COMMERCIALISING TECHNOLOGY CAPABILITIES: A DYNAMIC RESOURCE REUSE APPROACH TO THE ASSESSMENT OF OPPORTUNITIES AND SEQUENCING OF TARGET MARKETS

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Innovation is a two sided coupling process, which involves the matching of capability with a situation of utility. Technology intensive organisations such as publicly or privately funded R&D centres and universities generate significant technical capabilities which need to be assessed for their ability to generate utility for end users. Most technical capabilities can generate utility in a variety of situations, but what is a systematic way for assessing the relative merits of exploiting the different opportunities and their fit with the organisation?

This paper provides a conceptual model and framework to assist managers in making this decision. It takes into account the real life dimensions of time, capability and demand maturity the impact of uncertainty whilst still being flexible to the variety in strategic intent between commercialising organisations.

SECTION 1: INNOVATION AS A PROCESS OF MATCHING OF CAPABILITY AND UTILITY

Freeman characterised the fundamental innovation challenge as one of coupling capability and utility:

"Innovation is essentially a two-sided or coupling activity.[...]. On the one hand, it involves the recognition of a need or more precisely, in economic terms, a potential market for a new product or process. On the other hand, it involves technical knowledge, which may be generally available, but may also often include new scientific and technological information, the result of original research activity. Experimental development and design, trial production and marketing involve a process of 'matching' the technical possibilities and the market. (Freeman, 1982 in Mainea, 2006)

Coupling is particularly challenging where there has been little prior interaction between the type of capability and area of utility. Where there has been little accumulation of resources to pursue this particular set of opportunity paths, assessment is particularly difficult. Stokes (1994, 1997) made a significant contribution to understanding the place of science-based capability development in innovation by locating research in two dimensions: a 'quest for fundamental understanding'; and 'considerations of use'. He argued that research which scored highly on both dimensions, an area known as Pasteur's quadrant, held special significance because of its ability to open new areas of development with significant social impact.

Whilst an intriguing perspective, the model lacks consideration of the time dimension and an adequate treatment of uncertainty – this limits its wider applicability. We have extended the Stokes model to address these and other shortcomings and we use this extended model as our conceptual foundation.

In reality capability and utility, and the organisations that explore and facilitate coupling, co-evolve. Our approach models the evolution of a coupling through its lifecycle. The model has three dimensions: 'capability certainty' (the degree to which we understand our technical capability), 'utility certainty' (the degree to which we understand its potential utility); and time. At time zero, our model corresponds to the Stokes model, but over time by the investment of effort and resources a particular capability-utility coupling has the ability to move in the two dimensions, so reducing uncertainty.

Research and development is the process by which capability certainty is improved and strategic marketing, business development and demonstration is the process by which utility certainty is improved. Together these processes can transform a vague idea into a value creating technology.

The utility possibilities of a capability may range from the highly generic to the highly specific - a single application is a special case. Cases of multiple capability-utility couplings that originate from the same underlying capability are often referred to as 'generic technology' or 'platform technology' in the literature.

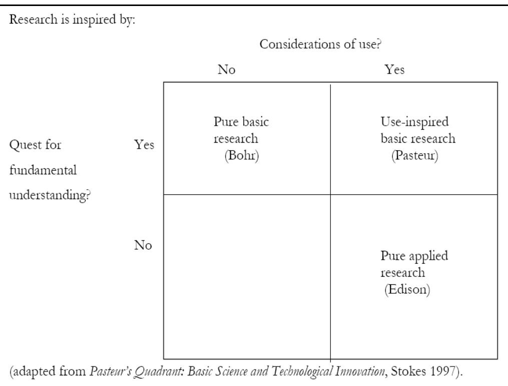
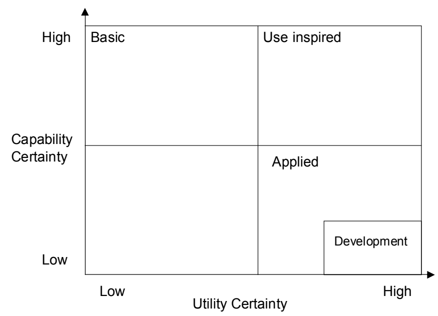
Making Strategic Choices

Shane (2004) identifies five potential benefits for ventures exploiting generic technology:

- flexibility to pursue alternative market applications if the initial market / application focus is not successful;
- a spectrum of temporal commercial opportunities, short to long term, based on the maturity of markets ;
- scope to spread risk and R&D costs across applications;
- scope to compare and prioritize alternative target market opportunities; and
- the range and possibly also the depth of opportunity attracts investment.

All options (or paths) involve uncertainty and all require significant and irreversible investment, and hence strategic choices must be made. All organisations seeking sustainability and/or growth have the goal of establishing a path of increasing returns - whether those returns be economic and/or social. But how do organisations decide which path will generate increasing returns and provide the best fit with their strategic objectives, capabilities and opportunities to create utility? These paths are also rarely independent. Investment in pursuing one may also generate capabilities useful for pursuing another, and success in one area of utility may lower the risks in another.

