Competition and Technology −−How to Make Money From Hardware

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It is important to estimate the future profitability of products so firms can make a rational decision on a business case. Moreover, there is a need for reliable guidelines to determine whether business cases are sound. We present here a different view of the problem and suggest a simple framework for estimation of risk and profit for various products. Our approach is based on estimating the number of competitors in the market niches that our products would target as the major factor in market share and profitability.

1. Introduction.

It would be valuable to understand why profits on some products drop rapidly and others not. This could help guide product development. Clearly, the planning and preparation required to produce a low profit 'commodity' is very much different from a situation where competition is low. Therefore, it is highly beneficial to have a model that can estimate the profitability of a product before it ventures into production.

We cannot provide quantitative analysis because the answers involve many intangibles like marketing−driven consumer preferences, corporate name recognition, and esthetics. Whenever possible, we try to adopt the view point of rational consumers. It is our hope that some of the arguments presented in this article may be useful for the development of business cases for R&D−related ventures.

The life−cycle for any product begins with introduction, and proceeds to market acceptance. Soon, competitors appear, either other companies competing with the product's manufacturer, or other products that fulfill a similar function from the same manufacturer. Other products, if better, will capture market share, and eventually make it uneconomic to manufacture the product. Other manufacturers, if they make equivalent products, will be forced to compete on price, and will drive down profit margins so that only the few most efficient manufacturers will continue to make the product. In general, products tend to become commodities, especially in stable, slowly changing markets.

However, what is a "product?" At first glance, for example, automobiles don't seem to follow this model. They have been around for ninety years, and there are a bewildering variety of models produced every year, over a wide range of prices. The answer is that cars, like most things in our society, are not one product, but a distribution of products. 1957 Chevrolet sedans are a product. They were introduced, became popular, and would clearly have become obsolete long ago, if the manufacturer hadn't stopped producing them first. One should not mistake the improvement in a general category or products (like four−passenger sedans) for improvements in a specific design.

What we see on the market as a "car" or an "LCD display" is a cloud of similar designs, each slightly different yet fulfilling similar functions, and each individually following its own life−cycle, with its own degree of success. If we look at the market over time, we will see a continuous flux of new designs entering the cloud, and older, lower performance designs going out of production.

Before we discuss the details of our analysis, it is a good idea to first define a few of the terms that would appear:

* Product: something that fulfills a specific and well-defined function. For instance, "91 octane gasoline" is a product, rather than "gasoline". Some cars need the higher octane rating, and thus "87 octane gasoline" is not equivalent. Similarly, "personal computer" is not a product, but "100MHz Pentium PC" might be.
* Product class, or product cloud: a collection of similar products (e.g. "gasoline" or "PCs"). The members of a cloud fulfill the same general function, but differ in speed, price, features or size.
* Parameter: Something about the product that you could specify. Examples are: octane rating, color, CPU speed, memory size.
* Trivial parameter: A parameter that can be manufactured easily in all possible variants. Color is usually trivial, as one just buys a different can of paint and sprays away. A product does not need to be redesigned for trivial parameters; they come off the same assembly line.
* Dimensionality: how many non-trivial parameters a product has.
* Volume of a product cloud: the potential number of significantly different products that could be built to fulfill the same general function. Product classes vary widely in how many members they could have. For instance, gasoline has, commonly, three, while the class of machine screws has hundreds of different products.
* Commodity: a product where competition is very high, product differentiation is negligible, and manufacturers are competing primarily on the basis of price. In the electronics industry there are few products that are true commodities in the sense that gold or pork bellies are, where the identity of the manufacturer is totally irrelevant. The term is useful shorthand though, as some products, especially highly standardized ones, come close.

2. Product Clouds

Since the profit on a product is closely tied to competition, we will estimate the intensity of competition. We get from product clouds to an estimate of competition by looking at how densely the region around our product is occupied by products from other manufacturers.

