Innovation Dynamics in Follower Firms: process, product and proprietary technology for development

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Abstract

This paper analyses how firms organize for industrial innovation from a position significantly below being globally competitive. It investigates how follower firms can go beyond the boundaries assigned to them by their national environments and by the world's leading technology-driven firms. The paper reports on detailed case studies of how a range of successful firms in developing countries managed to break these boundaries to increase competitiveness through innovation.

Our key argument concerns the innovation dynamics of follower-firms. We argue that technology-followers approach the frontier with very different behaviour to that of leaders. We go on to report on a study of firms in less developed countries that have succeeded in moving up the value-chain. We construct and use a simple tool, based on resource-based theory, to map the alternative approaches taken by firms. It focuses on the relationship between process and product innovation and the nature of proprietary competencies. This allows the development of approaches to build technology strategies for innovation in LDC firms.

Introduction

To what extent can follower-firms in LDCs go beyond mostly subservient roles arising from their position in particular national environments and industrial sectors within particular global conditions? Are their positions and paths immutable or can firms change speed and trajectory?

Evidence is strong for the evolutionary thesis that existing position and path strongly determine the firm's possibilities for transformation (Teece and Pisano, 1994, Tidd et al, 1997). Firms need to build, absorb and embed a range of capabilities in order to survive and evolve. It is not easy for firms to transcend historically determined trajectories and change direction and speed (Nelson and Winter, 1977, Pavitt, 1990, Cohen and Levinthal, 1990).

Some models of business success assume that firms are capable of rapidly building capabilities where few exist. Although evolutionary theories of firm dynamics counter such notions of easy success, industrial development does depend on the notion that firms are capable of overcoming barriers to their growth and success. Industrial development remains at the heart of the development process. In the last decades, theories of industrial development have moved from those focused on infant industrial protection and local markets to those based on increasing global competitiveness either via low wages or innovative niches (for example, in mass consumer electronics and software) or if possible both (Wade, 1990).

At the same time, the concept of industrial innovation has also changed from straightforward application of science models (linear) to more complex conceptualizations involving networks and flexibility (Gibbons et al, 1994, Morosini, 2004).

This paper argues, with multiple case study evidence, that follower firms can innovate to improve their competitiveness. We present cases of firms that have moved to industrial leadership positions and firms that have succeeded in changing trajectory and speed (see table 1 for a list of firms and sectors studied). The data we analyze confirm and extend the idea that innovation dynamics in LDC follower-firms may differ from present innovation models and provide understanding, using mapping approaches, of the various routes within which a firm can evolve.

The data for this study have been collected over around ten years (Table 1). Data on most firms were collected from 1996-2001 for a series of projects that culminated in a book (Forbes and Wield, 2002). Data came from primary and secondary sources. We wish to acknowledge Aparajita Zutschi who helped collect the interview and secondary data in Indian firms and Cristina Casanueve for sharing her data on

Mexican firms. These data were added to in 2004 and 2005, including through the doctoral research of Dinar Kale on the Indian pharmaceutical industry. Some of the firm-level data was collected by sector, and some during studies of firms that were pro-actively thinking and practicing new approaches to industrial innovation, broadly defined. Data have been selected to allow illustration and development of evidence for the arguments and maps.

Table 1 Firms studied

Firm	Country	Sector	Reference
Tanzania Breweries	Tanzania	Beer	Semboja and Kweka, 1997, Forbes and Wield (F&W), 2002
South African Breweries	South Africa	Beer	F&W, 2002
Samsung	Korea	Electronics	Hobday, 1990, 1995
Infosys	India	Software	F&W, 2002
Ranbaxy	India	Pharma	F&W, 2002, Kale, 2004, Kale and Wield, 2006
Vitro	Mexico	Glass	Casanueve, 2001
Reliance	India	Chemicals	F&W, 2002, updated 2006
Bajaj	India	Auto	F&W, 2002, updated 2006
Titan	India	Watch	F&W, 2002, updated 2006
Cemex	Mexico	Cement	Casanueve, 2000,
Mittal Steel	India/UK	Steel	F&W, 2002, updated 2006
Hero	India	Bicycles	F&W, 2002
Indian pharma	India	Pharmaceuticals	Kale, 2004 Kale and Wield, 2006
Indian software	India	Sotware	F&W, 2002 Athreye, 2005

