Incentivizing Commonality: An Evaluation Of The Benefit and Cost Impact of Platforming Strategies

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Abstract - Commonality strategies have become an important means of cost-sharing across systems. However, decreases in realized commonality have important implications for the cost-sharing effects of commonality. We review the spectrum of benefits provided under different commonality strategies, with a view to determining how these benefits scale – whether by number of variants, total production volume, or by production share, etc. Building on these benefits, we construct a framework for evaluating incentives for commonality. We explore a number of incentive structures, such as allocating commonality investment among variants. We find that each structure has advantages and disadvantages, and we hypothesize that appropriately representing savings will be a more robust policy than artificially inflating non-common parts prices. These findings have important implications for the design of Aerospace product families. In addition to the technical and organizational coordination required to execute commonality, program managers need to be aware of the underlying bias of cost incentives in play during development and production. [1] [2]

Table of Contents

1. Introduction

Commonality strategies have become an important means of cost-sharing across systems. We define commonality as the sharing of parts of processes across systems. This sharing has a number of benefits, including reduced development cost, economies of scale in production, and decreased inventory costs. However, recent work by Boas [1] has shown that platforms with products built sequentially often exhibit decreases in commonality.

Decreases in realized commonality have important implications for the cost-sharing effects of commonality. We review the spectrum of benefits provided under different commonality strategies, with a view to determining how these benefits scale – whether by number of variants, total production volume, or production share.

Building on these benefits, we construct a framework for evaluating incentives for commonality. Divergence, or decreases in commonality, often results when variants make decisions which sub-optimize the overall platform. We explore a number of incentive structures: allocating commonality investment among variants, taxing non-common parts, setting transfer prices for common parts among variants, and pooling common parts investments at the corporate level.

These incentives are discussed in the context of interviews conducted at 14 firms in the aerospace, automotive, and manufacturing industries. Firm details are not discussed in depth, as this is the subject of another paper – rather, they are cited as examples of existing practice, to add context for the framework.

2. Benefits of Commonality

The benefits are separated into builder and producer benefits, to recognize that not all benefits accrue to the builder. They are roughly ordered according to lifecycle phase.

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[2] IEEEAC paper #1756, Version 2, Updated October 26, 2010

Builder benefits

- Reduced development cost on later variants
- Shared testing equipment investment
- Learning effects in testing – fewer labor hours / unit
- Shared manufacturing equipment and tooling investment, or the ability to move to higher volume production methods (automation)
- Learning effects in manufacturing – fewer labor hours / unit
- Shared validation equipment investment
- Reduced validation scope / time on later variants
- Fewer internal quality control rejections
- Reduced external testing / validation (ex. aircraft type certification)

Builder or Purchaser benefits

- Reduced purchasing cost (bulk discount from suppliers)
- Lower inventory for production and sparing (fixed storage cost and variable acquisition and maintenance costs)
- Lower training expense (fixed capital cost and variable hours)
- Shared fixed cost of operations / support
- Learning effects in operations / support (lower service time / cost)
- Slower replacement rate for spares from higher quality / better design (overlaps with inventory saving, includes reliability)

3. Benefit Scaling Analysis

Which benefits dominate depends heavily on the industry and program-specifics. However, there are some generalizations that can be made based on platform parameters.

Almost all of these benefits scale with the degree of commonality between variants, everything else being equal. More sharing means less unique development work, fewer unique manufacturing tools, etc. The dominant constraint for high degrees of commonality is lack of product differentiation causing sales cannibalization, which is a relevant concern when planning commonality, but out of scope in this discussion of commonality benefits. Cook (1997) notes “ironically GM’s market share relative to Ford only began to recede in the mid 1980s as GM’s brands – Chevrolet, Pontiac, Oldsmobile, Buick, and Cadillac – became less distinctive through the use of common platforms and exterior stampings that reduced product differentiation.” (reproduced from de Weck [2]).