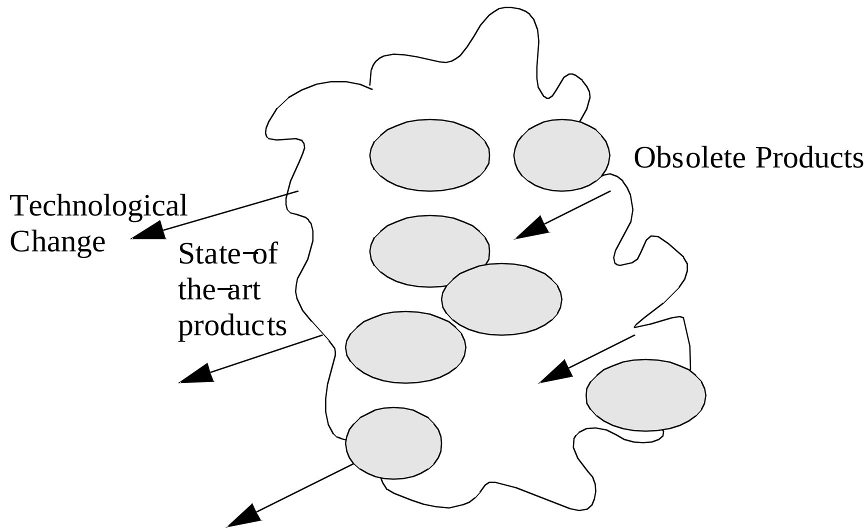

Figure 1. The cloud of potential products and some actual products (grey). The boundaries of the cloud move (arrows), and we consider product designs to be fixed. The size of the ellipses denotes how far apart products can be before customers consider the difference significant. This figure displays a situation with little competition, as there is still room for more products inside the cloud.

If you are in an uncompetitive situation, such as being the first manufacturer out with a novel technology, there won't be any nearby products. For a while, you will have the only product in the product cloud. Conversely, in an old, established industry (*e.g.* corded telephones), we find not only phones that perform similarly to ours, but phones that perform similarly *and* look like Mickey Mouse®, or phones that perform similarly *and* are transparent with neon lights inside.

The cloud of potential products always has edges. Sometimes the edges are very hard, for instance when manufactured products get good enough to push up against limits set by the laws of nature[1], other times they may be fuzzier[2], but you can always define a size to the cloud. Often, the edges are set by the state of the technological art; such edges can be rapidly moving. The cloud of potential products contains only products that could be made with present technology.

The useful way to measure the volume of the cloud is by counting the number of products that

1. One example where the edges are very firm is the speed of signals in optical fibers. Everyone's fibers transmit data at nearly the same speed (to better than 1%). This limitation comes about because there are only a few materials sufficiently transparent of which one could make to make useful fibers.

2. An example is the speed of commercial airliners; they all fly at Mach 0.85 (within 4%, except the Concorde) because the laws of aerodynamics cause the fuel consumption to jump dramatically as the airflow over the wings goes supersonic. At Mach 0.85 the local airspeed over some areas of the plane is just getting up to the speed of sound. The Concorde, of course, pays the fuel penalty and charges nearly ten times as much for a ticket. A truly fuzzy example might be sizes of disk drives on PCs. They range from 100Mb to 2Gb, but there are still limits: you can't fit your software on anything smaller than 100Mb, and software and processor speeds are currently insufficient to make good use of much more than 2Gb.

could fit inside while still being significantly different. By significantly different, we mean that the designs be different enough so that the user will make a buying decision based upon that specification. For example, "significantly different" octane ratings for gasoline differ by two or three points. People will perhaps buy 91 octane gasoline over 89, but would certainly laugh at an advertising campaign that promised 91.1 octane. Similarly, once someone has become slightly experienced with computers, they know that a 120 MHz processor isn't really much more exciting than a 100 MHz processor. To be substantially different, one processor needs to be perhaps 50% faster than another.

