A Partner Selection & Collaboration Model in After-Market Supply Chain

Ali A. Yassine[1*], Thomas Roemer[2]

[1] Product Development Research Lab, University of Illinois at Urbana-Champaign, Urbana, IL. 61801

[2] MIT Sloan School of Management, Cambridge, MA. 02142

Abstract

This paper presents an approach to modeling product development collaboration between original equipment manufacturers (OEMs) and after-market suppliers (AMSs). Collaboration, through the exchange of design information, enables faster time-to-market for the AMSs' products. In addition, by co-marketing the products, both the OEM and AMS can gain significant reputation benefits. In this paper, a decision-theoretic model is presented, which models the interaction between an OEM and an AMS as an extensive-form game. Firms are classified based on specific assumptions and the expected and optimal outcomes for each pairing of firm types are enumerated. The model is then analyzed under the context of an uncertain environment, and examined to show how firms may gain leverage due to the uncertainty.

Key words: Product Development, After-Marker Supply Chain, Collaboration, Partner Selection, Game Theory.

[*] Corresponding author. Tel.: +1-217-333-8765; fax: +1-217-244-5705
E-mail: yassine@uiuc.edu

1. Introduction

Consumers today have an ever-changing set of tastes, and manufacturers are scrambling to find ways to deal with those changes. Aftermarket products are one solution to this problem.[1] An aftermarket product is any product which would have no reason for existence without another primary product, and yet is purchased independently of the primary product. Software titles and video games are perfect examples since they would not have any use without the operating systems or hardware that are used with them. The automotive industry is particularly ripe with aftermarket suppliers since the development time for new vehicles is typically very slow compared to the march of technological change. By taking advantage of the latest trends in technology and consumer tastes, aftermarket products can significantly affect the image of the OEM's product as well as sales.[2]

Typically, due to their organizational structures and economies of scale, it is not practical for an OEM to offer custom products with a wide range of options, so OEMs look for a practical solution to dealing with rapidly changing tastes and technologies. By collaborating with aftermarket suppliers (AMSs), original equipment manufacturers (OEMs) can insure that customized products are available to consumers as soon as possible after the launch of the OEM's product. Specifically, in the automotive market, specialty equipment after-market suppliers (AMSs) typically offer more innovative products than can be offered by the OEM. By collaborating with the AMSs, consumers

[1] The three primary categories of after-market products are loosely defined as: (a) replacement parts, (b) service and maintenance, and (c) specialty equipment. While replacement parts and service account for the bulk of the market (roughly 90%), the specialty equipment market still accounts for over $26 billion in annual retail sales (Source: AAIA 2002).

[2] In the automotive industry alone, the retail sales figures in the U.S. are both significant and growing. Between 2000 and 2002, the market's retail sales numbers grew from $247 billion to $264 billion (Source: AAIA 2002).

can purchase and install custom parts closer to the release of the vehicle, adding to the brand image of both the OEM and the AMS's products. Other industries face similar issues, particularly the personal computer and video game industries, where systems have higher value to the customer when there are a multitude of software titles and games available for purchase and use with a particular system.

The situation with Honda Civic and the Toyota Tercel is a case in point. Once they were nearly identical in the consumer eye, appealing to the practical-minded who wanted a low price vehicle with good reliability. Honda recognized that the same vehicle could be marketed to young buyers due to the fact that the baseline model was offered at a low price. To do this, Honda needed a way to make the simple, practical, and aesthetically conservative Civic attractive to younger consumers. The answer came through the automotive after-market. Honda took steps to build a large following of suppliers developing performance-enhancing and style-personalization products specifically designed for the Civic. Young consumers now have the opportunity to purchase the baseline Civic at a low price point, and make incremental improvements as funds allowed, each adding to the style and personalization of the vehicle. The Tercel, meanwhile, never gained the popularity with the youth crowd, and only recently has Toyota taken steps to attract this crowd by establishing the Scion label, which consequently has the majority of after-market parts actually produced and marketed by Toyota rather than external suppliers.

Supply chains are no longer just characterized by suppliers and customers, but extend even to direct and indirect competitors, and complimentors. Although OEMs seem to benefit from the existence of AMSs, in many cases there may be a conflict of interest if the OEM and AMS also offer competing products within other market segments. In addition, OEMs expose themselves to the risk of information about product design, technology, and marketing effort being released into the hands of competitors. AMSs, additionally, risk the possibility of costly redesign and rework if they are to design a product based on information received from the OEM that is later modified due to changes in design. In addition, starting development earlier is characterized by a much more uncertain demand environment as well. Considering these points, it is far from obvious whether OEMs and AMSs should collaborate at all and to what extent the collaboration should take place.

In this paper, we establish a framework which can be utilized to determine whether or not an OEM should collaborate with a specific AMS, and how. Based on some broad classifications of firms pertaining to the types of profit they might expect, we can analyze the expected behaviors for each specific pairing of firms. In addition, we show what the expected outcome of any collaboration is, and when and how one party might be able to induce behavior other than that which is predicted by the model. The model is further enhanced by allowing for uncertainty in the strategies of the firms. This uncertainty provides a clear explanation as to why certain OEMs have leverage over certain AMSs. In order to better model the collaboration, we also present a flexible framework for quantifying the benefits and costs associated with collaboration.

In section 2 of this paper, we review relevant literature from the fields of interfirm collaboration and management strategy. In section 3, we outline some basic assumptions necessary for a model, compare the model we propose with some existing work, and provide a means through which to calculate the expected profit, which will be necessary to apply the model in practice. In section 4 we lay out the decision situation as an extensive-form Bayesian game, which will serve as the basis of our model. We then go on to characterize the types of OEMs and AMSs, based on profit dominance of the various possible outcomes, and determine the ideal strategies and expected outcomes of each pairing of OEM/AMS. Section 5 provides conclusions and suggests directions for future work.

2. Related Literature

Literature on management strategy and organizational behavior describe collaboration as a means through which to combine resources in order to develop novel solutions to business problems (Hamel 1991, Gray 1989). Collaboration implies that two firms establish an agreement that leads to the sharing of some resources, through which each firm improves its product-market combinations (Hagedoorn 1994). More specifically, collaboration implies that entering into the relationship is voluntary and not directly tied to either payments or any form of legitimate authority (such as a regulatory agency). Thus, they are not reliant on hierarchical controls or market mechanisms (Heide 1994).