Shane was right to label these 'potential benefits'. Without an appropriate tool to manage these decisions exploitable opportunities are likely to remain hidden amongst the multiplicity of potential opportunities. This paper develops such a framework.

	
Pasteur's Quadrant Stokes (1997)	Updated Model: The dimensions of uncertainty in innovation

The need for decision tools

The challenge of strategic choice between capability-utility couplings is significant for technology intensive organisations that develop broad capabilities; particularly universities, research centres, defence science and technology agencies, corporate R&D facilities and SMEs in high tech industries.

As investment in research, and the role of innovation in competitiveness, both increase there is understandably greater interest in developing greater understanding of the knowledge/ technology/ application connections. As stakeholders who fund research seek a broader outcomes-orientation and greater accountability there is an increasing need for systematic and effective processes for assessing capability-utility opportunities. Similarly, the 2002 conference of the Product Development and Marketing Association, principal sponsor of the Journal of Product Innovation Management, identified the question of '*How do we find the 'best' application for a given new technology*? *Can we map applications to technologies?*" as one of the key issues for research .

Existing opportunity analysis methods cannot capture this complexity, interaction and uncertainty, The basic 'guess' and check approach, the combined opportunity assessment framework and net present value calculations, provides an oversimplified and static analysis. Even the more advanced methods such as those based on real options analysis:

- consider opportunities in isolation;
- do not consider the real world range of strategic interests or the current situation of the host organisation; and
- do not consider the variety of paths to market/ leverage models that are possible.

Where multiple opportunities not only exist but interact, a more realistic, robust, flexible and strategic tool is required

To develop the framework for this tool we need a deeper conceptualisation of the coupling process, the role of the firm in this process and the path of increasing returns, which is discussed in Section 2.. Section 3 draws on the Resource-Based View (RBV) of the firm and dynamic capabilities to model the processes by which a firm can strategically modify its resource base to leverage multiple opportunities. Section 4 draws on the demand-based view of innovation to model the emergence of innovations in the selection environment and the implications for exploiting opportunities. In Section 5 we operationalise the models to develop a tool for identifying the more favourable paths through a sequence of opportunities.

SECTION 2: CONCEPTUALISING THE COUPLING OF CAPABILITY AND UTILITY

A capability may generate utility in a range of applications. The level of value creation in those applications is shaped by a range of situation-specific factors. An organisation that is host to the capability on which the opportunities are based may pursue a wide range of alternative leverage paths to generate value from the capability, from 'soft' (contract research, consulting), through licensing, to 'hard' (speculative product development) (Connell, 2004).

Each opportunity involves different levels of risk, requires the host to have or develop different resources, and develops and distributes different types and levels of value. For example, a research organisation may use their capability in a particular field as a basis for carrying out contract research, to provide consulting services to firms (eg in contributing to product or process design), to provide a license to firms to use that knowledge in a particular application, or to spin-off a venture to develop and launch a product (in which it may contract out production or marketing etc) – or it may do some or all of them in sequence or in parallel.

Increasing returns arise when a resource that is a major source of competitive differentiation (eg a large factor in product costs, a key driver of product quality, or a key barrier to entry) is re-used across production units (economies of scale) or product lines (economies of scope). Both are important in assessing commercial strategies for generic technologies.

Coupling of a capability and an area of utility may take many forms with different specific performance attributes, even in one area of application (eg in terms of weight, size, costs etc). Each bundle of performance attributes will be associated with different levels of potential utility for different users, and with different levels of value creation. For example, many significant new technologies have first been applied in military applications where users place a high value on product performance rather than price.

Couplings are dynamic, capability levels improve over time, the capability levels of competing couplings change at different rates over time, and utility in different applications may increase or decrease. Consequently, the potential set of options, and not only the attractiveness of specific options, changes over time.

Identifying 'real' opportunities

With a capability as the starting point, each option has two primary dimensions: the application/user combination which generates utility and value; and the commercial strategy for leveraging the capability. An opportunity only exists when each of the following conditions are met:

- Generates on overall surplus above the costs of generating the utility, taking into account the level of risk involved and the returns to alternative applications;
- Provides an adequate return to all of the participants in the commercialisation pathway, taking into account their risks and the value of the resources they contribute.

The organisations that are the capability hosts must actively search their environment to understand the utility of their capabilities and identify which couplings are the most attractive opportunities. What is attractive depends not only on the potential economic value creation and the level of that value that can be appropriated by the host organisation, but also on the resources, interests and strategies of the host. For example, a research organisation may value highly reputation, future research funding, or social standing due to overall value creation (rather than their appropriation of that value). For the remainder of this paper we will take the perspective of a firm deeply involved in managing the coupling process.