These benefits can be broadly separated into two categories – those that scale with volume, and those that scale with the number of variants. For example, learning effects in manufacturing scale with volume – more the units produced, the greater the learning. On the other hand, shared development benefits scale with variants: to first approximation, the development effort is fixed, and the more variants which share that investment, the cheaper their individual share and the total platform cost. Ward (2010) institutes a similar fixed variable distinction and the same scaling assumption.

These two scaling relationships are not mutually exclusive (i.e. more variants typically implies higher volumes). However, dividing the benefits of commonality into these two camps is helpful in articulating which costs of commonality are fixed [3]. As written, 7 of the 15 benefits refer directly to spreading fixed cost (i.e. scale with variants), and a further 2 benefits include both fixed and variable costs (lower inventory and reduced training expense).

The fixed / variable distinction is a crude accounting simplification intended to hide more complex relationships (step costs on production lines, costs which are fixed over different time periods, etc). Further, the concept of scaling with variants is dependent on the idea that adding a variant represents a new project, which is allocated funds to cover the presumed share fixed costs. Adding a variant with a production run of 1 unit, little development effort, a marginal contribution to revenue dependent entirely on leveraging past investments in commonality and a low profit margin, is unlikely to contribute much to other variants. This is not to say that these variants cannot contribute to profitability, but they are unlikely to cause discrete jumps in manufacturing learning or fixed cost spreading.

Nevertheless, this fixed / variable distinction helps shed light on commonality benefits – creating a common platform is a type of fixed cost investment. It involves investment in the near term for longer term benefit, it represents a risk in that it constrains future flexibility and capital, and it offers future capacity for expansion. This recasting of commonality in fixed cost terms will be helpful later on when we examine the incentives created in common platforms.

Finally, we examine production share as a scaling variable. More precisely, we consider equal divisions of production share against the case of a dominant variant, while holding total volume constant. As such, production share dominantly impacts fixed benefits. Benefit to the platform as a whole increases when parts and processes are created once and reused with little or no modification. At first glance, this suggests that a dominant variant produces high benefit. However, as identified in Boas [1], the lead variant can skew the common design, effectively destroying reuse opportunities by later variants. While equal production share requires more negotiation for defining the performance envelope of common components, it can guard against dominance – essentially a hedge at unknown cost.

The unknown cost of mediation among variants can loom large – several cases studied had substantial 'complexity cost' initiatives underway. For example, a large automotive firm found that millions of orderable combinations (10 colors x 4 interiors x 3 sound systems etc.) created both upfront design burdens and downstream overhead. Scaling a common platform by adding variants can, in the worst case, lead to the same product proliferation that gave rise to a need for consolidation or commonality in the first place, except with the added twist that products are *supposed* to interface / share.

We have found scaling by production share to be an unproductive argument – finding some optimal production sharing is unlikely to result in generalizable conclusions, and production share is not necessarily a controllable variable (mostly set by market sizing studies). Rather, the concepts of commonality ownership and platform complexity are much more powerful and controllable in the discussion about maximizing commonality benefits.

In sum, benefits cannot be said to scale uniformly with any one factor but degree of commonality, and business cases must be built on detailed analysis of benefit projection. However, early consideration of benefit scaling can and should highlight safeguarding and management of fixed commonality investments and their associated free-riding benefits to later variants. Further, the scaling discussion highlighted important limits to growth – adding volume to the platform for scaling benefits must be weighed against the complexity of managing a platform with many variants. Finally, note that the above discussion is conceptually simplest when considering parts-based commonality, but is also applicable to parts or process *similarity*.

4. Incentives

The aim of an incentive system for commonality is not to ensure maximum commonality. Rather, from a narrow perspective, its function is to maximize the lifecycle benefits of commonality. The distinction hinges on opportunities for beneficial divergence – a program that realizes 70% commonality (and the associated benefits) is preferable to a program that enforces 80% commonality at the cost of schedule delays and budget overruns.

