Creating and Leveraging Options in the High Technology Supply Chain

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Management of high technology companies is made challenging by the extremely rapid pace of change in technology products and markets. The most fundamental driver of this change is Moore's Law, named after Gordon Moore, one of the founders of Intel, who observed over three decades ago that computer processing power doubles approximately every 18 months. Moore's forecast has proved highly accurate to date, and due to on-going advances in semiconductor design and manufacturing techniques shows no sign of abating over at least the next decade.

The exponential rate of increase in computing power captured by Moore's Law has fueled extremely rapid development in both high technology products and services and in the companies that supply them. To manage effectively in the presence of this pace of change, technology companies have been required to develop effective methods of designing and delivering successful products to highly volatile, rapidly changing markets.

This article provides a brief review of the evolution of the business processes that have allowed the technology industry to continue to shorten its product lifecycles and increase the responsiveness of its product delivery processes. In brief, these processes combine improvements in the breadth, quality and frequency of information flows both up the supply chain, about current product demand, and down the supply chain, about the product configurations and volumes a company is currently able to supply, with improvements in the ability of the supply chain to respond rapidly to this information as it arrives.

Most of the new business processes developed to date are the result of innovations in supply chain management. While not derived using real options techniques, many of these innovations have natural interpretations as real options, and as described below can be effectively modeled and analyzed using real options techniques. In contrast, many of the processes currently being developed and implemented, also described below, have been derived using real options methods. These approaches are particularly well suited to leverage both the new flows of information and the greater supply chain flexibility enabled by the emerging business-to-business marketplaces for technology products and components.

Finally, while the examples in this article are drawn from the technology industry, almost all have clear parallels in other industries. The role of improved information flows and supply chain responsiveness, whether enabled by advances in supply chain management, the application of real options techniques, or the integration of a firm's business processes with emerging business-to-business marketplaces, offer opportunities for substantial improvements in performance, both within firms and among the networks of firms that enable products to be delivered to market.

The Evolution of Business Models in High Technology

Under their traditional business models, technology companies designed products with features that reflected their best estimates of customer requirements. Once launched, the composition of these products remained relatively static over well defined product life cycles of at least six months and often a year or more. The products were generally manufactured to a demand forecast in planned, high volume production runs, and safety stocks of components and finished products were maintained throughout the supply chain to ensure high availability of the product despite demand variability and the risk of supply disruptions.

The weaknesses of this business model are now well understood, and lie in its lack of responsiveness to actual market conditions as they evolve. While the manifestation of these weaknesses are physical, including substantial inventories throughout the supply chain and the delivery of the wrong quantities of products to the market, including too few products, too many products, and products with wrong features, their origin lies primarily in limited and often poor quality information flows. These information flows include both information about demand that flows up the supply chain, from customers to sales, marketing, manufacturing, product design and procurement, and information about supply that flows down the supply chain, from procurement, manufacturing, sales and distribution to distributors, retailers and customers.

Without accurate, current information about supply and demand conditions, even a supply chain that is physically capable of being highly flexible cannot respond efficiently to changes in the cost and quantity of the products that can be produced, or to the type and quantity of the products the market demands. To make an analogy to an option on a stock, if changes in the price of the stock over time cannot be observed, it is impossible to exercise an option on it effectively, and therefore to capture its value.

The problems caused by limited information in a supply chain are often compounded by strategic behavior of supply chain participants that seek to use proprietary information they may possess to their advantage. This behavior frequently leads to the magnification of boom and bust cycles in product manufacturing and availability, as firms over-order if concerned a product may be in short supply, and cancel orders if they expect a product may later be in excess and therefore available for a lower price. As documented by Lee, Padmanabhan and Whang (1997), the impact of this "bullwhip" effect on production plans and inventories can be significant.