Most firms rarely have a comprehensive understanding of the couplings available to them. The 'fog of uncertainty' clouds their understanding of the utility their capabilities could generate in different applications, and the further potential utility that could be created by developing their capabilities in particular directions. This uncertainty will be particularly high where there have been few similar couplings of such capabilities and applications. In such cases it is inevitable that the commercialisation of a capability will involve an element of probe and learn. The lack of established relationships for information flows and sheer unfamiliarity contribute to the fog, but investing effort in one application provides a focusing device that can help reduce the uncertainty surrounding related applications. Firms have two well defined processes for reducing the cloud of uncertainty surrounding a coupling, 'research and development' reduces the capability uncertainty, and 'strategic marketing, business development and demonstration' help reduce the utility certainty.

Identifying a path of increasing returns

In this paper, we argue that developing a path of resource reuse through a series of capability-utility-leverage-model couplings is the best way to reduce the cumulative risk and improve the reward from a portfolio of opportunities. The optimal path will be dependent on the individual organisations resources and strategic intent, its tolerance for risk and the balance between private appropriation and public benefit. The framework provides the analysis tools to help assess the opportunities available to the organisation.

The approach acknowledges that before a capability is useful, it must be developed to an extent that it meets a threshold for coupling in the opportunity set. Investing to this point is a risk and no reward is possible until meeting this threshold. Continued investment in capability development beyond the minimum level will enable a progressively larger number of couplings to be available as opportunities for exploitation. Potential users with a good understanding of the potential of a capability and the capacity to contribute to the capability/application coupling shift that threshold[i]. With an appropriate tool it is possible to assess and identify a path between these couplings that supports the strategic intent of the organisation.

Having described the overall model that we are proposing, in the next two sections we will provide further detail on how capability development and the selection environment are modelled . In section 5 we leverage the model to build a tool for managers to identify a path through a series of applications which is compatible with their strategic intent.

SECTION 3: CAPABILITY EVOLUTION WITHIN THE FIRM

The firm or organization can be viewed as a bundle of resources, and the resources of an organisation that enable effective operation range from tangible equipment and facilities to such intangibles as knowledge, capabilities, management systems, reputation and relationships with suppliers and customers. Scarce, relevant and difficult to imitate assets are (increasingly) sources of competitive advantage. Such assets generally cannot be bought but must be built, usually involving investment in complex activities with uncertain outcomes.

The exploitation of a capability/ utility coupling (the commercialization of a specific application of new knowledge) typically involves leveraging this intangible resource to gain access to complementary resources, such as finance and production facilities, that are required to create commercial value When a new venture is formed a process of resource mobilization begins where the new firm buys, builds or borrows the required complementary assets/resources. In the early phase of pursuing a capability/utility path the focus must be on the activities of product, process, market and organizational development - activities which generate more specialized and dedicated resources.

The path of commercialization involves a commitment of resources to irreversible and increasingly specialized asset accumulation. Clearly the entrepreneur will seek to avoid irreversible commitments to assets with little re-use potential and maximize the generation of re-usable assets. The process of pursuing specific applications of a core capability will require, and will generate, different resources, some of which may be significant in determining the probability of success or the level of profitability in another application area. Some groups of applications may hence provide substantial opportunities for economies of scope, in which case licensing the technology to different firms, or generating a number of independent spin-offs, would lose substantial opportunities to appropriate greater value

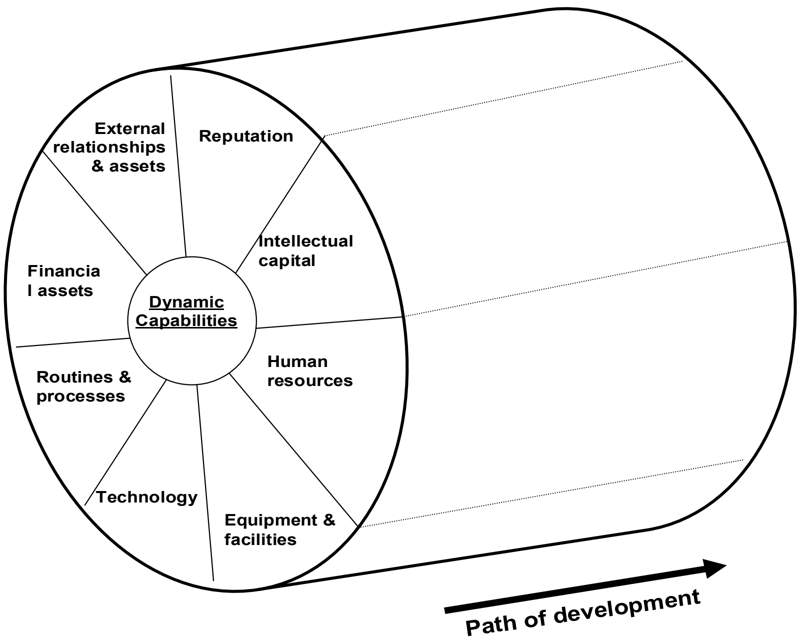
As the venture develops the entrepreneur/manager is also concerned with the most effective coordination or orchestration of these resources to produce and market goods and services and so create value for intermediate or final users. The orchestration of resources for effective and efficient operations has become more challenging, not only due to complexity but because specialization has led to greater interdependence with the result that orchestration involves the coordination of more external suppliers.