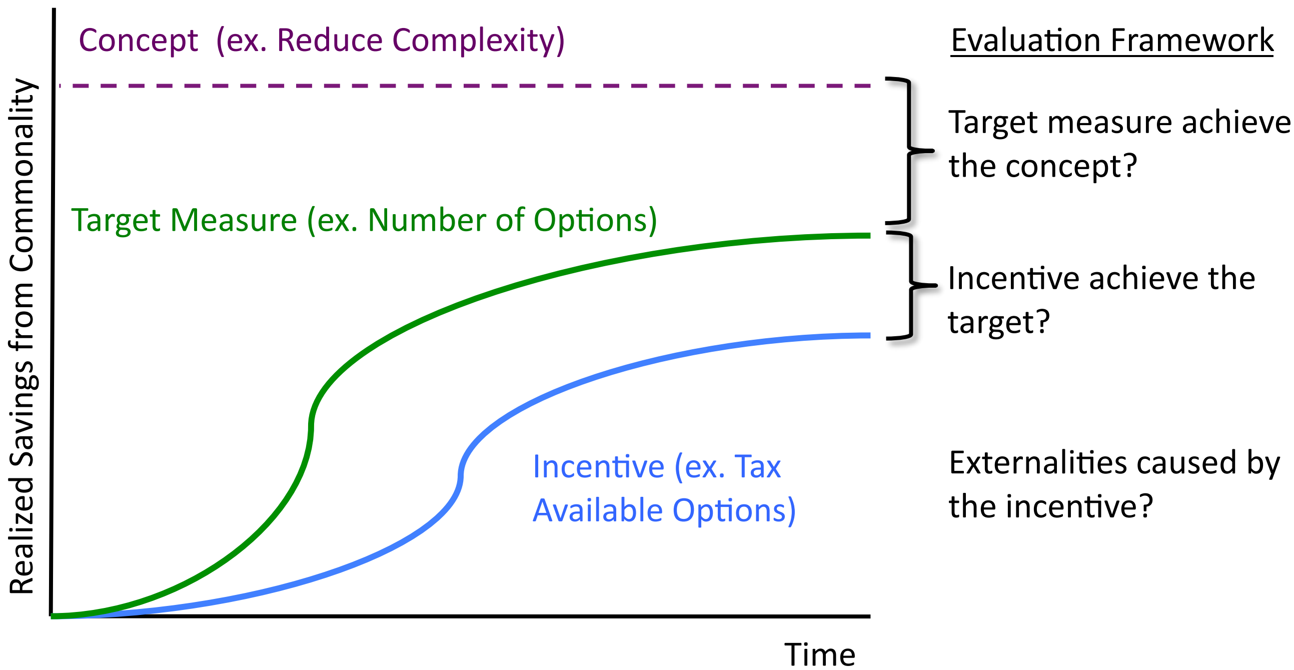
Taking a broader perspective, an incentive system should reward decisions which weigh lifecycle benefits against opportunities for beneficial divergence. In the example cited above, beneficial divergence from 80% commonality has internal benefits, however, it can also have external benefits – for example, enabling sales in niche markets. In an ideal case, the benefits of commonality are known, thus enabling a comparison between benefits of commonality and benefits of divergence. However, in the absence of perfect information about future commonality benefits, many organizations have employed either commonality targets or incentives to arbitrate challenges to commonality.

Past research [1] indicates that divergence often occurs for unacceptable reasons, such as the pursuit of uniqueness, failure to consider lifecycle benefits, or variants making decisions which sub-optimize the overall platform. The incentives described below are primarily aimed at maintaining commonality levels among variants, rather than at setting the ideal commonality level for the program.

The four categories of incentives that we investigate are: allocating commonality investment among variants, taxing non-common parts, setting transfer prices for common parts among variants, and pooling common parts investments at the platform level. For each, we will describe both the concept behind the incentive, and a representative metric or measure for operationalizing the incentive.

There are three aspects that we would like to examine for each incentive:

1. How well the incentive achieves the target measure?
2. How closely the target measure matches the concept?
3. What externalities may be associated with the incentive?