Fortunately, important developments in the field of supply chain management over the last decade have had a significant impact on these problems. Leveraging advances in information technology, firms first developed the ability to more effectively monitor their manufacturing processes, and later their product distribution and sales channels. The techniques of modern supply chain management have directly affected the levels of inventory throughout the supply chain, and indirectly enabled more rapid identification of bottlenecks in the supply chain. More recent supply chain innovations such as collaborative planning between firms in a supply chain have improved the informational efficiency of the supply chain both through informal mechanisms, such as weekly conference calls, and formal methods, such as the establishment of direct links between agreed upon components of the firms' internal information systems.[1]

By substantially improving the breadth, quality and frequency of the information flows in the supply chain, these innovations have enabled a range of more flexible and responsive methods of doing business. These include shorter product lifecycles and more frequent changes in product features, mix, and production volumes, all of which allow firms to better tailor their offerings to current market conditions. Behind the scenes, better information allowed component and product inventories throughout the supply chain to be reduced, and production and distribution to be more closely matched to current demand. The net effect has been that existing or potential sources of flexibility, or optionality, in the supply chain that were of little relevance when the information necessary to effectively exploit them was unavailable have become extremely valuable. Drawing again on the analogy to an option on a stock, once regular, accurate, and cost-effective

[1] See references by Lee and Billington (1992) and Davis (1993).

information on the current value of a stock is available, the value of options on the stock begin to approach their "full information" value.

Supply Chain Innovations and Real Options: Examples

Many of the most interesting innovations in supply chain management, and in the business processes and models they have enabled, have natural interpretations as real options enabled by improved information flows in the supply chain. Supply chain innovations of this kind include product postponement and dual response production. Supply chain enabled business processes and models include the build-to-order, direct-to-customer model pioneered by Dell, and the outsourcing of manufacturing by technology companies to electronic manufacturing services companies first adopted in large scale by Hewlett Packard. Each is briefly summarized and interpreted from a real options perspective below.

Product Postponement

Product postponement is a product design, manufacturing, and delivery strategy that enables a range of customization options late in the manufacturing and product delivery process. By doing so it allows products tailored to current customer requirements and market conditions to be delivered on short notice, while maintaining little finished goods inventory. To draw on a simple example of postponement from the personal computer industry, a base system that contains a particular processor, hard drive and chip set may be produced in high volumes at a central location. These partially complete systems are then shipped to distribution centers closer to customer demand points, where additional hardware and software is added in response to either shorter-term, more accurate regional demand forecasts or to actually realized demand.

From a real options perspective, the alternative design, manufacturing, distribution and late stage customization elements of a product postponement strategy can easily be modeled and analyzed as features of alternative real options which a firm may choose to construct. Specifically, the option created is an option on the maximum of several assets, where the number and type of assets is determined by the number and type of different end products the chosen customization alternatives enable, and the exercise prices are the costs of the alternative customization steps. For example, a firm may be able to create the flexibility to sell computers into the strongest market of three alternative international markets by postponing the type of

power supply and the language of the software installed. Alternatively, it may choose to postpone the installation of a system's graphics chip to enable late stage customization of its graphic capabilities. In each case the value of the option created must be weighed against its cost, which is the cost of maintaining inventories of the "base" system and of relevant customization components at each postponement location. Postponement options are accordingly most valuable when there is substantial uncertainty about which product features will be in demand, and when the cost and risk of maintaining postponement related inventory is low. Finally, postponement options ~~may~~ also allow the firm benefit from the flexibility to select the components used in the customization process based on their current cost and availability.

Example: Postponement of HP's DeskJetPlus Printers

In the mid 1990's the worldwide supply of HP's DeskJetPlus printers ~~HP postponement example~~was produced in Vancouver, Washington, and distributed through four regional distribution centers located in North America, Europe, Latin America and Asia. Because the product was sold in virtually every country on every continent, configuration to local voltage and plug conventions was required, as were manuals printed in the appropriate language. Initially, all of this "localization" activity was done at the printer factory in Vancouver.

In order to meet customer demand with a high level of availability, a range of regional inventory and logistics options were considered, including air vs. ocean shipping. In comparison, a postponement strategy under which the "localization" step in the product assembly process was relocated from the factory to the distribution centers proved to be substantially more efficient.