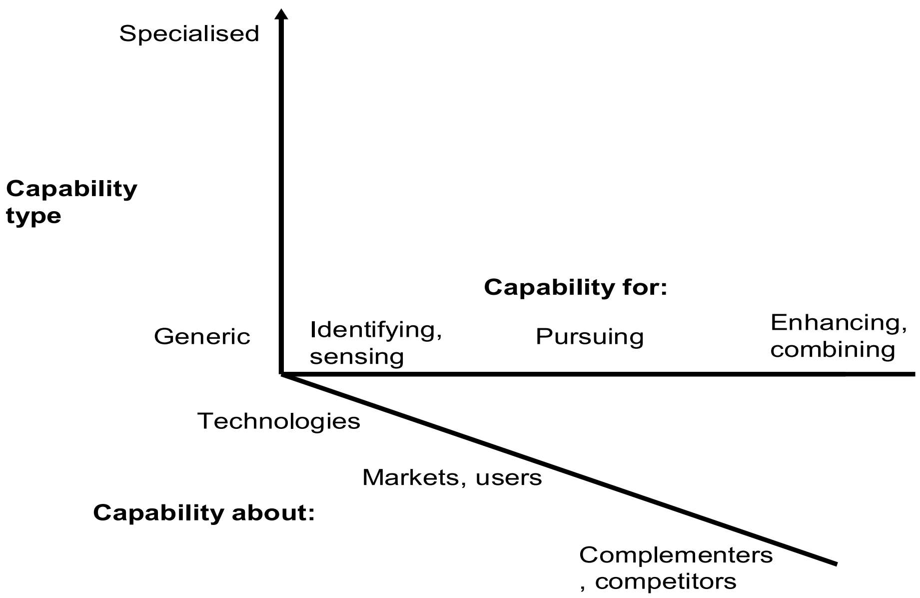
Resource identification and accumulation

A key skill of the entrepreneur or manager is to identify what resources are required for value creation and to gain access to these resources (or more correctly to the services they provide) on the most favorable terms. The availability of certain resources will both enable and constrain the opportunities or couplings that a firm is able to exploit. Identifying what resources are required and either acquiring them or gaining access to them is itself a key capability, which, because it is concerned with changing an organization's resources, is a type of dynamic capability. In a fast moving environment the capabilities to '..create, extend, upgrade, protect and keep relevant…' the asset base are vital. There are three key components of such dynamic capabilities:

- Capacity to identify, sense and shape opportunities and threats;
- Capacities to respond, act on decisions, and capture opportunities; and
- Capacities to further develop an organizations tangible and intangible assets, including its links to external assets (Teece, 2007, p1319).

The framework in this paper is essentially a structured heuristic for the first of these capacities. But we emphasise that the framework is more effective the more that decision makers understand latent demand in users and the evolution of industries and markets. Analysis complements but cannot substitute for entrepreneurial decision making. We suggest that the framework is used to develop a set of options, in a sense each an hypothesis about coupling opportunities and the paths to realize them, and to continuously test them in the light of new information and insight. Each option is a potential path of development. In pursuing any path the organization accumulates further 'local' dynamic capabilities (as well as resources for production, marketing etc that provide short term competitiveness) –ie it builds knowledge, competencies, relationships etc that strengthen its capacity to sense opportunities and develop assets close to its current resource and market position. Just as there are likely to be interactions between options in terms of the resources they require and generate, so there are also likely to be interactions between options in terms of the dynamic capabilities they require and develop. For example, a firm that develops new products for the military market will deepen its capacities to sense and develop new opportunities in this domain but pursuing this path may contribute little to the firms capacity to sense and develop new opportunities in high volume consumer markets.