Innovation dynamics in follower firms

To say ‘industrialization has never been easy’ is an extraordinarily naïve understatement. All successful late industrializing countries have had the benefit either of a large and rapidly expanding local market or of infant industry protection, and usually both (Gershenkron, 1962, Wade, 1990). But late industrializers have tended to grow up relatively quickly in comparison to previous industrializers, at least in some key sectors. What is not clear is how long the protection period for infant industry should be. Wade suggests that protection requires to be integrated into a coherent industrial policy:

> ‘There are indeed many cases where protection has not had any noticeable innovation - or investment enhancing effect (eg India). This reflects the failure to integrate protection with a wider industrial policy, or link it to export performance, or make the quid pro quo conditions credible, or to maintain macroeconomic stability. If protected producers know that in the foreseeable future protection will be much reduced or that government will pressure them to enter export markets, then protection may give them breathing space in which to undertake the necessary investment and innovation’ (Wade p 359).

However, he goes on:

> ‘Import protection is, as neoclassical theory says, a powerful tool. Like any powerful tool it can be badly used producing a trade regime full of inconsistencies … But that is not the end of the story. The East Asian evidence suggests that protection can also be used in combination with other measures to foster the creation of internationally competitive industries’ (Wade p 361).

Thus infant industry establishment is more than import-substituting industrialization since the aim is the establishment of internationally competitive industries, not the substitution of local for foreign production.

Export orientation is also associated with state-led policies to strengthen industrial development. Exporting has several benefits for firms. Competing with international best practice forces firms to provide value for money. Serving larger markets allows firms to operate at international scale. The key benefit for East Asian firms was learning by exporting. Selling in export markets was a disciplining tool that focused local technological effort on making firms internally efficient and pushing them up the product value-chain as local wages rose.

So, follower firms in follower countries were able to learn how to build capabilities for innovation that allowed significant industrialization. What does that mean for innovation?

There are many models of industrial innovation. Rothwell attempted to group them into five generations. The earliest, technology-push, made R&D the starting point, the resulting idea gradually becoming marketable innovations in firms with heyday in the 1950s and 1960s. Then, market pull theory, from the 60s and 70s, emphasized the key role of markets in pulling innovations. Both 'models' are firmly within the linear model school which held sway in policy circles until the 1980s and beyond.

Rothwell's locates his third, 'coupling' model, in the 1970s and 80s. It attempted to take on board 'real-life' feedback loops and complexity identified in the by then extensive research into innovation in firms. Rothwell identified two further variants. 'Integrated' models (1980s), such as that of Kline and Rosenberg (1986), which modeled the parallel development of product development teams and linkage with users, and finally, 'systems integration and networking' models (post 1990). All three latter models take account of complexity, and are close to more theorized notions of Faulkner (1994), Gibbons et al (1994) and Nowotny et al (2001).

Hobday's review of firm level innovation (2005*)* both praises and critiques these models. There is praise for capture of the academic knowledge and best practices of the time. The critique is perhaps of over-rationality and not taking account of the extreme variety of firm innovation behaviour.

Important for the focus of this paper, however, is that none of these 'models' 'attempts to deal with the issue of latecomer catch up from behind the technology frontier' (p 129). The five models do not integrate any empirical evidence from follower-firms, rather taking their lead from big R&D-rich firms with formal R&D units, in countries with massive science and technology infrastructure, using the concept of 'innovate' to mean first in the world.

Crucially however, industrial and technology policy for LDCs did take account of the thinking in each age. Linear approaches influenced their actions in early periods, with investment in science in the hope of eventual application. More recently, they have, to some extent, taken account of complexity, systemic and networks approaches in some circumstances, such as in cluster strategies. But such changes have taken place only very recently indeed, if at all, in many LDCs.

Concerning this paper's focus on innovation dynamics of firms, there is very little to guide follower firms in LDCs. There are exceptions. Hobday is one, together with a group of Korean academics (Kim, 1997, Lee et al, 1988 Lee and Lim, 2001). Particularly, Kim argued, with evidence, that the process of innovation in catching up countries is fundamentally different from that of developing countries. Others have taken up these new ideas (for example Ernst et al, 1998, Kaplinsky, 1995) Although our argument appears to hold best for the NICs of East amd SE Asia and for the more industrially advanced LDCs such as India and Brazil, maybe even Russia and East and Central Europe, there are examples of interesting firm level innovation dynamics everywhere in rather inauspicious environments (Kaplinsky in Zimbabwe, 1994, Hewitt et al in Tanzania, 1997, Oyelaran-Oyeyinka, 2004, 2006 in Nigeria and other African countries).

Even fewer studies have delved into the complexities of industrial policy, though Wade is a major exception and Evans manages brilliantly to summarize the key elements with respect to national policy environments.