To implement the strategy the optimal inventory levels at each distribution center were determined as a function of the length and variability of the lead time to replenish the center from the factory, and the level and variability of demand at the center. As a result of the implementation of the postponement strategy, total inventory investment in the supply chain was reduced by 18%. In addition, shipping costs were reduced substantially, since printers were shipped in bulk from the factory to the distribution centers, where they were placed in individual packages after being localized. Finally, the strategy substantially increased the "local content" of the product, creating a collaborative presence for HP and reducing taxes and tariffs paid.

Dual Response Manufacturing

Under dual response manufacturing a firm utilizes two types of capacity. The first is a long lead time, lower cost resource, and the second a shorter lead time, higher cost resource. Capacity resources with different characteristics of this kind may be associated with different manufacturing processes, such as a high volume, heavily automated process and a low volume, more manual process, or by relatively similar processes located in regions with different economic characteristics, such as a facility located in a low labor cost region such as China and another located closer to a primary demand location ~~s~~ in a higher cost country~~ies.~~

Access to two manufacturing resources with different costs and lead times allows a firm to tailor its production to better match the characteristics of its demand. For example, it may choose to use higher cost but more flexible capacity resources to produce the initial product volume required to support the launch of a product it wishes to speed to market, or that it believes has uncertain prospects for success which will be significantly reduced after its launch. It may then transfer subsequent production to the lower cost resource to support later high volume production, and use the short lead time, higher cost resource on an on-going basis only to manage short term fluctuations in demand, as well as any disruptions in supply from the long lead time source that may occur.

From a real options perspective, dual response manufacturing can be represented with two capacity options, the first with a long exercise lead time and low exercise price, and the second with a much shorter exercise lead time but higher exercise price. Modeling manufacturing resources as capacity options with lead times makes clear that there are costs associated with longer lead times other than simply waiting longer, namely that production plans must be based on more distant, and thus more uncertain, forecasts of demand. This requirement increases the likelihood that the option will be exercised for either more or less units than the firm will actually require in the future, and therefore increases its risk. Because few financial options have exercise lead times, "exercise risk" of this kind in real options, while quite common, is frequently overlooked.

Given the cost, risk and lead time trade-offs between alternative capacity options, the optimal portfolio of manufacturing options for a firm to maintain over time will depend on the variability of the demand for the firm's products over their product lifecycles, and the specific cost, reliability

and lead time characteristics of its manufacturing options. Finally, there is clearly no reason that a firm should limit itself to only two manufacturing options if a wider range of distinct capacity options are available. The same concepts and analytical approach apply to the more general case where there are three or more capacity alternatives.

Example: Dual Response Manufacturing of HP Inkjet Printers
Hewlett Packard has used dual response manufacturing to supply inkjet printers to North America for several years. Initially this was done using a combination of high volume, low cost production resources in Singapore and higher cost, shorter lead time production resources in Vancouver, Washington. More recently substantial production has been moved to Guadalajara, Mexico, where the combination of a wide range of recently built manufacturing resources and geographic proximity to the primary demand points of North America offer a desirable new alternative.

Build-to-Order, Direct-to-Customer Business Model
The build-to-order, direct-to-customer business model relies on information flows and generates physical and financial flows very different from those of the traditional PC industry business model. Under ~~the~~ this model, a company communicates, by either telephone or through the internet, currently available products and product features and their costs to prospective customers, who in turn specify the configuration of the particular product they wish to buy. Once the customer's request is complete, the company then immediately bills the customer and individually builds and ships their product.

Companies that use the build-to-order, direct-to-customer model, such as Dell, frequently interact with their suppliers using a similar just-in-time approach driven by ~~on actually~~ completed sales. For example, suppliers to Dell are required to maintain component inventories at or near Dell's factories, at their own risk and expense. When Dell includes one of their components in a system they are notified immediately, and only at that time do they bill Dell. Because Dell sells and bills its customer for the computers it produces before it builds the computers or pays its suppliers for their components, it is able to avoid both component or finished goods inventory. In addition, the financial flows which result generate its now famous negative "cash-to-cash" cycle, under which it receives payment from its customers before it pays its suppliers. The need to carry and finance inventories of components of course doesn't go away, it is simply shifted to

the supplier. Improvements in the efficiency of the supply chain overall as a result come principally from improved information flows about the number and types of products customers currently wish to buy.

