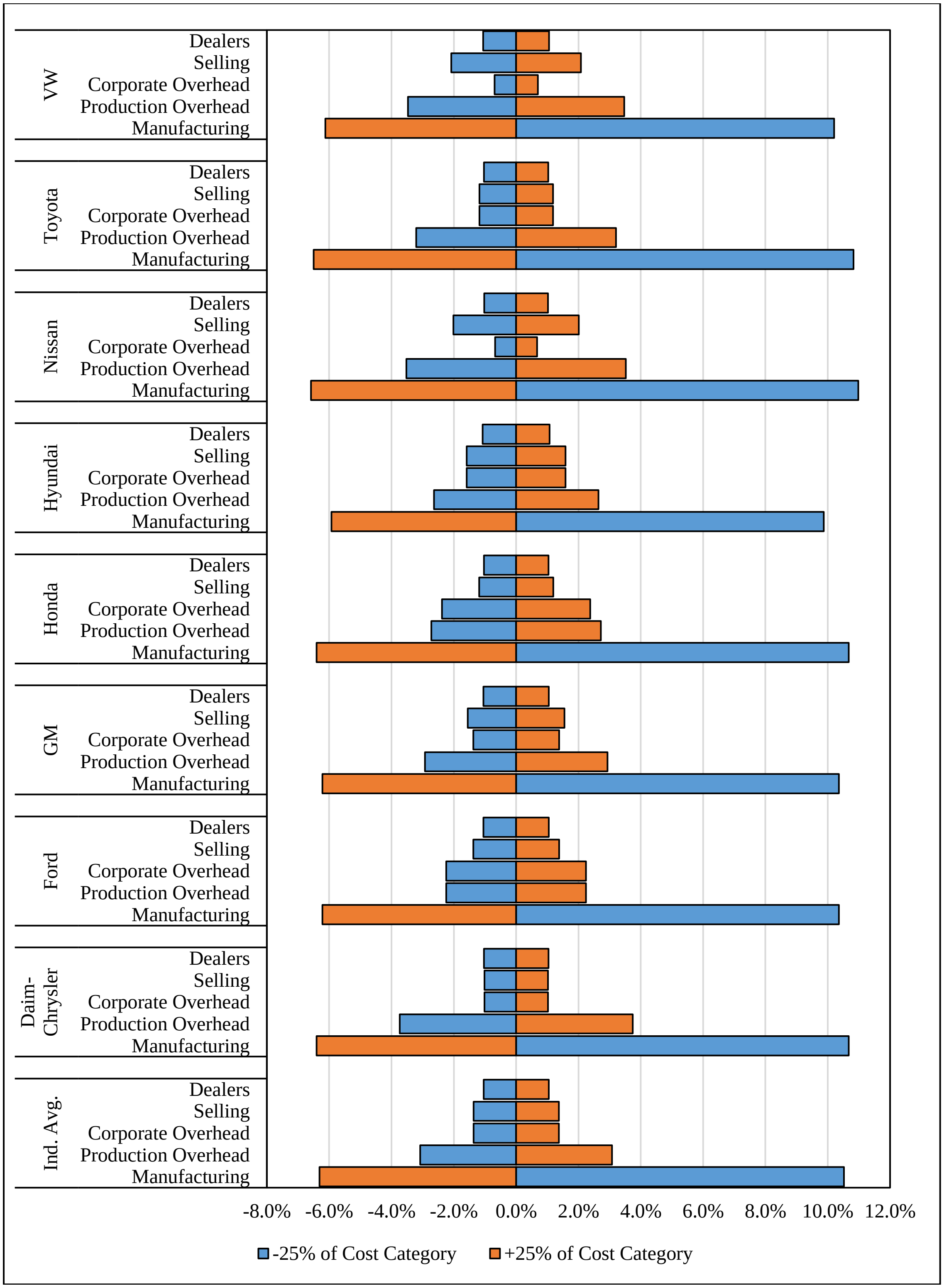

Figure 10: Sensitivity of each OEM's 2007 markup factor from Rogozhin, Gallaher, and McManus (2009) due to a 25% variation in the listed components of cost.

Comparing this examination to that in Section 3.1.2, we see that the two research teams, Vyas, Santini, and Cuenca and Rogozhin, Gallaher, and McManus have similar formulations for markup factors, but they have different valuations of the individual cost components (Vyas, Santini, and Cuenca 2000; Rogozhin, Gallaher, and McManus 2009). Both formulations have a common relationship between manufacturing and the other components of cost, and variations in manufacturing cost effect the greatest change on the overall markup factor. However, the valuation of those cost components differ, as can be seen in Table 1. This then propagates through our sensitivity analysis to indicate that the Vyas, Santini, and Cuenca formulation identifies the Selling cost component as a dominant factor in the sensitivity analysis, while selling is not indicated as the dominant factor in Rogozhin, Gallaher, and McManus (2009). We notice that Vyas, Santini, and Cuenca include dealer costs in their selling category; however, even if we combine those two factors in the Rogozhin, Gallaher, and McManus study, we see that they would indicate a change in RPE markup factor of between 2% and 3.2%, still roughly half of that indicated by Vyas, Santini, and Cuenca. Direct comparison of these two approaches may not be entirely equivalent, but it does provide an insight into how these different components of cost can influence the markup factor. Again, this examination does not purport to suggest the components of cost examined will vary in a linear fashion; we merely show how these components combine to produce the markup factor.

4 SUMMARY

This literature study examined the state the of the cost markup literature for light-duty vehicles. It found that there is general consensus for a markup factor of 2.0 for vehicle parts produced by OEMs and a factor of 1.5 for parts that are outsourced. There is a wide acceptance that these values are not indicative of any specific part, or OEM. Rather, they highlight that over time the market has shown that it will, on average, across an OEMs entire fleet, allow the OEMs to set their prices such that their return is consistent with the markup factors presented. Some vehicles will have higher markup factors and they will thus subsidize vehicles with lower markup factors. Further, we can observe from the mathematical formulations from Vyas, Santini, and Cuenca and Rogozhin, Gallaher, and McManus, which we explored in detail, that changes to manufacturing cost are the most influential in affecting markup factors and that they are inversely proportional while most other factors are more directly proportional (although we disclaim that linearity within those cost components should not be taken as a broad assumption, but a simplifying factor of the examined literature) (Vyas, Santini, and Cuenca 2000; Rogozhin, Gallaher, and McManus 2009). Furthermore, EPA and NHTSA highlight that new technologies will initially have lower RPE values than would as those technologies mature due to learning advancements and economies of scale (EPA and NHTSA 2018). So, while we do not find a specific variable markup factor approach from other researchers that is widely accepted, we did examine the origins of the commonly identified 1.5 multiplier, the factors that influence it, and the way they do so.

5 ACKNOWLEDGEMENTS

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