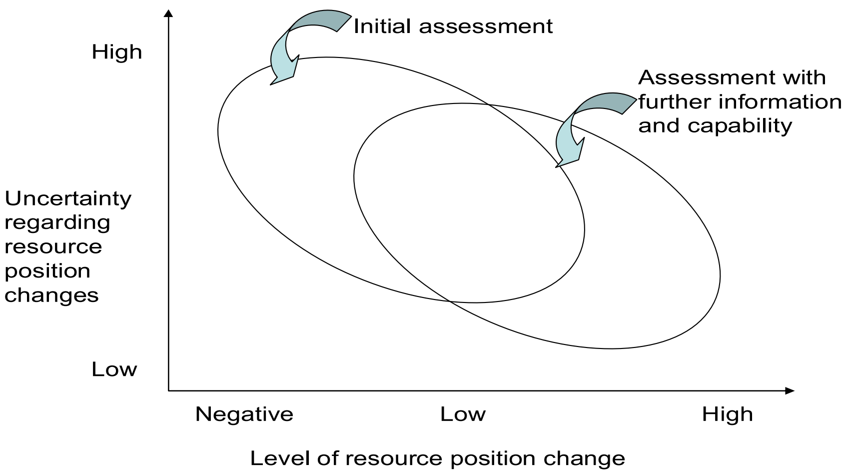




Many of the resources that are drawn on in commercialisation, both the dynamic capabilities used to solve problems and to guide and generate resources in the early stages and the more operational resources, may be external and accessed through contracts or collaborations. Teece (1997) provides a very useful systematic framework for assessing the strategic implications of alternative mechanisms for accessing complementary assets

SECTION 4: MODELLING UTILITY IN THE SELECTION ENVIRONMENT

Only through a path of increasing returns can capability development along any particular trajectory be sustainable. Each application 'project' changes the resource position of the firm. Most analyses focus on the generation of revenue (ie on additional financial resources). However, in the context of a generic technology other changes in the resource portfolio may be more important. As noted above experience generates information that may enable superior decision making, changing the assessment of options. Participation in the development of applications may also generate resources that are valuable in a strategic way, for example enhanced reputation or capability that attracts investment or partners[ii]. Hence, some changes may shift the threshold, leading to rebalancing of the portfolio of options.



The nature of the demand environment plays a significant role in innovations. Adner and Leventhal (2001, 2002), Adner (2004), (2002), and Adner and Zemsky (2005,2006a, 2006b) develop a *demand-based perspective* on the emergence of innovations which we use to model the selection environment. To develop the building blocks for our assessment framework we must first characterise the demand patterns of individual users. For much early stage commercialisation firms interact with users and not markets and hence aggregate market analysis is likely to be of limited value.

Users are *heterogeneous* in their willingness to pay for specific bundles of performance attributes. They have a *minimum functionality threshold,* related to their utility preferences. Users also have a *net utility threshold* which identifies the interaction of price and performance. The net utility reflects the highest price a user is willing to pay for a product which just meets their requirements. Users with the same minimum functionally threshold may have different net utility thresholds. Users exhibit *decreasing marginal utility*- as a user's requirements are exceeded their willingness to pay for subsequent improvements will become increasingly small to the point that a firm will be unable to extract any meaningful premium from further improvement (Christensen, 1997).

Hence, a *demand curve* characterises particular users' willingness to pay for performance improvements. The familiar technology S curve, shows the magnitude and rate of capability improvement in relation to the investment of effort or passage of time. The value of an innovation thus depends on the interaction of these two graphs at any particular point in time.

"At the early stages, before performance is sufficient to meet the threshold requirements, the issue of price is irrelevant; consumer evaluation is focused on performance for inclusion in the relevant choice set. As performance improves, consumer evaluation and the selection will shift to focus on the relative price to performance of competing offers in the choice set. With further technology development,

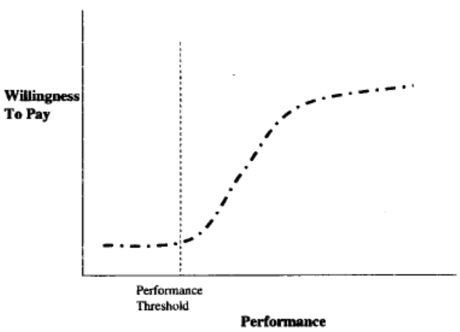
consumers performance are further exceeded, their willingness to pay for additional improvements is diminishing as a result of decreasing marginal utility and the basis of evaluation will shift to place an increasingly heavy emphasis on price" Adner (2004)

The interaction of the performance supply and user demand changes over the lifecycle of a coupling. There may be periods of *performance undersupply*, where the demand for performance exceeds the ability of the technology to supply. In this situation the competitive priority for the incumbent is continued investment in technology development. But the incumbent is vulnerable to two types of challenge. *Superior attacks from above* occur when an advanced technology with superior performance moves down the cost curve, becoming more affordable and can substitute for the established technology. *Emergent attacks from below* occur when a technology that was initially inferior surpasses the performance of the incumbent through more rapid performance improvement.