From a real options perspective, the build-to-order, direct-to-customer business model can be viewed as creating a set of call options on spreads. The spread for a particular option is the difference between the price at which the company is able to sell a product with a particular configuration and its cost of delivering that product. Because the company only buys components after it sells a product, it knows the precise payoff of each of its spread options, and can avoid the risk of either purchasing the wrong components or ~~the~~ components in the wrong amounts ~~of components~~, or building the wrong products or products in the ~~the~~ wrong amounts ~~of products~~.

The traditional technology manufacturing business model can also be viewed as creating a set of call options on spreads. Under the traditional model the relevant spread is the cost of specific products built with components purchased under procurement contracts and the price those products can be sold for over their associated product lifecycles. Because time lags exist between the time the relevant component procurement contracts are signed and the time the product or products in which they are incorporated are manufactured and sold, there is a substantial time lag between the time the price and quantity of the component side of the spread is locked in and the time the price and quantity of ~~of~~ the product side of the spread is determined. As a result, the payoff the spread option will provide is uncertain at the time it is exercised. The extent of this payoff uncertainty is determined by the level of uncertainty about the number of products the firm will be able to sell and the price at which those sales will occur. On one side the firm faces the risk that it will be left with excess components or finished goods inventory, and on the other that it will loose sales due to an excess of demand relative to available supply.

A more careful review of the differences between the spread options generated by the build-to-order, direct-to-customer business model and those generated by the traditional technology manufacturing business model reveals three additional significant differences: 1) the range of distinct options generated, 2) the volatility of the spreads the options are written on, and 3) the frequency at which the options can be exercised.

1. Number of Options Generated

The "no advance commitment" approach to component sourcing practiced by Dell and some other build-to-order, direct-to-customer companies, combined with its configure-to-order approach to manufacturing and sales provides it with substantial flexibility in the mix of components sourced and the configuration of products built over time. This flexibility creates a large number of distinct product spread call options over time. In addition, through direct interaction with customers as they configure and purchase products, direct companies are able to bring component and product configurations with desirable cost and performance characteristics to the attention of their customers on an almost real time basis. This helps them avoid lost sales due to shortages of particular components for which acceptable substitutes are available, and more generally enables them to ensure that the most valuable product spread options in their portfolios are exercised over time.

2. Volatility of Spreads Options are Written on

Because Dell and many other direct companies buy~~s~~ their components and sells their products in what are in effect spot markets, the value of their spread options are enhanced by the generally highly volatile nature of these markets. In contrast, under the traditional technology manufacturing model firms generally buy their components and sell their products under contracts that may last three to six months, and in some cases extend to a year or more. The prices negotiated under these contracts are generally significantly less volatile, which in turn reduces the value of the spread options created.

3. Frequency at Which Options Can Be Exercised

The ability of direct companies to purchase components on a spot basis and to direct customers toward particular product configurations on a near real time basis allows them to exercise different product spread options on a daily or even hourly basis. This allows them to capture the value of options with the greatest value at each point in time. In contrast, under the traditional technology manufacturing model a firm can only select a product spread option to exercise when it introduces a new product, which clearly occurs much less frequently.

<u>Electronic Manufacturing Services Firms</u>

Over the last five years the proportion of technology products manufactured by contract manufacturing firms, now increasingly known as electronics manufacturing services, or EMS companies, has grown dramatically, and the

use of EMS companies is rapidly becoming the standard manufacturing process for many technology companies. The initial success of EMS firms was enabled by their investment in networks of large, efficient manufacturing facilities around the world which allowed them to offer lower costs and global manufacturing reach. More recently they have leveraged these networks of manufacturing assets by developing the ability to build and test prototype products and their associated manufacturing processes, and then by using identical processes in each of their facilities worldwide, to ramp global production of the products extremely rapidly. Finally, while large technology firms still generally source the components their EMS partners use to build their products, EMS firms are increasingly bundling the procurement capabilities necessary to support the delivery of products with increasingly short product lifecycles and volatile demand.