Since collaboration is not a matter of market transactions, then it exhibits mutual interdependence, where each party is vulnerable to actions of the other that are not under direct control (Pfeffer and Nowak 1976). Also, without a higher power or authority, the agreements are inherently unstable due to the possibility of future noncompliance or opportunism on the part of one of the firms (Parkhe 1993). The self-interest orientation leads to actions which may be individually rational but are sub-optimal given the situation (Williamson 1985).

Typically, in order to consider any act of cooperation to be collaboration, then there must be some sort of ongoing commercial relationship between the firms. The collaboration may involve the sharing of information, the sharing of resources, or even mutual brand positioning. For any of these types of collaboration, the exact outcome of the arrangement and success is difficult to define. Therefore, collaboration is expected to take place on a relational basis, rather than a contractual one (Cabral 2000).

Firms may have a variety of reasons for entering into these collaborative relationships. In the most general sense, firms enter to achieve goals which they feel they could not achieve alone. In one case, firms may form relationships to acquire resources that it would not be efficient to develop internally (Powell 1996) or to acquire new skills (Gulati 1999). For example, this may involve utilizing another firm's logistics network or sales force, so that the primary firm may focus on product development. Firms may also establish collaborative agreements to share risks and reduce costs (Barringer 2000). The typical example of this is when firms share the development costs of a new technology. Firms may enter into an agreement in order to learn about new markets or to learn more about the market (Doz and Hammel 1998). In the automotive market, after-market suppliers are typically much more in tune with customer needs than OEMs, and therefore an OEM can benefit from the knowledge of the AMS. Other reasons for establishing collaborations include reducing dependence on suppliers or simply to maintain competitiveness in the face of increased competition.

3. Model Assumptions

Phomma (2003) introduced two earlier models of collaboration in the after-market supply chain. These models were designed to describe the expected collaborative relationship between an OEM and a single after-market supplier (AMS). In the first model, it is assumed that product sales are a function of the time spent developing, and that OEM profit gained through the existence of the development time as well. In the second model, it is assumed that early release of design information from the OEM is accompanied with some probability of rework.

In both cases, the author is able to show that it is likely that the OEM and the AMS will have differing ideal start times for development. The author proposed that incentives will be necessary to bring the two firms into alignment and make collaboration happen. But additional research (Engau 2003) implies that contracts and direct incentives are fairly uncommon, at least in the automotive industry. Have the proposed models failed to grasp the real essence of the problem, or are some of the after-market firms failing to take advantage of the misalignment? The incentives would, in theory, flow to the after-market firm since the OEM is not absorbing any additional cost related to starting earlier development.

3.1. Basic Model Assumptions

It is our position that the existing models fail to capture the true essence of the situation. In this section we establish guidelines for a model between after-market suppliers and original equipment manufacturers for the automotive industry, which can be extendible to other markets with small alterations to the model. We concur with the previously developed models that certain features must exist in a model (Phomma 2003). We assume that after-market parts (have the capacity to) alter demand for the OEM product. Additionally, we assume that OEMs release design information to the after-market suppliers in order to gain some advantage, allowing for the possibility that some OEMs either do not recognize the potential for advantage or otherwise do not gain from the existence of after-market parts. The release of design information, as well as additional collaboration, comes at a cost to both parties, either directly or indirectly.

Basic observations and intuition led us to a set of postulates about the collaboration which also need to be present in a tractable model. We recognize that the decision situation for each party is complicated by uncertainty in demand, as well as uncertainty in each party's collaborative tendencies. In the automobile industry, demand is often misestimated by as much as 40% in either direction (Jordan and Graves 1995). Further, OEMs and AMSs often interact on a repeated basis. This indicates that reputation is important, and that private information may play a role in strategy formulation (Parkhe 1993). Certainly, firms are profit seeking, and as such are best advised to make decisions which maximize the expected utility over those decisions.

Finally, we set a more stringent requirement, which is that demand for the after-market part must in some way be dependent on demand for the OEM product, and vice-versa. The basis for the final postulate comes from two idealized facts, which are (1) demand for the after-market part would be zero if there were no corresponding OEM product, and from value theory (2) an after-market part with infinite value would create demand for itself, which would necessarily create demand for the OEM part. In reality we fall somewhere in between, but the grounds for a relationship are well established.

3.2. Profit Formulations for the OEM and AMS

As stated in the assumptions, the OEM and AMS must deal with attempting to maximize profit in an uncertain environment. Given the additional assumptions we have made, there are a restricted class of profit formulations which meet our needs, and in this section we present one such profit model that will be used to motivate the remainder of the paper. We began by making certain limiting assumptions about the characteristics of the market (subscript M denotes OEM and S denotes AMS). For one, both parties are operating under a strict market window, ending at a known point in time (W). If they choose to collaborate, there is a cost of collaboration for each party (C_M and C_S). Development cost is completely supported by the AMS, and can be represented as a function of time by a constant (A_S). Also, our first model will make the assumption that there is a fixed development time for the after-market part (τ_{dev}), and that receiving information from the OEM does not speed up development time. Future extensions will allow for this possibility, though it can be shown to have minimal effect of the strategies undertaken.

Revenue for each party can be represented as a function of time, meaning that demand rate (D_M and D_S) is constant across the market window, making revenue rate (R_M and R_S) also a constant. As mentioned previously, the AMS's demand is dependent on the (baseline) demand for the OEM product, which allows us to represent D_S as $\delta_S D_M$, where δ_S is some constant. Total demand for the OEM product is influenced by the AMS part by altering the customer's perceived value, without influencing cost. This allows a demand effect independent of the purchase intent, and leads to different demand rates in the market where consumers are aware of a particular after-market part (d_A) and where they are not (d_N). This also means that demand is a function of after-market part awareness (m). More information about how to determine this effect is included in Appendix A. Finally, anticipated baseline demand for the OEM part is uncertain and can be modeled as a continuous distribution, and yet becomes more certain (reduced variance) as the product launch date nears. The variance is important because we assume that both firms are risk averse, and therefore prefer to have less uncertainty given the same possible outcomes.