As long as this cloud is not too oddly shaped, we can see that the number of parameters it takes to describe a product is very important. Imagine, for simplicity, a square product cloud, and imagine each parameter has three options (high, middle, low). Then for a simple one−parameter case, the product cloud has a volume of three. In a two−parameter case, the cloud has a volume of nine (three choices of the first option, times three for the second). The volume of the product cloud increases exponentially to 27, 81, 243,... thereafter as the dimensionality increases. Perfumes are a good example of a product cloud with many parameters: perfumes are mixtures of dozens of different scents, each of which can be varied independently. The number of distinguishable perfumes is very large.

What controls the size of the cloud? Generally, it will be the smaller of two limits: our ability to produce multiple variants on a product, and the number of meaningful variant of the product itself.

3. Marketing

Admittedly, deciding what is a 'significantly different' product is an art. "Significant" often involves intangibles like label consciousness or fashionable trends. For example, a blue jean has only a few functional variations: it is a pair of thick pants and it looks blue. But thanks to marketing marvels and the ingenuity of designers (the designer of blue jeans is their R&D), a blue jean is a fashion statement, and people pay attention to small details. Since people look more carefully at their jeans than one would expect, there are potentially more different jeans in the product cloud. Thus a simple product like a blue jean can still avoid becoming a commodity by incorporating minor variations among products as long as the customers are convinced of the importance of the difference.

The extreme case of marketing success is the proliferation of designer labels. Competition can be avoided if you can convince people that your logo somehow makes the product better. If the logo is then trademarked, you now have a legally protected enclave without competitive pressures. Logos and designer labels are handled in our model simply by correct counting of significantly different products.

4. Competition

We can estimate the amount of competition amongst manufacturers simply, by using the pigeonhole principle. We count the number of potentially interesting, functionally different designs in the cloud (the volume), and count how many designs are being manufactured. If there are more designs in manufacture than will fit into the cloud's volume, you can know that some manufacturers will be in head−to−head competition, making essentially the same product. Conversely, if there are few manufactured designs and a large volume, manufacturers will be able to avoid one another, each producing products that have no exact competitor.

The intensity of competition should thus be proportional to the density of manufacturers per volume of the cloud. Therefore, this intensity of competition can be used as a qualitative criterion for finding commodities. In some cases, it is even possible to be quantitative −because the volume of a product cloud changes so rapidly (exponentially) with the dimensionality, we can sometimes provide a definite answer to the intensity of competition even though the input data may not be precise.

Examples:

* Greeting Cards.

  The volume available to the cloud of greeting cards is virtually infinite, because the number of imaginable greeting cards is very large. Virtually any sentence in English, if coupled with an appropriate image, can be used as a greeting card for some occasion. To put a number on it, consider just a sample five word sentence: one preposition (a few choices), one verb (100 choices), an adjective (100 choices) and two nouns (100 choices each). Multiplying, we find that there are perhaps 100 million possibilities, and the numbers grow exponentially as you consider longer sentences or more than one sentence. The number of cards then has to be further increased by considering the large number of images that could be attached to each sentence.

  The number of actually manufactured (and widely distributed) greeting cards at any one time is on the order of a few thousand. You can see that no two greeting card manufacturers will ever need to produce the same card. This, of course, is how they manage to charge $1.00 for a single sheet of paper and envelope. People choose greeting cards on the content —they aren't presented with a rack of hundreds of identical "Happy Birthday!" cards so that they can pick the cheapest one.

* Gasoline

  The situation for gasoline is nearly the opposite of that for greeting cards. There are typically three varieties of gasoline that are distinguishably different, so the volume of the cloud is three. There are six or more major gasoline producers, each of whom makes all three grades, so there are at least eighteen designs in the cloud. With many more designs than distinguishable products, competition is fierce, and consumers simply shop for the cheapest brand.