In this paper we build on these authors, using our studies of firms in developing countries, using a simple mapping tool. Our approach has been to construct a means of mapping a firm's position (its current assets and capabilities) and path/trajectory (where the firm has come from and where it might head). The tool was developed using resource-based theories of innovation – such as the work of Penrose (1959, 1995) on firm growth, Teece et al (1997) and others (for example Winter, 2002, Eisenhardt and Martin, 2000) on dynamic capabilities, Marsh (1989) on the distinction between exploitation and exploration in organizational learning, together with the synthetic work of Tidd et al (1997).

In brief, a firm's competitive advantage is shaped by its assets and resources. Some firms studied built distinctive proprietary assets. Assets are not primarily fixed assets like plant and equipment, but knowledge assets that are unique to each firm (Teece et al, 1997). Such assets include: technological assets, including both those that can be protected with intellectual property rights, and also the tacit knowledge that often determines a firm's competitiveness; complementary assets, which include brand, marketing, distribution, after-sales systems and financial resources; institutional assets, including the public policy environment within which the firm operates, and the national innovation system within which it innovates; locational assets, such as proximity to attractive markets and being part of a dynamic industrial cluster; and, reputational assets, the image that others hold about a firm which is key to how it is seen in the outside world,

A firm's capabilities (or competencies) determine the effective use of its assets - its resources and knowledge. Capabilities include skills and functional competencies that allow the firm to take advantage of opportunities. They are the mix of skills and organizational routines and processes used to produce, to improve production, and to introduce new products and processes. Core competencies (Prahalad and Hamel,

1990) are unique to the firm. Although the concept was initially restricted to technology, we use it more broadly - indeed, in a follower, the core competencies will tend not to be leading edge technological. For Samsung, the Korean electronics firm, the move from original equipment manufacture to higher technology products, to own design manufacture and to own proprietary equipment manufacture involved building a strong engineering product design capability that cross-cut different types of product. In particular, it demonstrated its ability to produce prototypes and deliver product in record time. Process industry cases we studied, like the Indian chemicals company Reliance and Korean Iron and Steel firm Posco, ability to complete plants before schedule and operate over-capacity is core to their success. Another firm, Mittal Steel's, core competence is the ability to turn poorly managed plants into efficient low cost producers and spread best-practice rapidly around the group.

At any point in time the sum total of a firm's assets and capabilities define its position. A firm's future direction is shaped to a great extent by its current position. Present position is itself shaped by past trajectory, and the path taken brings opportunities for and constraints on future trajectory. That is, the firm's existing routines constrain future behaviour. Firms, if they are to innovate, must build the capabilities to explore future opportunities (Marsh, 1989) and make choices about both what to do and what not to do. The essence of strategy is choice. Although position and trajectory constrain firm choice, choice ultimately determines which direction the firm takes.

We took these concepts - assets, capabilities, position, path, and choice - to develop the mapping tool to observe the innovation processes and practices of firms that have succeeded in moving from followers towards becoming leaders.

These strategic concepts can be applied to the process-product-proprietary map we developed (figure 1). The map grid shows the firm's current position, and the path it followed to get there. Where it goes from here will be constrained by its current assets, capabilities and choices. Indeed, the firm can continue to be successful, at least in the short-term, within the same quadrant. But jumping quadrants requires choice, and the will to change position.

So, to summarise, in an attempt to use innovation models but also to go beyond their universalist style, we take a firm-level approach to mapping position and path. In this way, we try to integrate the notion that firms are unique and that there is a high variability in firm behaviour. We test our approach with a set of case studies [1].

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[1] The case study firms and sectors were chosen (Table 1) from a large set of cases, some undertaken with primary interview data (with senior managers including R&D managers) integrated with relevant secondary source data from publications. Some were undertaken by other researchers. Development of the process-product-proprietary map involved two activities. Thinking about the key concepts: assets,

Process, product and proprietary

Successful technology follower-firms tend to break the rules of classic industrial innovation models. They begin with process rather than product innovation. They enter international markets by competing through manufacturing, and process innovation is thus crucial. Evidence is now strong that in the early stages of catch-up efforts, innovation needs to concentrate on the shop floor and focus on changing operational systems and structures in a down-to-earth 'hard slog' way . Manufacturing innovation is key. The classic entry point to competitiveness is wage competitiveness and incremental shop floor innovation - the 'new manufacturing' made famous by Japanese firms and then taken up by others, especially in East and SE Asia. There are basic rules, such as adopting these manufacturing techniques and systems, but there are many ways of innovating on the shop floor. This form of process innovation is not straightforward at all. Kaplinsky (1994) chronicled its uneven implementation in pre-collapse Zimbabwe and, with Humphrey (Humphrey et al, 1998) in India. But the hard slog of improving process capabilities is essential for catch-up firms if value is to be added via innovation.