The emergence and development of EMS firms has played a critical role in enabling flexible, low cost production of the highly volatile, short-life cycle products now common in the technology industry. By pooling demand across many customers, EMS firms are able to smooth production and support investments in a wide range of capacity resources, as well as in the advanced manufacturing management processes necessary to generate the greatest value with those resources. Their customers benefit from greater flexibility and lower costs, and by avoiding the need to make the investments in the capital assets and large labor forces necessary to support internal manufacturing, resources which now increasingly look out of place on the balance sheets and income statements of technology firms. In essence, EMS firms have given technology firms flexible access to a wide range of manufacturing options, where previously they held a much smaller number of less flexible and more capital and labor intensive options.

A Complete Real Options View of the Firm

The discussion and examples above identified the principal sources of optionality in the technology product design, procurement, manufacturing, and sales process. These include product design and configuration flexibility enabled by supply chain innovations such as postponement and build-to-order, alternative manufacturing capacity resources leveraged by dual or multi-response manufacturing strategies, often executed through EMS firms, and alternative sales channels, including traditional retailer and distributor channels and direct-to-customer sales channels.

From this range of options, a firm must select a portfolio of options to develop and monitor. Over time it must then identify the optimal subset of that portfolio to exercise at each point in time. A visual depiction of this options-based view of the firm is shown in figure 1.

In the hub and spoke structure in the figure the spokes on the left side represent the firm's procurement alternatives, and the spokes on the right its sales alternatives. The circle in the middle represents its portfolio of product design, manufacturing and marketing options, the composition of which is determined by the portfolio of procurement transactions and relationships, manufacturing resources, and sales and marketing strategies it selects over time. Before discussing how a firm can identify the optimal portfolio of options to develop and exercise over time, it is useful to briefly review the set of procurement and sales alternatives represented in the figure.

Procurement Options

In addition to the traditional relationship based approach to procurement, figure 1 includes spokes for spot market buys and "structured contracts". The term structured contract is used to refer to a contract between a manufacturer and supplier that specifies either fixed prices and quantities, or in which prices and quantities are bounded to defined ranges. Relative to less structured relationship based procurement contracts, where commitment and risk sharing usually occurs informally and the term of the relationship is typically long, structured contracts may be either short or long term in nature, and provide defined levels of commitment and risk sharing between the two parties. In contrast, spot market purchases provide great flexibility, but offer no assurance of availability or price. At present there are few active spot markets in technology components, and the majority of procurement is done under relationship based contracts. This is beginning to change quite rapidly, however, due to the emerging role of electronic marketplaces and sales channels. ~~TradingHubs?? EHitex.com~~For example, in May 1999 Hewlett Packard launched an electronic marketplace focusing on component parts and finished goods. This company, TradingHubs.com, has since developed into a multi-company electronic exchange called the high tech marketplace, or ehitex.com, which will attempt to create active spot markets.

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Sales Options

In addition to the traditional contract based relationships with distributors and retailers through which branded, announced products are sold, figure 1 includes spokes for direct sales channels, "branded specials," second brands, and sales of components. As noted in the discussion of direct-to-consumer business model above, relative to the traditional indirect distributor and retailer based sales channels, direct channels allow the products and prices which a firm offers to be varied dynamically in response to current market conditions, including markets for both components and end products. There are drawbacks to the direct model, however, including the higher logistics costs associated with shipping systems individually rather than in bulk, and the fact that at present only a relatively small percentages of buyers make their purchases directly.

Branded specials attempt to deliver benefits similar to those offered by direct sales, including allowing both opportunistic procurement and product offerings tailored to current market demand, but to deliver these benefits through traditional indirect channels. This is done by offering, through indirect channels, specific product configurations designed to capitalize on a particular market opportunity in defined and generally limited volumes. For example, in response to a shortage of a key component of a branded, announced product, such as a~~n alternative~~ microprocessor in a personal computer, a firm may offer a branded special that is identical to the product except that an alternative close substitute component is used to replace the component that is in short supply. By offering the branded special the firm is able to take pressure off demand for its branded announced product, for which it may be facing shortages, allowing it to maintain customer goodwill and avoid losing sales to competitors. Alternatively, the firm may offer a branded special in response to a specific product market opportunity, perhaps in the form of a request from a key distribution partner that feels it can capture a particular sales opportunity with a product slightly different from those the firm currently offers.