The OEM's concerns about the AMS can be represented by an (uncertain) information leakage cost (L_M), which is decreasing as the launch date nears. An OEM would typically attempt to keep some of the information about its new products a secret until it has reached the market, at which point competitors would very likely be able to reverse engineer the product. The cost of information loss is related to demand, since the release of information would likely allow competitors to match the technology and provide an adequate substitute, thus reducing demand for the OEM's new product. Therefore, the evaluated cost is tied to both the newness of the product and the point at which the information is leaked. Additional information related to measuring this effect is included in Appendix B.

These assumptions listed above lead to specific profit formulations for the OEM and the AMS. Each party attempts to maximize their profits subject to the decision variables available. For the OEM, that means whether to offer information and whether to collaborate. For the AMS, that means when to begin development (for completeness, this also includes the limiting case to not develop at all, though to simplify the analysis, this decision variable is not included in the profit formulation since no profit or cost is realized). The profit maximization for the AMS would be:

$$\begin{aligned} &Max \quad R_S \delta_S D_M (W - (\tau_{start} + \tau_{dev})) - C_S - A_S * (\tau_{dev}) \\ &w.r.t \quad \tau_{start} \end{aligned} \tag{1}$$

The AMS is seeking to maximize profit with respect to the start time, which may depend on whether information is offered to her. The first term represents revenue generated by having an after-market part, and may include the added revenue from full collaboration. Since D_M is an uncertain variable with variance decreasing in time, there is a trade-off for τ_{start}. Later start times would lead to a larger D_M, but would decrease the window (W- (τ_{start} + τ_{dev})) term. The second and third terms are constants related to the cost of collaboration and development. Similarly, the profit maximization for the OEM is:

$$\begin{aligned} &Max \quad R_M D_M (W - (\tau_{start} + \tau_{dev})) - C_M - L_M \\ &w.r.t \quad \tau_{start} \end{aligned} \tag{2}$$

The OEM is seeking to maximize profit with respect to the start time, which he may be able to influence through his own decision variables. The decision variables (whether to offer information, when to offer information, and whether to collaborate fully) are excluded from the profit formulation for the time being. The first term represents revenue generated by having an after-market part, similar to the AMS's profit structure. The second term is the cost of collaboration, and the final term is the information leakage cost. Since L_M is an uncertain variable with variance decreasing in time, there is a trade-off for τ_{start} for the OEM as well.

4. A Decision-Theoretic Model

In order to map out the optimal strategies of the AMS and the OEM, we must investigate the ordering of the decisions which must be made within the collaborative environment. Prior to any development beginning by either party, the OEM has the option of offering early design information to the after-market supplier. We assume that if the OEM does not offer design information at this point, the best the AMS can hope for is to begin development at a later point, which will likely be the product release date (as depicted by AMS2 in Figure 1). AMS1 begins development based on partial information received from the OEM, and will most likely complete development earlier than AMS2 due to this early information release. One can quickly see how, with a fixed market length, the sales will decline due to a shortened window (see Figure 1).

Figure 1: Development Timeline for OEM and Two AMS's

If design information is offered, then the AMS now has a decision about whether to develop an after-market part for the OEM product. If no part is developed, the AMS has no profit and the OEM has some (negligible) cost associated with offering information to the AMS. If the AMS chooses to develop an after-market part, then it must decide when to begin development of the part. In some situations, the OEM may have set a date in the future in which an AMS may have its design reviewed. If the AMS chooses to have the part development by this date, then we shall say that they develop "early," otherwise we will classify their development as "late." The final decision for the OEM is made at the review point. A successful review may lead to further collaboration, what we will call full collaboration, which may include things such as additional design support or a co-marketing opportunity. If the part is developed late, then we assume that the review will not be successful and there is little or no chance of further collaboration.

Figure 2 depicts the decision situation in the form of an extensive form game. Circles represent decisions, payoffs are listed at the end of each branch, and a dotted line indicates that the decisions are tied due to lack of information about the current state.

Time progresses from the top of the tree to the bottom, where “M” nodes represent OEM decisions and “S” nodes represent AMS decisions. Each decision is labeled with a “D”, which will allow us to represent each firm’s strategy as a triple, relating the appropriate decision at each point (an OEM strategy of [Y, Y, Y] would indicate that the OEM will share info, and will collaborate fully regardless of whether the AMS develops early or late).

The expressions $\begin{vmatrix} M_x \\ S_x \end{vmatrix}$ indicate the expected profit for the OEM and AMS if the particular collaborative structure were to be realized. For example, if full collaboration occurs, and the AMS develops early, then the OEM has profit M_1 and the AMS has profit S_1. The representation in Figure 2 will be used in the following section to investigate how specific strategies will dominate based on the relationships between the M_x’s and S_x’s.