The relationship between process and product innovation is not simple - one (process) giving way to another (product). Unity between them is often crucial to move up the value-chain – many examples exist where new products were designed to improve the manufacturing process just as the manufacturing process must often be changed to improve the product. Riggs argued that the Japanese industrial 'miracle' through the mid-1970s was built around process innovation and incremental product innovation (Riggs, 1988). Another well-known example of the unity of product and process is the innovation in Hewlett-Packard's Singapore subsidiary that reduced the manufacturing cost of the HP41C calculator by 50% by redesigning the product to use fewer components. Thus, products can be changed to improve the manufacturing process, just as the manufacturing process can be changed to improve the product.

To develop distinctive capabilities in either or both process or product innovation another dimension is needed: proprietary capability. Proprietary capability comes from knowledge that is distinctive to the firm. In some cases, this proprietary capability takes the form of intellectual property formally owned by the firm: patents, trade-marks, designs, copyright. In other cases, the intellectual property may not be formally protected through intellectual property rights (IPR) - much mechanical

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capabilities, position, path and choice. And also by comparison with other strategic mapping techniques (eg Huff and Jenkins, 2001).

engineering know-how for example, is the sum of tacit knowledge spread among the firm's employees and routines (Patel and Pavitt, 1994). This knowledge is rarely IPR protected but is definitely proprietary to the firm: it often forms the core of the firm's competencies. Proprietary knowledge can also take the form of management capabilities, or widespread and distinctive knowledge in the heads of a large sales force. Proprietary knowledge works when it permits the firm to stay ahead of competitors. It is possible, then, to think of a proprietary dimension to a process/product map (see figure 1). It allows us to map the transformations of firms as they add value by building their assets and capabilities.

Process innovation plus - one quadrant innovation

Most technology-followers then, start competing internationally in the non-proprietary/process quadrant of our map. At the beginning of the 1990s Tanzania Breweries had been performing badly. Productivity had stagnated for well over a decade. In 1993, it was privatized and bought by South African Breweries (Forbes and Wield, 2002). In the next six years productivity rose six times, to more than the norm for South African Breweries subsidiaries around the world. At that point, it could be mapped as within the first quadrant of the grid (fig 1). Although product development has been weak so far, focused on variants of its main brand (Safari), it has invested in R&D to improve local hybrid barleys. But it has dramatically improved processes, invested in developing national standards and quality not only for its own products but for local glass, bottle tops, labels and sugar production. Its energy efficiency and water utilization are close to globally competitive standards (figure 2).

To explore further the issues of process, product and proprietary manufacture, we use the case of the East Asian Miracle firm (see Table 2). Hobday (1995, 2000) showed the importance of original equipment manufacture (OEM) – local manufacture to the specifications of multinational companies – as a means of building innovative capabilities within the firm. Firms like Acer and Samsung learned to improve manufacture under OEM conditions, whilst the transnational firm buyers of their goods designed, branded and distributed the products they made. Hobday chronicled the gradual transition from learning to produce; learning to produce efficiently; improvement of production then improvement of products - their performance and specification. This led in some cases to Own Design Manufacture (ODM), with local firms designing or partly designing and thus learning product innovation capabilities and gaining related knowledge assets. Some manufacturers have developed to become Own Brand Manufacturers (OBM).

By the late 1980s Acer was one of the three largest PC producers in the world. Samsung has been one of the two biggest microwave oven producers since 1989. At the beginning these ovens were made by Samsung in Korea with much design from GE. By 1990, the brand was still GE but with Samsung design. From the late 1990s there have many varieties of own brand Samsung ovens. The OEM phase took the firms from process towards product innovation (see fig 2).