Allocating Commonality Investment Among Variants

Building common systems, particularly in long lifecycle, fixed cost environments like the aerospace industry, requires significant investment upfront [4]. This investment essentially represents the additional effort involve in designing and manufacturing parts, systems, and processes that span the needs of all participating variants. Dependent on the product, this effort can vary between design effort (all labor) and capital equipment procurement (all assets).

The concern is that firms under-invest in commonality because of the challenges associated with multi-product investment. Large platform investments tie up capital, force coordination between disparate divisions, and pool development risks. As such, the operating principle in many firms is that the lead product bears the entirety of the platform's commonality investment. It can be argued that this leads to lower commonality levels, as individual products can't bear platform investments when they only recover a fraction of the benefit through their production and sales. We will later discuss a mechanism for enabling a product to charge later variants for common components.

The concept is therefore to divide the commonality investment (development cost, manufacturing facilities, etc.) among the variants. For this discussion, we presume that all variants are produced in parallel, then we relax this constraint when discussing externalities. The specific measure we investigate is to divide investment by intended variant volumes [5].

Allocation is not an incentive in and of itself, because the allocation is not controlled by variants (it is controlled by the platform). The incentives arise from the cost sharing – each variant has an incentive to include as much of their content (including unique content) in the common pool, while minimizing their contribution base (volume). Volume is a desirable target measure as it is a concrete measurement, and it is often correlated with variant revenue (although not necessarily net income). Further, as discussed under benefits scaling, most variable cost benefits scale directly with volume (such as learning curves in manufacturing). Depending on the shape of the learning curve, the largest volume variant has the greatest potential to secure savings, both for its units and for the platform as a whole. In a previous case study of an automotive manufacturer, we discovered a platform where a lower volume variant had been scheduled first, with the development of a higher volume variant to follow. The cost of development and control were dominantly controlled by the lead variant, which customized the design to its needs. The higher volume variant had less to gain from incremental contribution of the lead, and chose to eliminate its commonality with the lead. Had the cost of the development been allocated by volume, the second variant would have had a greater influence on the design, despite coming later in the timeline.

Externalities arise with this incentive when variants benefit disproportionately from the pooled resources. For example, low volume variants at the high-end of the product offering dominate design decisions due to higher performance requirements and a greater net income, essentially subsidized by less profitable variants. While volume is easily known after the fact, it is also one of the most volatile product development forecasts, due to uncertain market demand. Under this scheme, variants can choose to under-represent their respective markets in order to minimize their contribution.

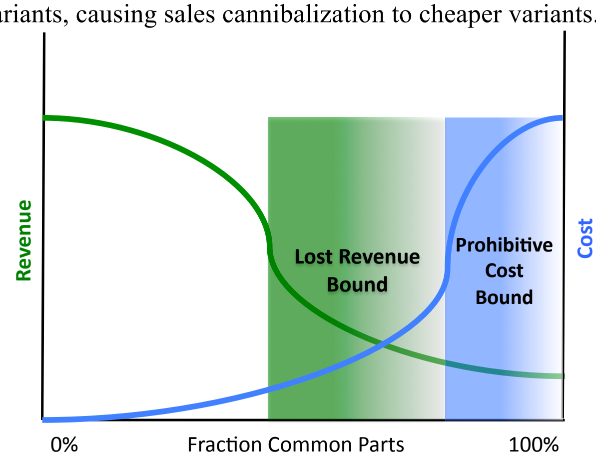
Other allocation bases, such as allocation by net income and joint requirements count, pose different incentives for the platform. We have also assumed here that products are built in parallel, as sequential development raises issues about the feasibility of transfer pricing when some variants don't have budgets yet.

In short, volume-based allocation works well when true volumes are known, net income is distributed proportionately to volume, and development is unlikely to be dominated by low volume, high performance requirements.

Taxing non-common parts

The intent of taxing non-common parts is to maximize adherence to the platform. It is an incentive focused directly on commonality levels, as opposed to the cost focused incentive above.