Second brands offer similar benefits to branded specials, but with greater differentiation from the firm's primary product offerings. Like branded specials they may be used to mitigate the effect of adverse component supply conditions. Relative to branded specials, they allow the firm to ship products with combinations of features perceived to be desirable to some segments of the market but far enough from optimal that the firm does not wish to offer them under its primary brand. They may also be used to profit

from lower margin or other more specialized market opportunities for which the firm prefers to use a second brand rather than its primary brand. ~~Mention Apollo?~~An example of a second brand is HP's creation of the Apollo brand of inkjet printers, which allows it to capture a wider range of opportunities in a market where its primary Hewlett Packard brand comprises over 50% of sales.

Finally, the firm may choose to sell components themselves. This is most likely to be motivated by the need to reduce inventories created by weaker than expected demand for one or more of its products. On occasion, however, the firm may choose to "overbuy" components to benefit from volume discounts, or may find that in certain environments the components it holds may be more valuable than the products it is able to build with them.

Constructing a Firm's Optimal Portfolio of Operating Options

Together with a firm's product design, manufacturing, and marketing alternatives, the set of inbound procurement and outbound sales alternatives available to it represent the set of building blocks from which it must construct its portfolio of operating options. Given the wide range of choices available to it, the obvious question is what portfolio should it choose?

A definition of a firm's optimal portfolio of operating options is easy to state; it is simply the portfolio with the greatest value. Identifying this portfolio is substantially more difficult, however, for two principal reasons. First, there are many possible portfolios to choose from. Second, the value of and optimal exercise policy for individual real options vary with the portfolio of which they are part.

Many Possible Portfolios to Choose From

The range of inbound procurement, product design, manufacturing, marketing, and outbound sales alternatives possible under the general business model of figure 1 can be combined to form many possible portfolios of operating options. For example, even if a firm arbitrarily chose to limit its consideration to portfolios with only two inbound sourcing alternatives, two manufacturing alternatives, and three outbound sales channel alternatives, it would have twenty-four different portfolios to consider.

To choose among these portfolios it must estimate the value of each. To estimate the value of an individual portfolio it must determine the optimal

exercise policy for the options in the portfolio over time. This requires that it estimate the optimal sourcing, product design, manufacturing, marketing and selling strategy for the portfolio under the range of possible future market conditions. Further, since some of the options require multi-period commitments, such as long term procurement or sales contracts, to determine their optimal exercise policy the consequences of alternative exercise policies must be evaluated over a sequence of future periods.

Option Values and Optimal Exercise Policies are Portfolio Dependent

There is a fundamental difference between real and financial options that makes portfolios of real options significantly more difficult to evaluate than portfolios of financial options. This difference is that both the optimal exercise policy for and value of a real option will in general depend on the composition of the portfolio of real options of which it is a part. The reason for this is that real options represent business decisions. As a result, when exercised they change the characteristics of the business on which they are defined. When a firm exercises one of its real options and by doing so changes the characteristics of its business, the optimal exercise policy for and value of each of the firm's other real options will in general also change in response.

For example, the option to buy from a spot market is much less valuable to a firm that holds a contract that allows substantial variation in the volume it takes under the contract than a firm that does not. Similarly, a firm that has a well developed online sales channel may assign a much lower value to developing relationships with other online channels than a firm that has no online channel of its own. In contrast, there are no interactions of this kind for financial derivatives. This is true because the value of financial derivatives is, by the definition of a derivative, determined based on the value underlying financial instruments on which ~~they~~ the derivatives have no effect. Rather than derivatives, an appropriate parallel term for real options might accordingly be "controllers" of their underlying assets.

This important difference between real and financial options is what makes it necessary to determine the optimal exercise policies for and values of the options included in each portfolio of real options separately. Doing so may clearly require a substantial amount of work. In contrast, the optimal exercise policy for and value of each of a set of financial options can be determined once, and the value of any possible portfolio then determined simply by summing the values of the individual options included in it. For

financial options "portfolio effects" only become relevant when a measure of the risk of the portfolio as a whole is desired, since to determine this risk an analysis of the correlation, or more accurately the joint distribution, of the payoffs of the options in the portfolio is required.