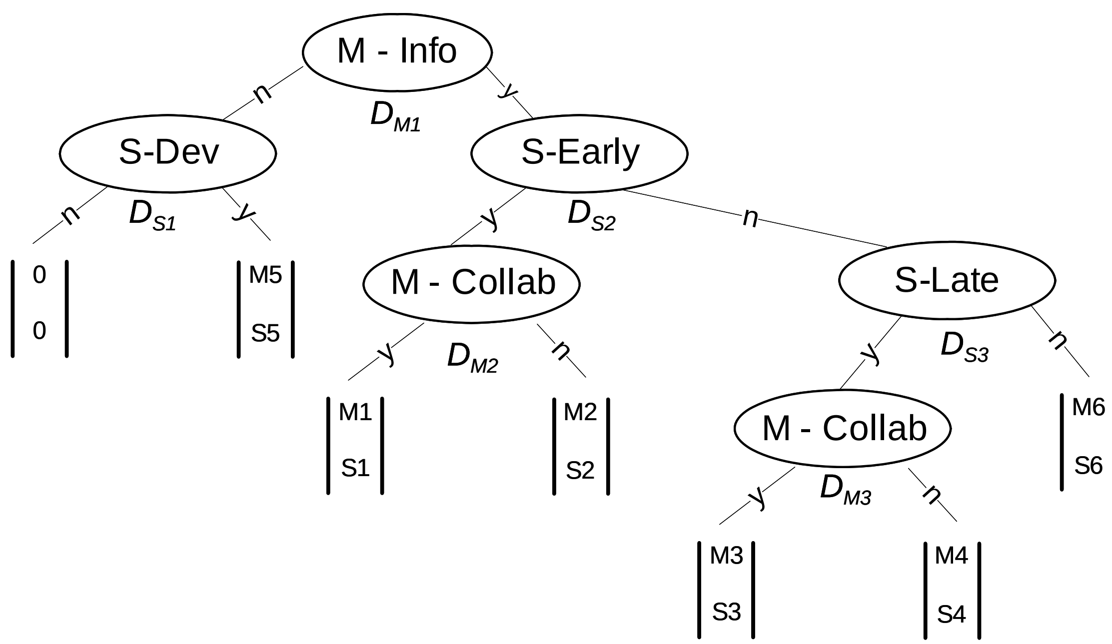

Figure 2: Extensive-Form Representation of the Decision Situation

When modeled as an extensive form game, our focus in modeling is to determine which strategies are not dominated and which strategies are sub-game perfect. For our purposes, sub-game perfection implies that the equilibrium is also an equilibrium in each sub-game, which helps eliminate idle threats as possible equilibrium points. In the remainder of this section, we first classify firms based on there preferences between the various possible outcomes, and then determine the equilibrium points for each possible pair of firms. In each example, the equilibria were found using backward induction, then verified with Gambit, a software tool for modeling extensive-form games.

4.1. Firm Classifications

While it would certainly be difficult to calculate the profit values expressed in Section 3 for every potential collaboration partner, this does not prevent our model from being useful. As we will show later, the strict evaluation of the profits has little bearing on the overall strategy if one already knows the ordering of the values from largest potential outcome to smallest. In many cases, a dominant strategy will often emerge, so there will be no need to analyze the exact values or even the ratio of the profits. Oftentimes, the firm's type will be more than enough information to determine the equilibrium strategy. Throughout this section and the remainder of the paper, strategy refers to the optimal behavior within a situation and type refers to the profit dominance structure, through which all strategies can be determined once the other player's type is determined.

Although the fact that we can guide strategy based on the profit dominance structure, the fact that there are seven terminal nodes leaves us with 7! possible orderings, and therefore 5,040 possible types for the OEM and 5,040 possible types for the AMS. In order to ease the analysis burden, a few basic assumptions can be made that will reduce the possibilities greatly. If we make the assumption that the after-market part will not decrease demand for the OEM's product (an assumption that may call for analysis in later research), then $M1 \geq M3$ and $M2 \geq M4 \geq M5$. This is because the longer the part is sold, the greater the demand effect will be. Also, $M6 \leq 0$, since by definition M6 yields no advantage to the OEM.

There are also several assumptions that can be made about the AMS's profit dominance structure. We assume that $S1 \geq S2$, which implies that an AMS which wants to develop at the OEM's optimal development start time (early) would prefer to collaborate fully with the OEM. Intuitively, this is reaffirmed since highly complex OEM-specific after-market parts are the ones which require the earliest start time – and are also the ones which benefit the most from receiving additional exposure by the OEM. It is tempting to assume that, similar to the OEM, $S6 \leq 0$, and to simplify the research we will assume this in certain scenarios. In fact, the scenario where $S6 > 0$ is quite common. An AMS can take the information received from the OEM and utilize it for means which reap a profit for the AMS, while leading to a loss for the OEM. Malicious information leakage to competitors and the development of directly competitive vehicles are just two examples of this.

In general, we assume that the OEM has some grasp over its own type, at least have a belief about whether or not the cost of collaborating is more or less than the profit which may be gained over the market window (as discussed in Section 3). The assumptions made allow us to reduce the number of possibilities to a manageable set of firm types, of which the OEM may be able to determine which type of AMS they are considering for collaboration without going through the trouble of estimating all of the parameters in the previously provided profit expressions. In the following two subsections, these types are given names and explanations of typical members in the automotive industry, in order to give the reader a better feel for what an actual firm fitting a type might resemble from a strategic standpoint. These classifications may also aid the OEM when analyzing potential partners based on minimal information.

4.1.1. OEM Firm Types and Strategies

In certain situations, it is safe to assume that the OEM considers it to be non-beneficial to collaborate at all. For this OEM, either $M_5 > 0 > \text{Max}\{M_1,M_2,M_3,M_4\}$ or $0 > M_5 > \text{Max}\{M_1,M_2,M_3,M_4\}$. This reduces our total list of possible types by recognizing that the ordering of any profit possibilities less than zero has no bearing on the decision making of the OEM. This "unwilling" OEM represents the trivial case in which it is not optimal to offer design information, possibly because the direct cost of sharing or the indirect cost of information leakage risk is too high. The other possibility is that, for the particular after-market part, the OEM may feel that it may have no effect (or a negative effect) on the demand for the OEM part. For instance, a company like Volvo would not be interested in custom engineered red flame decals for its line of family sedans, and may actually view their existence as having a negative demand effect.

In a slightly different situation, the OEM sees the advantages of having after-market parts, but does not consider it cost effective to help with the development in any way, since those parts are already being produced. For this OEM, $M_5 > \text{Max}\{M_1,M_2,M_3,M_4\} > 0$. This "reluctant" OEM considers it sub-optimal to offer design information, except in the situation where no product would be developed otherwise. While this situation is similar to the previous one, it is important to note that since M1-M4 are greater than zero, the OEM's strategy may differ considerably with the "unwilling" OEM, depending on the particular AMS with whom he is considering collaboration.

The "eager" OEM wants to collaborate with the AMS and therefore prefers that the AMS develop early. The corresponding risk is that he loses some amount if he expects to collaborate and the AMS develops late, and is an even bigger loser if no part is developed at all. It is safe to assume that $M_1 > M_2 > M_4 > M_3$ for this OEM, because M_1 and M_2 represent the situations where the AMS develop early. In addition, the OEM wants to collaborate fully when the AMS develops early ($M_1 > M_2$) but prefers to not collaborate fully when the AMS develops late ($M_4 > M_3$). When a highly-customized vehicle is paired with a highly desirable and highly visible after-market part, this profit dominance structure is likely to evolve for the OEM.