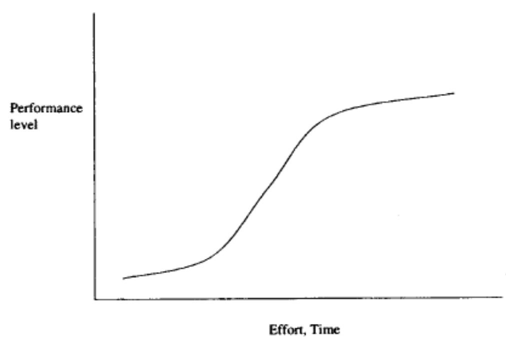
There may also be periods of *performance oversupply*, when demand matures before the technical performance. In this situation the competitive priorities for the incumbent are price reduction and continued product innovation - despite performance over supply with offerings at the same price point customers will choose the more advanced product. But the incumbent is vulnerable to a *'Christenson effect' or 'disruptive attack'* from a lower price, lower performing technology. In this situation the users willingness to pay is constrained by their decreasing valuation of performance improvements and technologies that are lower performing can satisfy the needs of some users and be rapidly adopted in their place.

We have identified three distinct competitive approaches that a challenger may use to attack an incumbent and steal their consumers, however further tools are needed to assess the likelihood successful invasion. *Preference overlap* is used to refer to the extent to which development activity and performance improvement that is valued in one segment is valued in another. *Preference Symmetry* refers to the symmetry of this overlap, the relative size of the functional shadows that the segments cast over one another. Depending on the nature and balance the preference overlap and symmetry three distinct competitive dynamics can occur.

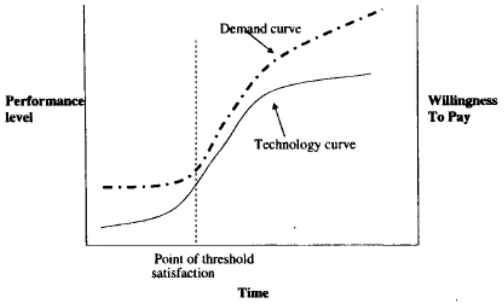
Competitive isolation, when technologies do not interact with each other occurs in conditions of low preference overlap where a partitioning of consumers occurs and each focuses exclusively on its own consumers. *Competitive convergence*, when two technologies evolve to compete head to head for the same consumer groups occurs when preference overlap is symmetric and each technologies development is directed towards expanding its appeal not only in its home consumer group but to its rivals as well. *Competitive disruption*, when one technology cedes dominance of its home market to its rival when segment preferences are asymmetric and one technological form maintains it dominance with its home consumer group while displacing its rival.



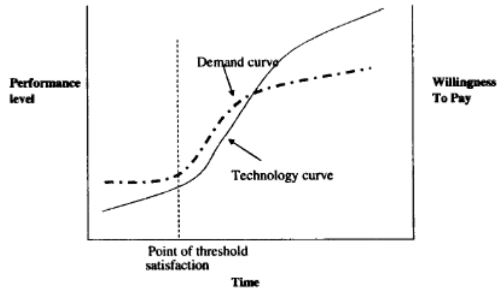
Demand S Curve (from Adner 2004)



Technology S Curve (from Adner 2004)



Technology Supply Matures before Demand (from Adner 2004)



Demand Matures before Technology Supply (from Adner 2004)

Invasion tactics

Given the competitive dynamics described in this section, products based on technical competencies can be introduced to different consumer groups at different levels of functional development and investments in product and process innovations can be made to successfully enter the initial market and then drive adjacent segment invasion. Investment in product innovations improves the performance and investments in process innovations can reduce the costs, depending on the segment being attacked relative investments can be prioritised to deliver the most appropriate proposition to consumers in the target segment. This approach helps with the building of a robust adaptive capability development plan which enables the exploitation of several capability-utility-leverage model couplings.

SECTION 5: IDENTIFYING A PATH OF MAXIMUM RESOURCE REUSE

The tool presented in this section is a decision framework designed to assist managers in technology capability intensive organisations to make better decisions about which opportunities they should pursue and how to sequence them. The previous sections explored the coupling challenge in detail and presented examined some deep theoretical models of the technology supply and demand environments b respected leaders. In this section, we seek to operationalise these models, by leveraging approaches from the robust adaptive planning literature to produce a usable tool for practitioners which helps to build a path through a series of opportunities.

The inherently high levels of uncertainty in this task mean the application of the framework is necessarily iterative and should be repeated as new information comes to hand. The benefits from its applications comes as much from identifying where effort to reduce uncertainty should be directed as facilitating robust decisions under conditions of deep uncertainty. In building the framework, we have sough to consider real world constraints and influences as much as possible, and whilst adding to the complexity of the framework, it also makes its results more applicable to real world situations.

The framework consists of a of steps, some which focus at the level of individual opportunities or capability-utility opportunities, others at a higher level, considering the relationship between opportunities and how their interactions could be beneficial. By working through these steps iteratively as new resources are developed better decisions about strategic technology investments can be made.

Stage 1: Capability Identification and Options Generation

As the matching process begins with an understanding of the capability, having a strong description of the capability is important, even if the capability is yet to be developed, it is often possible to describe the expected qualities of the capability in detail. The description should be independent of any proposed use.