The concept behind this incentive is that higher commonality levels produce greater benefits. Commonality has two prominent upper bounds. The first is technical difficulty / over-performance penalties, where unique functions are sufficiently different that a common solution is either technically expensive or imposes a prohibitive carrying cost for the unneeded functionality in base models. The second upper bound is product differentiation, where high commonality produces too little differentiation among variants, causing sales cannibalization to cheaper variants.



A tax is a linear incentive – it does not proscribe an optimal commonality target. The two parameters that operationalize a tax are the unit of measure and the tax rate. For simplicity, we assume the unit of measure is parts [6], as opposed to non-common manufacturing processes, for example. As a tax is a linear incentive, the optimal tax would set the marginal cost of the tax on the remaining unique components equal to the marginal benefit that those unique components provide.

Taxing unique parts is easily implemented, thus the concept and measure are well aligned and transparent. Although this approach may seem heavy-handed, consider that existing inventory systems often face challenges determining the overhead associated with new parts introduction. Two firms studied by the authors implemented a mandatory change order cost for new parts introduction at tens of thousands of dollars per part per year. These charges are essentially taxes on new parts.

While a tax may represent a useful incentive during development, divergence has been shown to occur frequently in detailed design or manufacturing. Thus, managers may incur heavy tax penalties late in development, when they have less ability to rework a common solution, and where divergence may in fact be the logical choice.

Additionally, where taxes are set punitively (i.e. greater than the fixed and variable cost of new part introduction), the rate indirectly sets the optimal commonality level. To the extent that the costs of commonality and the marginal revenue curves are not known in advance, it is therefore difficult to set this tax rate. Setting punitive tax rates presumes accurate cost – benefit knowledge and strong centralized control, as opposed to enabling employees to make decentralized decisions with lifecycle cost information. One firm studied by the authors set a punitive tax rate on new part introductions at the Enterprise level, led by the Vice President for Engineering, which was subsequently withdrawn after strong factory-based opposition.

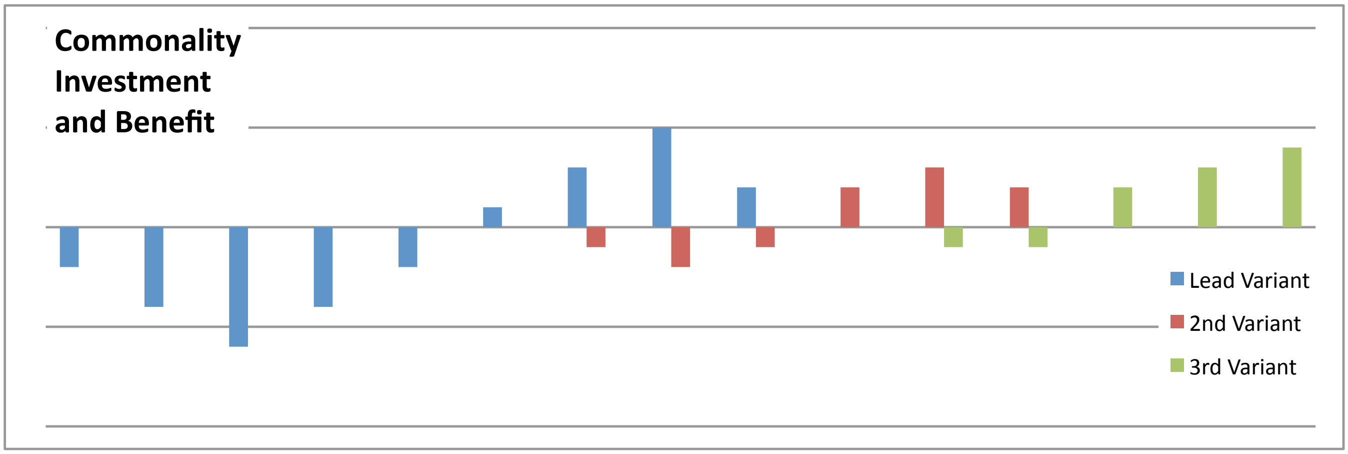
Transfer pricing for common parts among variants

The intent of transfer pricing is to enable lead variants to recapture their operating costs for shared components, or in extreme cases, their commonality investment. These arrangements can arise when later variants are scheduled in sequence or with significant offsets from the lead variant, and do not have precursor product lines able to fund commonality investments in parallel with the lead.