The "greedy" OEM wants the AMS to develop early, but would prefer not to collaborate fully. The value of early development is high enough that the OEM would prefer to collaborate fully if it knew that it was the only way to induce early development. Profit dominance for this OEM would be $M_2 > M_1 > M_4 > M_3$, which is similar to the previous situation except that the M_1 and M_2 are transposed. This would typically be the situation for a highly-customized vehicle, when the after-market part is not one whose reputation will help the OEM in advertising and promotions.

Finally, the more common situation most likely has the dominance structure $M_2 > M_4 > M_1 > M_3$. This "standard" OEM wants the AMS to develop early, but would prefer not to collaborate, even if it means the AMS will develop later. The cost of collaboration is high enough that the OEM would prefer not to collaborate. This OEM sees a benefit from after-market parts, but does not see a benefit from the additional collaboration forms such as co-marketing and trade show displays. This may be the most common example when the after-market part has a positive effect. The OEM wants to benefit from the part for as long a window as possible, but is just not willing to put up more than some minimal (information sharing) cost.

4.1.2. AMS Firm Types and Strategies

Likewise, the AMS has a variety of dominance structures, of which several can be ruled out or not considered. In one situation, the "complex" AMS considers it optimal to develop early regardless of the possibility of full collaboration, most likely due to a long development time. Examples of these types of products include chassis parts such as boots and joints, or engine parts such as valves and crankshafts. The profit dominance for this AMS would obey $S_1 > S_2 > \text{Max}\{S_3,S_4,S_5\}$. In addition, a slight variation on this type of AMS would obey the profit dominance structure $S_1 > S_2 > \text{Max}\{S_3,S_4\} > 0 > S_5$. This type of "dependent" AMS does not consider it worthwhile to develop if the development is started without information.

The dominance structure $S_5 > \text{Max}\{S_1,S_2,S_3,S_4\} > 0$ represents the trivial case in which it is optimal for the "simple" AMS to develop late, assumedly because there is a short development time or the cost of collaboration is too high. Products in this class may include those which are developed for multiple OEM platforms, such as wheels and tires, or a variety of non-unique accessories.

The "standard" AMS only wants to develop early if there will be additional collaboration. Otherwise, late development is optimal. These manufacturers can benefit from having design information, but may not want to develop as early as the OEM likes. Products of this type may include exhaust systems and turbochargers, which can be developed in a moderate amount of time, and whose suppliers can benefit greatly from the additional exposure which collaboration might provide. The dominance structure for this AMS would be $S_1 > S_4 > S_3 > S_2$. In addition, a slight variation on this type of AMS would obey the profit dominance structure $S_1 > S_4 > S_3 > S_2 > 0 > S_5$. This type of "hopeful" AMS does not consider it worthwhile to develop if the develop is started without information.

The "unwilling" AMS in this case does not consider the development of the part to be beneficial unless there will be additional collaboration. The firms who develop this type of product likely do not have the marketing muscle needed to "sell" the product, but have the engineering know-how to make it happen. In this case, some assurance regarding full collaboration is necessary, making the relationship more similar to a typical supplier-manufacturer relationship. The profit dominance structure for these AMS's would be $S_1 > 0 > \text{Max}\{S_2, S_3, S_4, S_5\}$.

4.2. Dominant Strategies in a Certain Environment

As we have already pointed out, there are three possible types of collaboration considered here; none, information only, and full collaboration. In addition, we have defined specific firm types by characterizing the profit dominance structure. Given this, we can determine the equilibrium points, and therefore the expected outcome (in terms of the type of collaboration) for each OEM/AMS pairing. Table 1 spells out the outcomes which would be realized when a specific type of OEM collaborates with a particular type of AMS. For example, a greedy OEM would wish to collaborate fully with a complex AMS, and therefore the expected outcome would be M1/S1.

		M5 > (others) > 0 Reluctant	M1 > M2 > M4 > M3 Eager	M2 > M1 > M4 > M3 Greedy	M2 > M4 > M1 > M3 Standard	M5 > 0 > (others) Unwilling
S1 > S2 > (others)	Complex	M5/S5	M3/S3	M1/S1	M1/S1	M5/S5
S1 > S2 > 0 > S5	Dependent	M1/S1	M3/S3	M1/S1	M1/S1	0
S1 > S4 > S3 > S2	Standard	M5/S5	M3/S3	M2/S2	M2/S2	M5/S5
S1>S4>S3>S2>0>S5	Hopeful	M1-4/S1-4	M3/S3	M2/S2	M2/S2	0
S5 > (others) > 0	Simple	M5/S5	M5/S5	M5/S5	M5/S5	M5/S5
S1 > 0 > (others)	Unwilling	0	M3/S3	0	0	0

Table 1: Equilibrium Payoffs for each Possible Pairing

There are several key observations which can be made by analyzing the outcomes presented in Table 1. First, although we did not specify specific profit values, and in some cases we did not even fully enumerate the profit dominance structure, in the majority of the situations we were still able to determine the equilibrium strategy. The combination of a dependent AMS and a reluctant OEM yields to a highly indeterminate situation. Further clarification into the strategies would be needed to determine the outcome, even though the other combinations yield specific expected results even without the higher level of specification into profit dominance.

Although they represent two obviously different types of OEM's, the greedy and standard OEM can expect identical outcomes because the OEM makes the final decision whether to collaborate fully. If the AMS knew an OEM was either greedy or standard there would be no need to evaluate further whether M3 dominates M2. An additional and rather interesting observation is that the second level determination of whether M0 is greater or less than zero for the complex/dependent and hopeful/standard AMSs only matters if the OEM is reluctant or unwilling. In all other cases, the outcome would be the same.

The other combinations in the table are consistent with intuition and/or observed behavior in the marketplace. Certainly, it is not a stretch to believe that an eager OEM and a complex AMS, when communicating their true intentions, would result in early development and full collaboration. Similar statements can be made about the majority of the other equilibria listed in the table. What is limiting about this type of analysis is that it assumes that each partner reveals their intentions fully and honestly. The next section focuses on the scenario when one party is uncertain about the type of the other, which results in a Bayesian game.