Figure 1 process-product-proprietary map

Product	Product – Non proprietary quadrant	Product – proprietary quadrant
Process	Process – non – proprietary quadrant	Process – proprietary quadrant
Non-Proprietary		Proprietary

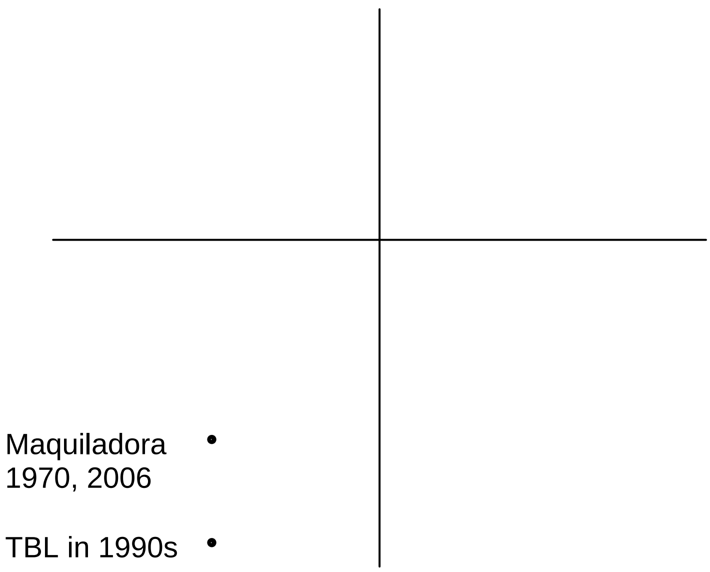


Figure 2 Hard slog – firms that add value within one quadrant

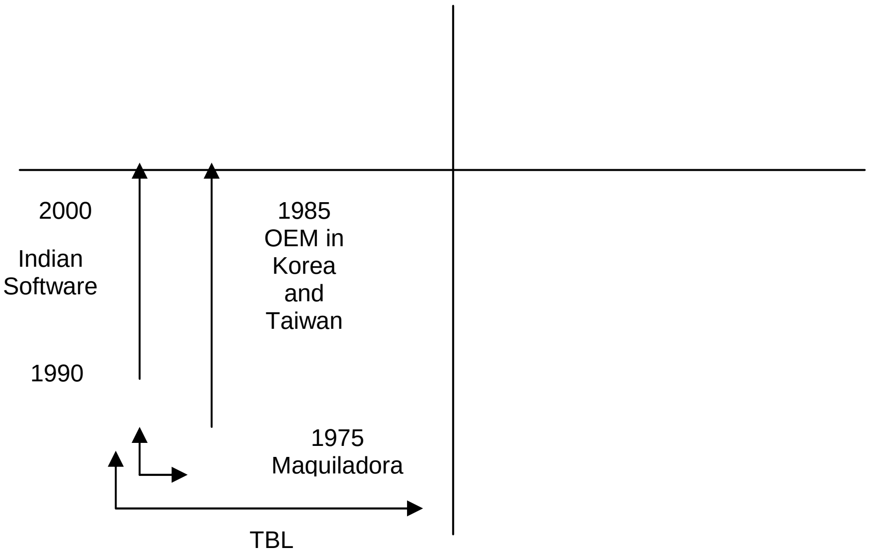


Table 2 Technological and market transition

	Technological transition	Market transition
1960s/70s Original equipment manufacture - OEM	Local firm learns assembly process for standard, simple goods	Foreign transnational corporation (TNC)/buyer designs, brands and distributes
1980s Original design manufacture – ODM	Local firm designs (or contributes to design, alone or in partnership with foreign company), and learns product innovation skills	TNC buys, brands and distributes. 'TNC gains post production value added
1990s Original Brand manufacture – OBM	Local firm designs and conducts R&D for new products	Local firm organizes, distributes, uses own brand names, and captures post production value added

Source: Table 5.1 from Hobday (2000) in Kim, L and Nelson, RR.

Firms in the Mexican maquiladora programme illustrate a dramatically different strategy –they are internationally wage competitive, but have, by and large, made little effort to move from wage competitiveness to process, product or proprietary manufacturing innovation. These firms have succeeded in growing, employing 1.4 million people in 3,800 factories by the year 2000 (Buitelaar and Perez, 2000). They are clearly internationally competitive - their very existence depends on duty free imports and 100% exports. In their export orientation, the maquiladoras were remarkably similar to the Original Equipment Manufacture (OEM) suppliers of East Asia, where firms began by making products to the specification of technology-leading firms in the US, Japan and Europe. Indeed, items like toasters and TV sets were often dual-sourced from a maquiladora and an East Asian firm at the same time. Subsequently, development was very different. While both started with low value-added assembly based on low labour cost, the East Asian Miracle firm moved up the learning hierarchy. Maquiladoras started with low-wage assembly and stayed with low-wage assembly. The maquila firms, in their vast majority, learned to produce efficiently based on low labour costs, and stayed with those capabilities. There has been relatively little technological deepening and deepening of local value-added, no development of assets or capabilities for innovation.