A Practical Approach

The complexity of conducting a comprehensive analysis of each of a firm's possible portfolios of real options creates a need for a more pragmatic approach capable of ~~that capture~~capturiong the most important features of a comprehensive analysis. At a minimum, such an approach must help the firm choose an appropriate set of options and provide guidance on how to best exercise those options over time. Fortunately, the recent trends in the evolution of the technology industry described above allow this to be done with increasing efficiency and effectiveness, as described below.

Selecting Options to Create and Maintain

As noted above and summarized in figure 1, the building blocks from which a firm's option portfolio is built are its product design, procurement, manufacturing, marketing and sales channel resources. Of these, the firm's manufacturing and sales channel resources have traditionally required the largest investments and been the least flexible, and have thus merited the greatest attention. Due to the evolution of the manufacturing and sales business processes and models of the technology industry described above, however, both of these categories of decisions have become substantially simpler to make in recent years, as described below.

The trend toward the outsourcing of manufacturing to electronic manufacturing services firms has given technology firms flexible access to a wide range of manufacturing technologies distributed throughout large international networks. From a real options perspective, the development of the EMS industry can ~~as a result~~ be viewed as offering technology firms flexible access to a diversity of low cost manufacturing options. The flexibility of this new contractual access to the manufacturing resources allows firms to carefully match their manufacturing assets to their manufacturing requirements over time, or from a real options perspective to only exercise capacity options that they are sure will have a positive payoff. In contrast, in addition to being limited in number, the long term nature of the capacity options previously available to firms, which were options to make long term investments captive ~~in-house~~ manufacturing assets, forced firms to assume substantial risk of loss. As a result, t~~T~~he old manufacturing

options were as a result difficult to analyze and risky to exercise. In contrast, the new manufacturing options are both simple to analyze and can be exercised with little or no risk.

On the sales channel side, most technology firms have an established set of indirect sales relationships. As a result, the sales channel resources they must decide whether to develop are generally direct and other online channels, most of which are relatively inexpensive to establish. Since a firm should create any option with a value greater than its cost, detailed analysis of inexpensive options that have the potential to create substantial value is not required. As a result, for most firms it makes since to develop a range of new online sales channels, and most firms are in fact doing so. This result reflects another important difference between real and financial options, which is that many real options are proprietary. As a result, they are available to their holders at their cost, rather than their market value. In contrast, since financial options can be freely created, they are always priced at their market value.

In summary, the evolution of highly flexible contract manufacturing options and new low cost sales alternatives both increases the value of a firm's option portfolio and substantially simplifies its analysis, including both its valuation and optimal exercise. The creation of the new business processes and models that have enabled this change is of course not coincidental, or an external event unrelated to the economics of the technology industry. Rather, it reflects a broad realization in the technology industry that substantially more value can be created given the highly volatile and dynamic nature of the industry when technology businesses are operated in this way.

Monitoring Markets Over Time

The greater flexibility that outsourced manufacturing and online sales channels enable allows technology firms to be highly responsive to market conditions and opportunities as they evolve. To capture these opportunities firms must actively monitor markets for components, manufacturing resources, and their current and prospective products, and adjust their exposures to each through contracts, partnerships and trading relationships over time. Given this trend toward market-based strategies, like firms in other industries that purchase primary inputs or sell primary outputs in active markets, such as firms in the energy, metals, chemicals or agriculture industries, the performance of technology firms will increasingly depend on

their ability to analyze, interact, and manage risk through markets. As the industry makes this transition, expertise in manufacturing facilities investment and processes, critical competencies of technology firms in the past, will grow increasingly peripheral, and expertise in market analysis, contracting, trading and risk management will grow increasingly central.

From a real options perspective, the trend away from long term facilities investments, procurement contracts and product offerings toward shorter term, market based trading and contracting substantially simplifies the analysis of the optimal exercise decisions of a firm's real options.