The figure below illustrates a representative example. The benefits retained by the lead variant as insufficient to merit the investment, but taken from the perspective of the platform as a whole, the benefits are greater than the costs.

Transfer pricing occurs in many contexts outside commonality [7]. For example, a firm with separate production facilities for engines and final assembly may set engine transfer prices at the engine factory, so as to enable the engine factory to track its financials more easily and to avoid setting a firm-wide overhead rate. There are several established methods for setting transfer price, each of which contains different incentives. The two we will consider here are full cost pricing and marginal cost pricing.

Full cost transfer pricing is an attempt to fund both the fixed



Sample commonality investment and payback, where lead variant does not benefit from commonality, but platform retains positive NPV

and variable portions of part cost. As fixed costs are typically yearly costs, traditional 'full cost accounting' may omit commonality investments made earlier (such as tooling investment). Full cost also assumes a known production rate and an allocation base for fixed costs (such as units produced or hours by variant). Fixed cost allocations set with optimistic projections of volume will under-allocate, while pessimistic projections will return rents to the lead variant. Production environments where variant participation is uncertain may err to the pessimistic side of expensive transfer prices, making platform participation for later variants less desirable.

Marginal cost pricing arises in two contexts. First, when late variants can be shown to be profitable at marginal cost but not at full cost, and the fixed costs and investment in commonality have already been funded. Second, when the marginal cost exceeds the variable cost (i.e. production for every additional is more expensive, as is the case near capacity constraints).

In transfer pricing, the target for the incentive is not easy to compute or transparent. From the platform manager's perspective, the target is to set pricing to maximize margin across the platform. If all variants are assumed to make similar margin (i.e. no loss-leaders or significant volume differences), this translates into representing full cost as accurately as possible. Where capacity constraints and small niche markets exist, marginal cost pricing may more accurately reflect the margin maximizing price. For example, one interviewee described how relaxing full cost transfer pricing enabled the auto maker to successfully enter a niche foreign market, without compromising the coverage of platform fixed costs.

The externalities associated with transfer pricing are: rents by lead variants, free riding by later variants paying marginal cost, and divergence where pricing inhibits platform participation. Given that transfer pricing can be difficult to change, industries facing volatile demand will have to trade fixed cost coverage against the possibility of overcharging on transfer pricing. Industries with longer clockspeed cycles, like the aerospace industry, can implement stable transfer pricing schemes built on longer data histories. The challenge is negotiating prices and allocations at the beginning of a platform development – one firm described a yearly process by which new shared manufacturing equipment was allocated across the participating product lines, at significant effort.

It should also be noted that there is traditionally an expectation that transfer prices remain stable over time. The intent is to facilitate decision making, not incentivize costly internal hedging strategies. Several interviewees described an aversion to earning a return on fees charged to other variants, as might arise if transfer prices were both variable and controlled at the variant level.

Pooling common parts investments at the platform level

Pooling investments arises from the idea that individual variants under-invest in commonality if they cannot charge later variants for use of the common resources (as discussed above). The intent is that the platform has the full picture of platform profitability, and can therefore make investments in commonality where appropriate. This discussion presumes that the platform has sufficient capital of its own to pursue investments – some firms allocate all funds to individual products, and run small platform management teams from corporate overhead.

It is tempting to measure this concept by dividing an available pool of money to variants according to volume or margin. However, the subdivision of budgets creates the very problem this incentive is intended to resolve – variant sub-optimization. In order to hold funds at the platform level, it is also common to set the total size of the pool beforehand, which all but ensures that 150% of the pool will be requested. These two challenges illustrate that the firm needs a strong concept of the platform, and existing organizational methods for answering such questions as "if there is money left over at the platform level, how does it get redistributed to the variants?".