Samstad and Pipkin (2005) use data from Carrillo and Hualde (1997) that separate maquila firms into generations: the first generation is intensified manual work; the second, more rational work systems involving Total Quality Management, Just-in-Time and so on. They only found a handful of third generation firms - using design and some R&D to add value. The weak transformation of maquiladoras is illustrated in figure 2 with short lines. Samstad and Pipkin report that second generation firms had survived the recent downturn better than first generation ones.

Another example of single quadrant innovation is the development of the Indian software industry as its built capabilities in product service development. Indian software firms made investments in organizational capability but also coupled that with an exploration of higher value-adding business models – offshore whole project capabilities for robust delivery of failsafe information systems (Athreye, 2005).

To summarise, firms can make significant movement within a single quadrant - the process/non-proprietary quadrant (figure 2). Korean and Taiwanese firms in the late 80s moved rapidly to producing more sophisticated products within the same OEM arrangements. Indian software firms have moved towards higher value services but not proprietary products, but some leading companies are now attempting to go 'proprietary' in services. Narayana Murthy, Infosys Chairman talks of creating a 'service brand'. TBL has developed process capabilities much more than product capabilities.

So far in our innovation narrative, even with hard slog and big improvements, firms have innovated only within one of our four quadrants. Such movement, however, cannot be dismissed and treated as minor. It requires massive commitment and is the base on which to innovate further.

Moving quadrant - from process to product and proprietary

Innovating firms can move beyond the first quadrant. Moving up the value chain means capturing innovation rents via product innovation, or by building proprietary capabilities, or both. Crossing the quadrant boundaries requires that firms build new assets and capabilities. Building these new capabilities is hard and firms may need strong will to abandon capabilities which have worked well in the past. These moves require the entrepreneurial skills to articulate a vision of the future and the will to make it happen.

In theory, moving quadrants can happen in one of five ways (figure 3).

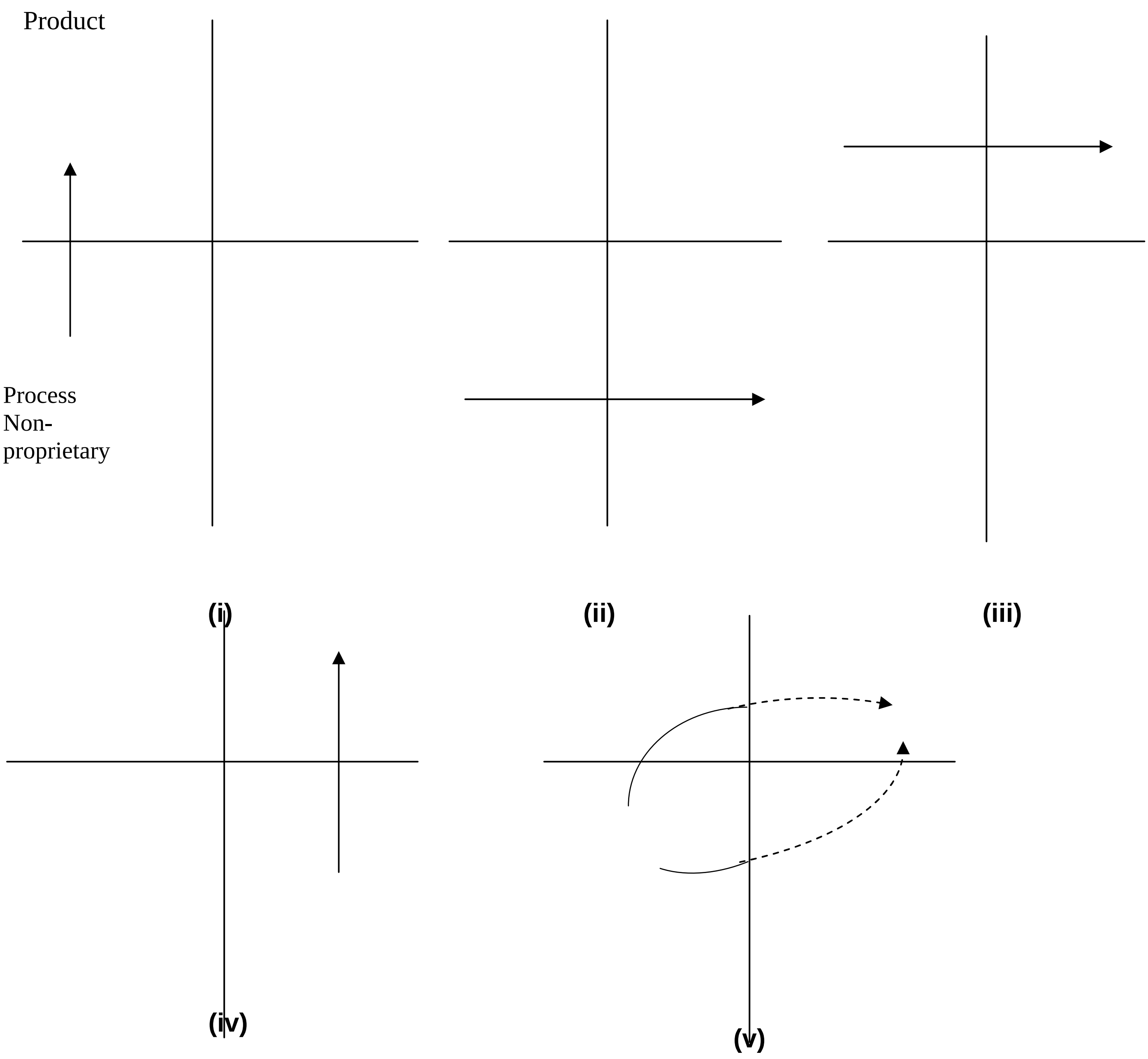
After adding value within OEM, between the early and late 80s East Asian Miracle firms moved from OEM to ODM in the 1980s, that is – in our map – moved from non-proprietary process innovation to non-proprietary product innovation (figure 3i). Such a move in microwaves and computers was much harder than in garments, and produced much higher value-added. Making this move involved winning over the buyer to the idea of the local firm doing design tasks and required local design and engineering skills acceptable to buyers. New designs were essentially detailed designs done within some East Asian firms to a concept provided by the OEM customer. For example, a customer might ask for a larger or more powerful oven to be designed by Samsung.