Next identify the potential capability-utility combinations, a process which is necessarily a creative human task. It is important to realise that any human has a bounded set of experiences with a limited set of utility domains and therefore potential couplings, and the depth of knowledge about a utility situation can vary widely. Consequently it is important to consult as widely as possible amongst people with a wide range of experiences as often as possible in order to identify as many couplings as possible. The search for couplings is ongoing and iterative. Having identified the potential couplings, it is important to define these as narrowly as possible, where an coupling is to broad, it should be split and defined as two couplings

Whist identifying a systematic way of doing this is beyond the scope of this paper, we have identified several existing and new frameworks which can assist in the creative human process by structuring the cognitive search process. In testing the framework we used at least two approaches, one which identified existing technology 'analogues' with similar combinations of performance attributes and a second approach which viewed the technology as a 'bundle' of performance attributes, identified its more 'unusual' attributes and cognitively searched for situations where this new level of performance would 'unlock' an acknowledged problem.

Step 2: Characterising performance demand

For each coupling in the set, a demand curve should be constructed which describes the nature of demand for performance in that particular coupling. The zone of opportunity and recommended method of attack are the most important outcomes for the frameworks of the demand assessment process which was described in detail in the previous section. The zone of opportunity describes the performance combination a technology must reach to have any possibility of servicing this coupling.

By superimposing the demand curves of all the coupling in the set, we see which price to performance combinations fall within the fertile 'zones of opportunity' and which fall outside it. When an estimate of the unit demand for each of these zones of opportunity are added as a third dimensions, the zones become opportunity peaks which identify from a demand perspective, which price to performance combinations are most 'fertile' and therefore when effort should be directed.

Step 3: Characterising technology supply

Unfortunately, the actual performance capability of a technology is not unconstrained, technologies have fundamental limitations in the degrees to which they can be improved, and the dimensions along which this improvement can occur. And whilst difficult to estimate, the performance requirements for some applications will be clearly achievable, others will be clearly unachievable.

The foreseeable bounds on the performance capabilities and the technology and the limits to its cost reductions should be estimated and overlayed on the graph. Only the portions of the 'zones of opportunity' which fall between these bounds are actually serviceable. The purpose of this stage is too fold; firstly to constrain the set of possible couplings down to a set of realistically achievable couplings and secondly to identify the most 'fertile' technical trajectory where the densest cluster of performance attributes occurs.

Step3: Characterising market segment invasion potential and 'fertility'

Within this new set it is important to further analyse the forces which will enable or hinder capabilities developed in the service of one application to be transferred to another. In modelling demand, we introduced the concepts of preference overlay and preference symmetry which helped characterise the degree to which there would be incentive for a capability to invade across boundaries. It is important to consider the preference asymmetry between all the couplings in our new set, especially the ones that share similar performance requirements, as this will help define the natural direction of invasion between couplings.

Step 4: Identifying a path maximum resources reuse

Our approach calls for decision makers to 'chart a path' though fertile ground, where there is significant resource reuse along this path between couplings. This task calls for at least two distinct processes to occur, the first being an assessment, accounting and valuation of the technical and non technical resources that are both required and developed in coupling exploitation. The second is the identification and development of the dynamic capabilities necessarily to purposefully identify and acquire these resources.

Whilst the number couplings sequences are actually combinatorial, we are fortunate that the process of technical development significantly constrains the search space to a small number of potential paths through the 'fertile' coupling and that they are generally ordered according to the level of performance required except where there is significant potential for disruption. The potential technology development paths then act as anchor set, and it is by investigating the non technical resources requirements for each of these paths that we can further restrict the set of paths. As such, we deliberately distinguish between the 'technical' resources and non-technical resources when assessing couplings.

All paths must originate with the current development status, so it is important to accurately assess the current resources that are held. The issues of strategic intent should be considered in the assessment of the staring point because it will direct the resource allocation priorities and as such the 'fit' between the organisation and the path. The same approach to assessing the resources for couplings, described later should be used to characterise the resources held at the staring point.

Step 5: Identifying appropriate leverage models

Before it is possible to identify what resources will be both required and developed through the exploitation of the coupling, it is necessary to envisage what 'success' would look like, and in particular which leverage model is likely to best be suited to delivering value to the end customer. The term leverage model has been used through this paper, to describe the spectrum of leverage options that can be used to extract value from capabilities, from 'soft' models such as patent licensing to third parties, 'moderate' models such as contract component design and delivery through to the 'hard' 'business' models which involve speculate product development for uncommitted customers. It is necessary to identify which model is best for delivering value to the end user and servicing the coupling and is most compatible with the strategic intent of the organisation. Having identified a leverage model, it is possible to speculatively identify the resources that will be required and developed through the exploitation of the coupling opportunity and the potential for reuse between couplings.