4.3. Uncertain Strategies

A more interesting and realistic situation occurs when one of the parties, be it the OEM or the AMS is unsure about the profit dominance structure of the other, and therefore cannot infer the type and corresponding strategy. For these situations, the game can be expressed as a Bayesian game, which is utilized specifically in situations where there is uncertainty about the type of the opposing player. We will explore two possibilities in the following sections, both from the point of the view of the OEM. For situations where the AMS firm type is uncertain, we explore the equilibrium strategies for the OEM in order to guide strategy. For situations where the AMS is unsure about the type of the OEM, we will explore just how the OEM can use uncertainty to achieve specific equilibria which are more beneficial to the OEM.

4.3.1. OEM is Uncertain about the AMS's Firm Type

Analysis was performed to determine the expected outcome (based on sub-game perfect equilibria) for each type of OEM paired with a possibility between two different types of AMSs. Table 2 lists the sub-game perfect behavior for the AMS, assuming that the OEM also plays the sub-game perfect strategy. The behaviors listed can be used to guide OEM strategy in the face of both certain and uncertain AMS types. The top half of Table 2 corresponds with Table 1, although the table lists the equilibrium strategies rather than the expected outcomes.

		OEM Firm Type				
		Reluctant	Eager	Greedy	Standard	Unwilling
AMS Firm Type	Complex	No	Offer	Offer	Offer	No
	Dependent	Offer	Offer	Offer	Offer	No
	Standard	No	Offer	Offer	Offer	No
	Hopeful	Undefined	Offer	Offer	Offer	No
	Simple	No	No	No	No	No
	Unwilling	No	Offer	No	No	No
	Complex/Simple	No	Offer	Offer	Offer	No
	Complex/Standard	No	Offer	Offer	Offer	No
	Complex/Unwilling	No	Offer	Offer	Offer	Offer
	Complex/Dependent	No	Offer	Offer	Offer	Offer
	Complex/Hopeful	No	Offer	Offer	Offer	Offer
	Simple/Standard	No	Undefined	No	No	No
	Simple/Unwilling	No	No	No	No	No
	Simple/Dependent	No	Undefined	No	No	Undefined
	Simple/Hopeful	No	Undefined	No	No	Undefined
	Standard/Unwilling	No	Offer	Offer	Offer	Offer
	Standard/Dependent	No	Offer	Offer	Offer	Offer
	Standard/Hopeful	No	Offer	Offer	Offer	Offer
	Unwilling/Dependent	Offer	Offer	Offer	Offer	No
	Unwilling/Hopeful	Offer	Offer	Offer	Offer	No
	Dependent/Hopeful	Offer	Offer	Offer	Offer	No

Table 2: Equilibrium Strategies for the OEM

In table 2, each possible strategy can also be represented as a triple for the OEM [D_{M1}, D_{M2}, D_{M3}], where the decisions correspond to those in Figure 2. The strategy "No" would be the strategy where D_{M1} = N. "Offer" would be any strategy where D_{M1} = Y, and "Undefined" could be either. Within the "Offer" strategy set, only the eager OEM would have D_{M2}=Y, and none of the OEMs in this example would have D_{M3}=Y. Table 3 highlights the strategy which the OEM expects the AMS to undertake, for each certain or uncertain type of AMS.

AMS Firm Type		OEM Firm Type				
		Reluctant	Eager	Greedy	Standard	Unwilling
	Complex	Dev	Early	Early	Early	Dev
	Dependent	Early	Early	Early	Early	No
	Standard	Dev	Early	Late	Late	Dev
	Hopeful	Undefined	Early	Late	Late	No
	Simple	Dev	Dev	Dev	Dev	Dev
	Unwilling	No	Early	No	No	No
	Complex/Simple	Dev	Early	Early	Early	Dev
	Complex/Standard	Dev	Early	Early	Early	Dev
	Complex/Unwilling	No	Early	Early	Early	Early
	Complex/Dependent	No	Early	Early	Early	Early
	Complex/Hopeful	No	Early	Early	Early	Early
	Simple/Standard	Dev	Undefined	Dev	Dev	Dev
	Simple/Unwilling	No	Dev	Dev or No	Dev or No	No
	Simple/Dependent	No	Undefined	Dev or No	Dev or No	Undefined
	Simple/Hopeful	No	Undefined	Dev or No	Dev or No	Undefined
	Standard/Unwilling	No	Early	Late	Late	Early
	Standard/Dependent	No	Early	Early	Early	Early
	Standard/Hopeful	No	Early	Early	Early	Early
	Unwilling/Dependent	Early	Early	Early	Early	No
	Unwilling/Hopeful	Early	Early	Late	Late	No
	Dependent/Hopeful	Early	Early	Early	Early	No

Table 3: Anticipated Strategies for the AMS

In Table 3, each possible strategy can also be represented as a triple for the AMS [D_{S1}, D_{S2}, D_{S3}], where the decisions correspond to those in Figure 2, a strategy of "No" corresponds with the triple [N, N, N]. A strategy of "Dev" corresponds with any triple that has D_{S1} =Y. "Early" and "Late" correspond with strategies that have DS2=Y and DS3=Y, respectively.

As discussed in Section 3.2, the most important aspects for the OEM are when the product gets released and whether information is leaked by the AMS to other manufacturers. Thus, the situations where information is offered and nothing is developed are particularly nasty situations for the OEM. From Table 3, we see that there are only a few situations which might lead to that particular situation, those which are listed as "Dev" or "No" indicate an example where, even if provided with information, the AMS might not develop early (or at all). While we will not discuss resource constraints and opportunity costs, but it suffices to say that resources are limited and investing in an AMS and getting no return is highly undesirable. Therefore, the OEM should not even offer information to an AMS if the expected outcome is either of the two.