The Indian bicycle firm Hero Cycles is an example of a firm that has moved towards specialized, more design conscious, higher value-added bicycle products. But it only has recently started its journey towards more proprietary products.

The other four options for firms involve the even tougher choice of moving towards proprietary innovation, whether through formal IPR and so on, or via tacit knowledge.

The Indian firm Reliance (figure 3ii) developed the capabilities to move its process skills to proprietary process innovation. It first invested in plant capacity that was ahead of market demand, running these plants at efficiency levels that set international bench-marks. It then developed its own proprietary process technologies that further added value

Figure 3 Moving up the value-chain (i) to (v)



Korean and Taiwanese firms, as they moved from ODM to OBM (figure 3iii), moved their product innovation capabilities towards proprietary, after adding value within OEM (figure 2) and Own Design Manufacture (figure 3i)[2]. Some firms had also been successful selling products in their own name in their domestic market. With globally efficient manufacturing plants and demonstrated independent new product development capability, they then moved to OBM, and introduced their own brand internationally.

The Mexican cement firm Cemex demonstrates another transition (figure 3iv), as it moved from a globally-leading manufacturing process operation to the development of new proprietary products, such as extreme temperature cement. Cemex has become one of the largest cement companies in the world, principally by building market share and ensuring a very high level of customer service, buying low performance firms and turning them round via massive efficiency savings and improved customer service, such as delivery guarantees as short as within 20 minutes of scheduled times. Its move to product innovation including investment in an R&D lab that developed extreme weather cements.

Finally, figure 3v represents the most difficult move up the value-chain as the firm attempts (hence the dotted line) to move directly to its own international brand, as India's largest digital watch maker Titan has tried. Titan grew through design and releases an average of one hundred new designs a year. In the late 1990s Titan entered the European watch market. Mexican glass maker Vitro, too, has moved quite rapidly towards new and proprietary products, through both process and product innovation, though the competition is tough in its core business of glass containers.

Innovation dynamics – capabilities for moving quadrants

A small proportion of follower firms have succeeded in building sufficient technological capabilities for proprietary innovation. In this section we use case study data to consider how firms go proprietary in process and product innovation, use design capabilities, and the different role of R&D in follower firms.

[2] Our map simplifies the complexity of transformation. See Ernst et al, 1998, for a more detailed analysis of the transitions.

Going proprietary through process innovation

Some firms in developing countries have been impressive process innovation-led followers. Particularly in process industries such as steel, petrochemicals and cement, a striking feature of the last twenty years has been the emergence of world-leading firms. Reliance, for example, has developed proprietary technology through process innovation. Many Indian companies were forced to restructure working practices to survive the economic liberalization reforms, but Reliance has benchmarked itself against the best internationally for nearly 20 years, well before the Indian economy opened up, with a practice of building global-scale manufacturing facilities well before there was any economic imperative to do so.