The most appropriate measure is savings to the platform as a whole. The term 'savings' is used as opposed to ROI, to avoid the implication of short term returns. Having a pool incentivizes variants to cooperate and bring commonality ideas forward, as it reduces their individual outlays. Variants may be inclined to overstate benefits or the cost of coordination, in order to increase the projection of savings. Firms with decentralized control and powerful product lines have found it challenging to examine or evaluate benefits, as they lack the detailed knowledge necessary to cross-examine variants.

Pooled investment is sometimes tied to the notion of commonality ownership. If the platform 'owns' the common parts in which it invests, it has a degree of control over its investment, in that it can moderate among requests to change common parts. Some organizations outsource commonality parts ownership to functional branches (ex. the engines group owns all alternators). While this can resolve the information asymmetry between platform and variant, it creates new challenges if the horizons of the functional groups are broader than that of the platform. Either strong platforms (as opposed to strong variants) or functional groups at the platform level can enable commonality ownership for investments.

Commonality ownership at the platform level without decision control over commonality levels poses further challenges. If the platform does not have explicit control over commonality levels, the common parts in the pool will become subsidized unique parts when variants make sub-optimized decisions. For example, one of the firms studied described a 2nd variant with high volumes who determined that an external supplier could more closely match desired performance and provide lower cost than the platform's braking system. The platform management had been significantly reduced after the development of the lead variant, and was not able to exert control over intended common systems. The 2nd variant diverged, increasing costs for the lead variant, which had assumed economies of scale from the volume of later variants.

The externalities created are tied to the implementation decisions for the common pool and to the commonality oversight parameters listed above (commonality ownership, commonality levels control). Variants will seek to offload near term development costs to the platform as 'common costs', and it is up to the platform to ensure their common development is scoped to benefit all. Even with appropriate platform control, sizing the pool too large will result in systems with more commonality than warranted. The risk of over-investment is present whether strong variants can overstate benefits, or whether the platform exercises control without sufficient grasp of product realities. The more generalized externalities is that centralized control will hurt individual product "finish" or differentiation. To first approximation, this risk can be sized as the relative budgetary control at the product and platform levels.

A further challenge that arises with pools is that firms often want to recognize revenue and expenses at the product line level. Allocating the pooled cost to variants raises all of the same concerns listed under 'allocating commonality investment among variants.

5. Conclusion

In this analysis, we attempted to enumerate all of the mechanisms by which commonality can lead to cost savings. We then review 3 scaling factors, to determine how many of the benefits are covariant. This analysis suggests that fixed cost sharing benefits are susceptible to changes in the number of variants, and are only affected by volume changes when capacity constraints are reached. Variable cost benefits scale more directly with volume, but are more challenging to predict when learning plays a role in driving down cost (as with development headcount reduction, testing time reduction, etc).

We then proceeded to analyze 4 commonality incentives, using a framework to capture how well the incentive achieves the target measure, how closely the target measure matches the concept, and what externalities may be associated with the incentive. We find that each structure has advantages and disadvantages. For example, allocating commonality investment among variants can potentially mitigate concerns around underinvestment in commonality, but comes with the risk that one variant will dominate requirements (and therefore cost), while paying a minority share. Some incentives were easy to measure directly (taxing common parts), while others acted indirectly on the commonality level (pooling common parts investment). To these ends, some policies set de-facto commonality levels, while others encouraged a trade-off around benefits and costs of commonality. With a view to future work, we hypothesize that appropriately representing savings will be a more robust policy than artificially inflating non-common parts prices.

These findings have important implications for the design of Aerospace product families. As the Joint Strike Fighter has recently demonstrated, meeting commonality targets is a challenging enterprise, particularly in long clockspeed industries. In addition to the technical and organizational coordination required to execute commonality, program managers need to be aware of the underlying bias of cost incentives in play during development and production. Further work will examine how commonality cost is captured within the engineering change order process, as an environment for divergence decisions.

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Biography

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