* Perfume

  As we mentioned above, perfumes are a high dimensional system, with many potential perfumes in the product cloud. There are probably many more distinguishable perfumes than manufactured perfumes. There is then little or no competition between manufacturers to make a particular scent mixture at the lowest price. This explains why, in this age of cheap organic chemistry, perfume costs hundreds or thousands of times as much as equivalently complex mixtures like gasoline or detergent.

* Airline seats

  Similarly, airline seats are competitive. If we consider possible trips between two major cities, the volume of the cloud is small. Potentially, you have the choice between coach and first class, and sometimes you would have the choice between a direct flight or one with a connection. The volume is two or four.

The number of actual options is typically larger than that, as a route would be served by several airlines, each of which offers the coach/first class choice. Typically, you might have six options (three flights times two seating choices). Airlines must then compete on price, and they do. Industry profits are negative, and all airline prices are essentially equal for equivalent flights. The heavily capital−intensive nature of the airline industry, and the fact that it costs almost as much to fly an empty plane as a full plane undoubtedly contribute to the lack of airline profits. The strength of the competition (ratio of offered to potential options) isn't as extreme as the case of gasoline.

* Television

Up until now, the number of potential television programs has far exceeded the few dozen that are actually produced at any one moment. Television networks and television production companies have not been producing commodities, and have been competing on the basis of content, rather than price. This is not likely to change, even in the 500 channel video future.

* Bolts

As a final example, consider bolts. The volume of the cloud is large, approximately ten sizes times 5 lengths per size times three head styles times several materials, times three thread styles[1], something on the order of 1300 varieties in common use. On the other hand, the manufacturing techniques for different sizes of screw are very similar, so one factory can make most varieties. There are many manufacturers, so each variety is made by many manufacturers, and competition between manufacturers is strictly on price.

As we have seen, this estimate of competition does work, at least on a qualitative level.

5. Extensions

A closer look at these examples would undoubtedly show that the amount of competition would vary within the cloud. For instance, designs on the edge of the cloud would typically have low market share, because they might be nearly obsolete (if on the trailing edge of the cloud), or expensive (if on the leading edge of technology), or merely a niche market (*e.g.* titanium bolts for aerospace applications). One expects less competition there, as there is less total money to be made from small markets. The center of the cloud would tend to have the designs with largest sales, and could be expected to have the largest competition[2].

Another consideration is that the 'footprint' of a product depends on it's price difference from it's neighbors. By footprint, we mean the distance to the closest significantly different product. As a product gets more expensive, people are more willing to substitute another similar, but slightly less desirable product for the expensive one. This is the mechanism that limits profitability of designer labels. For example, there is no competition for clothes with a DKNY label, but if the price difference is sufficiently large, most people will decide that Calvin Klein is close enough.

We think that it might be possible to develop a detailed model for this problem analogous to

1. Machine, wood, and sheet metal.

2. Airline service displays this characteristic. Competition for New York to Chicago traffic is fierce, but small cities are typically served by one carrier.

statistical mechanical methods used in physics. Product clouds have strong analogies to phase space. We think that a statistical description of competition could be valuable and accurate in situations where many products and companies are involved.

6. Conclusions

There are four ways to accomplish the desired goal of making products without strong competition:

1. Technical progress: the company that develops a new technology has the opportunity to sell it before it's competition knows how to make it. This pushed the leading edge of the product cloud, and provides some unoccupied volume for your products.
2. Picking products with many useful variants, so there is more room in which to compete.
3. Picking products that require large capital investments, so that competition develops slowly.
4. Marketing: advertising to create the illusion of functional differences between products, when there really aren't any. Celebrity advertising is a prime example.

Strategies 1, 3 and 4 are well recognized, even if they aren't always implemented well. Strategy 2 isn't, and it should be. What is not recognized widely is that all the strategies can be integrated together in one model. It is also possible to prosper even in the presence of competition by pushing manufacturing technology: in the shake−outphase, the company that can produce least inexpensively wins the largest chunk of a huge (though low margin) market. This may involve sophisticated manufacturing or organizational techniques.