Step 6: Categorising required resources

In order to assist in the structured identification and comparison of the resources required and generated through the exploitation of couplings, we have developed a resource categorisation scheme. We propose this preferred categorisation scheme as it splits the resources along boundaries which are influential on the degree of reuse. It is important to understand that resources differ in their reusability, some resources are easily reused whilst others are only available for one time use. This indicates that the 'cost' of acquiring a resource and its implicit ability to be reused should be important considerations when prioritizing the reuse of resources and hence selection of paths base on non technical criteria. Paths which effectively reuse the most expensive resources should be given highest priority.

We divide resources into tangible and intangible resources, tangible assets are by definition property of the firm. As tangible resources are a small portion of the assets of technology intensive businesses and most of the tangible resources are easily tradable for cash and relatively easy to replace we do not consider them significantly important. Except in the early stages of development, they are considered low priority for reuse.

We further divide intangible assets into relationships and knowledge. Relationships are bi-directional and held jointly by both parties and required continued mutual investment, they decay rapidly and are sunk costs, as such their reuse priority is high as reuse maintains the relationship and comes at very low incremental cost.

Knowledge can be held either internally by the firm or externally by other parties. Internal knowledge can generally be divided into codifiable knowledge and tacit knowledge. Internal codifiable knowledge is readily controlled by the firm, reusable, duplicatable, tradable, its reuse is important but also flexible giving it a medium resource reuse priority.

Internal tacit knowledge, the ‘know what’, ‘know how’, ‘know why’ and ‘know who’, ‘know where’ and ‘know when’ is very expensive to develop and as it is held by people, it is inherently hard to reuse despite notionally being held by the firm, thus careful assessment of this resources and how to reuse it should be given high priority due to the sunk costs and reuse difficulties.

External knowledge includes 3rd party knowledge of codifiable concepts such as product line, support information. This knowledge is held outside the firm, it is expensive and not reusable, meaning it has a low reuse priority. Tacit external knowledge in the form of reputation, or the perception of quality, reliability, trustworthiness and competence in businesses dealings, is expensive to develop and readily reusable, its reuse should be given a high reuse priority.

Step 7: Assessing the potential for resources resource reuse

Having defined a resource categorization scheme and prioritized their reuse, it is now possible to compare the resource reuse potential between couplings and make a more objective measurement of their ‘relatedness’ and the significance of the reuse potential between them. An objective way to define relatedness is to divide all the categorised resource into three groups, having exploited A, which resources are reusable in B, or having exploited B which resources are reusable in A and which resources are common to A and B. When each of these three groups is compared with other couplings it will be easier to judge which opportunities have a high degree of reuse which do not. When combined with the resource reuse prioritization scheme identified above, this gives a strong indication of which opportunities and in which sequence they should be ordered.

Step 8: Identify a path and the required Dynamic Capabilities

Based on the assessment of the required resources and the opportunities for reuse, propose a path of resource reuse through a series of applications. Having defined this path it is important to examine the classes of dynamic capabilities that will be required to deliberately to continuously and purposefully modify the resources base of the firm so as to drive the evolution of the firm along this path.

SECTION 6: CONCLUSION AND FURTHER RESEARCH

In the previous sections we have given several strong analytical tools for comparing the sequencing and degree of reuse and between multiple opportunities. And whilst we are unable to offer a systematic algorithm for weighing and then assessing these to produce a single ‘optimum’ resource reuse path, we have presented a well grounded set of tools for significantly constraining the search set.

The framework presented in this paper has been designed for use by organisations deeply embedded in the innovation coupling challenge and to operated within the constraints and of the ‘fog of uncertainty’ and the partial and incomplete information that this implies. By necessity, the application of this framework is iterative and ongoing and as the fog clears through the investment of effort the firms assessment of opportunities and sequencing of markets of target markets may change radically.

The benefit of using this tool are several, it helps to identify where current information is insufficient, develop a much better understanding of how opportunities relate and can be leveraged, avoid investment in opportunities that are unlikely to succeed, develop a much better understanding of the performance requirements applications and avoid investing in blind paths.

As indicated, the tool is most useful at the strategic choice stage, whilst the tool can still provide useful insight during execution, once committed as to the exploitation of an opportunity success of the exploitation is a stronger determinant of continued capability development then strategic choice.

Despite having extensively exploiting the strategic management literature in developing this framework, there are a number research questions and opportunities for using other areas of research to extend and further develop both our conceptual model of innovation as a coupling process and the opportunity assessment framework.

The impact of co-evolution, by the supply and demand environments dynamically interact in mutually reinforcing cycles has been deliberately avoided as although we consider this to be an important characteristic we were unable to find a sufficiently well developed way of modelling it.

It has also become apparent that our model, been inductively from the strategic management literature has many similarities to the models used in computational studies of complex adaptive systems (CAS) and we intend to investigate the origins and prospects for this similarity in the future.

NOTES

[1] This is an issue of particular importance in those contexts where there are few capable users. This is why operating in Pasteur's quadrant is as much about the overall capabilities of the innovation system

[11] Of course the resource changes may be negative reducing financial assets and diminishing reputations.

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