Meeting the Management Challenges of the Emerging Technology Industry Business Processes and Models

The combination of the rapidly increasing breadth and depth of markets for technology components, manufacturing services, and products, and the associated rapidly decreasing cost of acquiring, altering and replacing operating options in the technology industry is generating dramatic changes in the characteristics of the real options portfolios available to technology firms. These changes are making it possible for technology firms to be both more efficient and more responsive to market opportunities, allowing them to deliver products with shorter life cycles and rapidly changing configurations in flexible volumes at competitive prices.

To support significant changes in business processes and models of this kind, however, substantial changes in the skill sets, internal processes, and information technology infrastructure of technology companies are required. For example, while a senior manager responsible for manufacturing in an established technology firm today may have twenty years of experience managing manufacturing operations, he or she may no longer actually manage any manufacturing operations at all. Instead, her day may be spent primarily by engaging in negotiations, contracting and trading with external manufacturing partners and suppliers. Equally problematic, the same manager may still be measured on metrics such as per unit cost that were designed to measure the efficiency of internal manufacturing processes rather than the firm's current contracting and trading based methods of doing business.

To be effective under the emerging business processes and models of the technology industry, managers of technology firms must develop expertise in contracting, trading and risk management similar to those found in

industries where the role of markets is well established. To encourage this transition and to create the incentives and performance metrics necessary to support it, performance measures based on return on capital adjusted for appropriate measures of risk should replace existing asset and cost based measures.

While including risk measures in performance measurement and control systems is clearly crucial in any trading or contracting environment, doing so presents substantial challenges in an environment where risk, while always present, has in the past generally not been measured or managed. This transition can be facilitated with a combination of explicit risk management training for current staff and the gradual introduction of risk management techniques to key business risks. Both steps may initially be lead by external experts in risk, working either as consultants or as new staff members recruited from industries where such practices are well established.

The final management challenge created by the new technology business processes and models is the need they create for very close coordination across the key business functions of a firm, including design, procurement, manufacturing, marketing and sales. Coordination of this kind is essential if a firm is to realize the full value of its portfolio of real options, which as described above requires that the firm be able to combine flexible and opportunistic methods of sourcing, manufacturing and sales to deliver profitable products to market over time. Like the effective measurement and management of risk, achieving integration of this kind is likely to require significant changes in internal business processes and performance metrics. Fortunately, the same markets that are creating the need for this transition can also provide the appropriate transfer prices and performance metrics necessary to support these changes.

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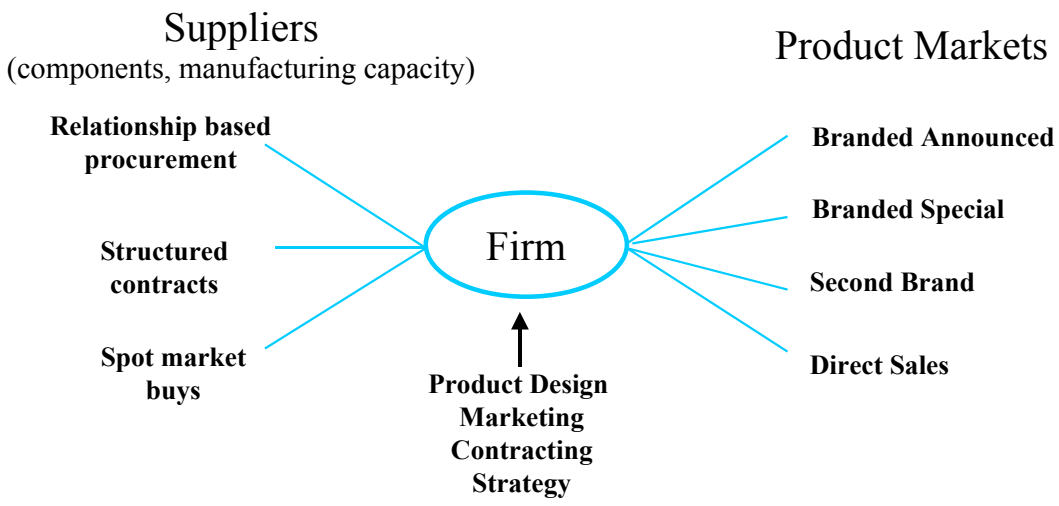

Figure 1: A Complete Real Options View of the Firm