In conclusion, we have presented a model that allows straightforward prediction of the profitability of products, before they reach the market, from numbers that are available or can often be estimated. The model emphasizes estimating the number of competitors that produce equivalent products.

Appendix: Competition in AMLCDs

Simple AMLCDs (Active Matrix Liquid Crystal Displays) are likely to be commodities soon, if they aren't already. The product could of AMLCD which are just display devices does not occupy a huge volume. Pretty much every manufacturer in Japan have the ability to producing small and middle-sized AMLCDs. Therefore, the center of the product cloud is fully occupied and the competition is moderately strong. As of now (1995), there is still competition on efficiency and viewing angle, but those problems will slowly be solved and eventually cease to be distinguishing factors. Within five years, small and mid-sized displays will be commodities.

In light of the previous discussions, there are three strategies to improve on the situation:

* Increase the cloud's volume: by integrating more functionality into the AMLCDs. So, instead of using AMLCDs as just a display, put memory and processing power into the device. The ultimate limit of this direction can be extended to put the whole system on a single glass plate.

* Push the edges of the product cloud. Though Japan has invested heavily in AMLCDs, there are still room for improvement on the performance of AMLCDs. The power consumption, and viewing angle, and especially the size and resolution, could be improved. Each would require a substantial research and developmental effort to make significant progress. The AMLCD is a lot closer to automobile than transistor in this respect. Automobiles are a big group developmental effort of hundreds of people rather than a genius stroke of a few like the original transistor discovery. From the first movable automobile to the modern low-maintenance, efficient vehicles, there were thousands of man years invested in its development. Currently, AMLCDs and devices that use them are close to the model-T era. The displays are functional, but far from ideal, and a substantial R&D effort is still necessary.

* Advertise to make people more conscious about small differences in display quality. Right now, most people don't own multiple lap-top PCs, so they tend to imagine that the displays are all the same. In reality, there are noticeable differences, especially so since the user spends so much time looking at the screen. If we had the best displays, it would not be hard to encourage people to migrate from other vendors.

* Expand the cloud by increasing the dimensionality. By adding memory and driver electronics to the display, you can substantially increase the number of significantly different displays. In addition to various display parameters, displays can now be distinguished on the basis of whether or not they have memory, and perhaps how much. That doubles or triples the number of significantly different displays all by itself. MPEG decoders are a similar option that could reasonably be added to the display. This expansion of the volume of the product could would be expected to reduce the intensity of competition, or at least introduce some new products without heavy competition. One must be careful with this approach, as introducing distinctions that the customer does not consider significant will not reduce competitive pressure. Thought would need to be given to the question of who is the customer --the ultimate consumer, or the engineers that design the final product.

7. How to Distinguish AMLCDs

As we discussed previously, label-consciousness is an important factor in determining the competition in the market. That's one of the reasons Intel pushed "Intel Inside" label so hard, for example. If we want to have a successful venture into AMLCD market place, the clever use of the a new label may be an important factor. However, in order to establish a well-known label, quality products and early entry into the market are important.

8. Market Size and Market Share

It would also be useful to consider the market size of AMLCD. Current LCD sales world-wide are $6 billion for last year, and over 90% of it is in AMLCD. Over 98% of global commercial production is in Japan. Japan has invested around $3 billions (R&D and production) into LCD up to now and they essentially have the whole market. Assuming the same production and distribution efficiency, it is not unreasonable to expect a $400 million worth of market sales for a $200 million investments in the AMLCDs.

Putting the market size aside, if any of the hi-tech communicators we saw the "You Will" advertisements is anywhere close to the future of communication market, the visual part of the interface is certainly a differentiating factor. People pay attention to displays, because they pay attention to the information on them. It is certainly an advantage to have some control on such an important link to the future.