The remainder of the table highlights whether an OEM can expect an AMS to develop early or late based on the AMS's belief about the OEM's type. For example, regardless of the uncertainty (excluding the simple AMS), the eager OEM can expect after-market suppliers of all other types and possible uncertain combinations to develop early in order to take advantage of the extended collaboration which is expected within this type of relationship. The table serves as a starting point for the OEM to determine whether to collaborate with an AMS based on relatively limited information (likely profit dominance possibilities). One can see that, for example, an "eager" OEM only needs to rule out the possibility of a particular AMS being "simple" before deciding on a strategy (offer information and potentially collaborate further). This can be as simple as judging whether the cost of collaboration for the AMS exceeds profit gained over the time which an after-market product is delayed if there is no information sharing. Similarly, the "standard" OEM must merely eliminate the possibilities of the AMS being "simple" or "unwilling" before making his decision.

4.3.2. AMS is Uncertain about the OEM's Firm Type

Because the OEM has the opportunity to make decisions both prior to and after the AMS's decision is revealed, the OEM has the opportunity to influence the AMS in more unique ways. The OEM can indicate one strategy at the point which D_{M1} is made, while returning to its true type at the point of decision D_{M2} or D_{M3}. Therefore, analysis was performed to determine the expected outcome (again based on sub-game perfect equilibria) for each type of AMS faced with a possibility of collaborating with an OEM who may be of two possible types. The value of this analysis is that it alerts us to possibilities for the OEM to reap a higher profit by inducing more optimal behavior from the AMS by falsely representing his own type.

		OEM Firm Type				
		Reluctant	Eager	Greedy	Standard	Unwilling
AMS Firm Type	Complex	**Eager**	Eager	Greedy	Standard	**Eager**
	Dependent	Reluctant	Eager	Greedy	Standard	**Eager**
	Standard	Reluctant	Eager	Greedy	Standard	**Eager**
	Hopeful	**Eager**	Eager	Greedy	Standard	**Eager**
	Simple	-	-	-	-	-
	Unwilling	-	Eager	-	-	-

Table 4: Opportunities to Influence AMS by Hiding True Type

Table 3 lists the type which the OEM should reveal to the AMS, alternatives marked "-" indicate that no strategy should be revealed. This corresponds to the situations where no information is offered, and therefore the AMS will be able to infer very little about the characteristics of the OEM. The six situations where "Eager" is given in bold indicate situations where the OEM can benefit by indicating a type other than the true type. This is the main insight which is garnered from this type of analysis. To correspond with the falsely indicated strategies, Table 5 lists the optimal strategy for the OEM when displaying the types listed in Table 4.

		OEM Firm Type				
		Reluctant	Eager	Greedy	Standard	Unwilling
AMS Firm Type	Complex	Info	Collab	Info	Info	Info
	Dependent	Info	Collab	Info	Info	Info
	Standard	No	Collab	Info	Info	Info
	Hopeful	Info	Collab	Info	Info	Info
	Simple	No	No	No	No	No
	Unwilling	No	Info	No	No	No

Table 5: Equilibrium Strategies for the OEM

Other key points can be drawn from Tables 4 and 5. It is clear that an eager OEM has high incentive to reveal his type truly, because any other combination casts doubt into the possibility of future collaboration, leading to late development in the case of the hopeful

AMS and delayed or, more likely, no development on the part of the unwilling AMS. For the unwilling and reluctant OEM types, the complex and hopeful AMSs can easily be coerced into developing early by creating uncertainty into the true type of the OEM. When the OEM introduces uncertainty into its type, additional types of AMSs are willing to develop early due to the possibility of the future collaboration introduced by the uncertainty. By offering information amidst an air of uncertainty, the prospect of further collaboration is often enough to induce early development

One other key note is that certain AMSs are robust to uncertainty in the OEM type. The simple and unwilling after-market suppliers can not be expected to alter their behavior in the face of uncertainty, while the standard AMS would switch to early development in the face of any uncertainty, not just those which include the eager type of OEM. But, as expected, the scenarios where the OEM leads the AMS into believing that it may be eager are those which lead to the highest payoffs for the OEM because the after-market parts are developed earliest.

5. Conclusions

The purpose of the research into after-market suppliers was to build a framework which could be utilized by managers at OEM firms when deciding when and how to collaborate with after-market suppliers. This paper has provided an overview of one such model which agrees with current qualitative research, and yet has extended the research in a way which better accounts for the observed behavior which was at odds with existing models. In general, the after-market parts discussed in this paper affect a customer's willingness to pay, and therefore there is a direct demand effect. The foundation of the model resides in understanding that the primary goals for the after-market supplier and very similar to those of the OEM. The after-market supplier would like its products to hit the market as soon after the release of the OEM product as possible. Likewise, increasing the length of the market window has a direct effect on OEM product sales because having a more highly valued product on the market for a longer amount of time would typically lead to higher sales.

In addition, by modeling the interaction as an extensive-form game, the model better represents the information and timing that go into collaboration decisions. We have provided here a set of classifications for firms on each side of the relationship which yield clear strategies when the classifications are known, and expected strategies when the classification can be represented as a degree of belief with respect to two (or more) possible classifications. The analysis can be made at a very high level, with intuition guiding the choice of appropriate firm types, or can be taken at a much deeper level. Full profit analysis can be performed by incorporating real sales figures and market research studies.

Next steps in the research will be to apply the model in practice to determine if the expected behaviors match the model's predictions. This will require expanding the model to include decision situations in which one firm must decide which firm or firms to collaborate with, and the opportunity costs and complications introduced by a network of collaborators. In addition, if one were to model collaboration as a repeated game (repeated across products), then one might better describe the evolution of the industry into its current state, the loyalties which develop between firms even in the absence of contracts, and the behavior of various firms attempting to influence suppliers to develop after-market parts for their products. Finally, the direct value method mentioned in the

Appendix has not been tested extensively when the product variant in question is not a product variant at all, but actually a market segment which has access to different information, in the form of awareness of the after-market part. The underlying theories are sound, but the survey methods will need to be altered to take into account this new type of research.

References

[1] Barringer, B. and J.S. Harrison, Walking a Titghrope: Creating Value Through Interorganizational Relationships. *Journal of Management*, 2000. 26(3): p. 367-403.

[2] Cabral, L.M.B., R&D Cooperation and Product Market Competition. International Journal of Industrial Organization, 2000. 18(7): p. 1033-1047.

[3] Cook, H. E. (1997). *Product Management: Value, Quality, Cost, Price, Profit and Organization*. London, Chapman & Hall.

[4] Doz, Y.L. and G. Hamel, *Alliance Advantage: The Art of Creating Value through Partnering*. 1998, Boston, MA: Harvard Business School Press.

[5] Engau, C. (2003). Collaboration between Original Equipment Manufacturers and After Market Suppliers in the Automotive Industry: Cooperation Models, Benefits, and Limits. Martikelner, Institut fur Produktionsmanagement, Technologie, und Werkzeugmaschinen.

[6] Gray, B. (1989). *Collaborating*. San Francisco, CA, Jossey-Bass.

[7] Gulati, R., Network *Location and Learning: The Influence of Network Resources and Firm Capabilities on Alliance Formation*. Strategic Management Journal, 1999. 20(5): p. 397-420.

[8] Hagedoorn, J. and Schankenraad, J. (1994). The effect of strategic technology alliances on company performance. *Strategic Management Journal* 15(4): 291-309.

[9] Hamel, G. (1991). Competition for Competence and Inter-partner Learning within International Strategic Alliances. *Strategic Management Journal* 12(3): 83-103.

[10] Heide, J. (1994). Interorganizational Governance in Marketing Channels. *Journal of Marketing* 58(1): 71-85.

[11] Jordan, W. C. and Graves, S. C. (1995). Principles on the benefits of manufacturing process flexibility. *Management Science* 41(4): 577-594.

[12] Parkhe, A. (1993). Strategic Alliance Structuring: A Game Theoretic and Transaction Cost Examination of Interfirm Cooperation. *Academy of Management Journal* 36(4): 794-829.

[13] Pfeffer, J. and Nowak, P. (1976). Joint Ventures and Interorganizational Interdependence. *Administrative Science Quarterly* 21(3): 398-418.

[14] Phomma, M. (2003). Product Development Collaboration between Original Equipment Manufacturers and After Market Suppliers. *Sloan School of Management*, Massachusetts Institute of Technology.

[15] Powell, W.W., K.W. Kopurt, and L. Smith-Doerr, Interorganizational Collaboration and the Locus of Innovation: Networks of Learning Biotechnology. *Administrative Science Quarterly*, 1996. 41(1): p. 116-145.

[16] Williamson, O. E. (1985). *The Economic Institutions of Capitalism: Firms, Market, Relational Contracting*. New York, Free Press.

Appendix A. Estimating Demand Effects

Surveys utilizing the direct value (DV) method (Cook 1997) can be designed to measure the consumer's willingness to pay for a particular product. The results of the survey yield three outputs. The first is the market awareness of the after-market part. The second and third are the value of the OEM product in each market segment (those aware of the after-market part and those unaware). With these three values, the new demand can be calculated utilizing the following formulation, where m is the market portion which is aware of the after-market part and the V_A and P_A are the value and price within the aware segments and the V_N and P_N are value and price in the not aware segment.

We can see that for changes in product value under constant price, assuming no changes in price or value by the firm's competitors, the change in demand due to change in value can be expressed as $\Delta D_i = K * \Delta V_i$, where

$$K = \frac{NE_2\bar{D}}{\bar{P}}$$

In this expression, *K* is the negative slope of the demand curve, $\bar{D}$ and $\bar{P}$ are the average demand and price, respectively, across the products in the market segment and E_2 defines the price elasticity. This leaves the expression for total demand, with the effects of the aftermarket part as

$$D_M = \left(m * K_M \left(V_A - V_N\right) + d_M\right)$$

This formulation allows for using d_M (the baseline demand of the OEM's product) as a constant or statistic, depending on the OEM's feeling about the sensitivity of its optimal decision to its own demand variability. One note of caution with this demand formulation is that the value V_N needs to be the value of the OEM part without the existence of the after-market part. DV surveys or historical data must be able to properly represent the value with and without the existence of a specific after-market part, while controlling for other variables.[3]

Appendix B. Estimating Leakage Costs

Information leakage costs should satisfy the following basic rules:

1. Cost and likelihood are evaluated independently, as is generally the case in economic analysis.
2. Cost of information leakage is decreasing in time as one approaches product release, since re-engineering will be possible once the product is on the market.
3. Cost is a function of the newness of the product, and the value provided by the new (and unique) characteristics.

Likelihood of information leakage is more qualitative than the other factors, but there is still room for taking an analytical approach to estimating it. We take a distinctly Bayesian view in assuming that, prior to any analysis, an expert may assign some probability to an after-market supplier leaking the information to another supplier. This probability may be effected by judging the number of partners with which the AMS collaborates (more may mean a higher likelihood), and by the history in the market (a longer history might indicate a more trustworthy partner).

As time passes, the firm is advised to update this probability to reflect the observed behaviors. Observing compliance would lead to a decreased likelihood, and observing

[3] Common sense would alert the reader that while having a custom set of rims and a custom turbocharger might add (linearly) to the total value of the vehicle, offering two different competing sets of rims would not have the same effect. When considering specific situations of this nature, additional surveys can be designed to determine the expected effects of a specific portfolio of after-market parts. The portfolio is essentially a set of features, and a complete analysis utilizing conjoint analysis (Cook 1997) and a much more lengthy survey could bring to light the effects.

information leakage would lead to an increased likelihood. As time passes, the initial expert analysis will lose its importance as the number of observations increases. Alternatively, this fact can be used to judge whether or not it is cost effective to monitor the partner at all. If the costs are significantly low, or the length of collaboration is deemed to be rather short, there will be no reason to bother.

In order to determine the expected cost of information leakage, we turn again to the S-Model (Cook 1997). The S-Model shows how demand for one item will vary as the value of one of the competing items changes. Therefore, in order to determine the expected cost of information leakage, one must determine how the value of the competing product might change if the information is available. If the information leaked is a new technology, then it is likely that the amount of value added by that new technology could be assumed to be added to the competitors offering as well. This would nullify (to some degree) the advantage gained by offering the new technology. Performing another analysis, utilizing the S-Model, will provide the new profit under information leakage, and therefore the expected loss of information leakage would be the current expected profit and the newly calculated one.