In 2000, Reliance was the largest Indian private company for both profit and sales (Forbes, 2002). Over 1991-2000 profits multiplied nineteen times. Having started as a small textile concern in the late 1960s, Reliance is today a fully vertically integrated petrochemical firm. It ranges between the first and tenth positions in global volumes in its various businesses. In the mid-90s, it was the world's largest integrated PET producer, the second largest producer of paraxylene and third in the production of purified terephthalic acid (PTA).

Reliance has long built global-scale manufacturing plants. In the 1980s, Reliance built a polyester plant with an annual capacity of 40,000 tons, equivalent to India's entire annual consumption at that time. In 1997, Reliance commissioned the world's largest single-stream ethylene cracker.

These world-class plants have been built in record time. Reliance's first backward integration project in polyester yarn and fibre was completed in 17 months against a global standard of 26 months. For a PVC plant, Reliance took 24 months for project completion, three months below the global standard.

Reliance is also among the most vertically integrated companies globally. In polyester, value-addition from naphtha to final fabric is 7,000 per cent, providing significant raw material, freight and handling savings. Reliance practises what it calls sweat technology to consistently operate plants at over 100 per cent of capacity. Major savings have come from repeated de-bottlenecking of processes. For example, engineers at a plant manufacturing polyester yarn at 100 per cent capacity realized the main reactor had the capacity to take in more air. Investment in a new compressor increased capacity significantly at one-fifth the cost of a new plant. Sweat technology allows Reliance to push volumes and maintain margins; its profit margin of 19 per cent has been well above the 14 per cent of its leading global competitors Du Pont and ICI.

From its demonstrated mastery of shop-floor innovation, Reliance now focuses on developing new technologies. The catalysis group in Reliance's research division is developing 'green technologies'. A joint technology development with National Chemical Laboratories (NCL) in Pune involved a novel non-polluting zeolite-based catalyst for manufacturing linear alkyl benzene being tested at Reliance's polyester yarn and fibre plant.

Reliance's global scale and ambition sets it apart from its Indian counterparts. International consultants and financial analysts routinely rank Reliance among the top ten Asian firms. There is, however, a qualification. Reliance's success has come from dominating the domestic market. As India's petrochemicals sector liberalizes, Reliance will for the first time have to face foreign rivals on an increasingly level playing field.

Mittal Steel group is today top ranked in the global steel industry. It has plants around the world including the US, Canada, Mexico, Germany, Poland, Kazakhstan, South Africa and Indonesia. Mittal's success comes from a number of factors, with acquisitions accounting for the majority of its growth. It has a tradition of taking over under performing units around the world and turning them into some of the lowest cost producers in its field. This is in part achieved through greater capacity utilization.

Cost control is possibly the most important success factor. Since 1998, Mittal has reduced costs in all operating subsidiaries. Financial analysts rank Mittal among the lowest cost steel producers in the world today. Its technological vision shows in the shift from traditional blast furnaces to directly reduced iron and more efficient mini-mills. R&D is important to the company at a time when many steel plants around the world are downsizing R&D budgets. The R&D centre in Chicago is being expanded and converted into a global resource centre for the group and the French R&D Centre focuses on product development. The US centre holds patents in steel-making processes and steel products. The centre has also undertaken product development with several US auto-makers, including Ford. For Honda, a total of five new products help reduce the weight of its cars and improve fuel economy. A new steel was developed for Toyota, which will lead to more dent resistant outer body panels.

With global benchmarking for everything it does, Mittal is a global steel company. Cemex, the Mexican HQed multinational cement producer, is also a world leading firm that was recently a follower-firm.

Each of these three firms licenses international technology when it needs it, then improves it further, leading to the building of proprietary assets and competencies. In Reliance and Cemex, each firm has emerged as a world-leader built around dominance in its own, protected, home-market. All firms move rapidly up the value-chain by innovating in process innovation. Each firm represents what it takes to be good at process innovation - spreading best practice quickly around the group; rapid project execution; constant incremental innovation.

These firms permit us to illustrate more clearly what we mean by proprietary through process innovation: the firms each 'own' assets and competencies that are distinctive relative to competitors (table 3). It is not the particular assets or competencies that these firms own that matters as much as the fact that they add up to a distinct and difficult to duplicate capability that is a basis for future competitiveness and therefore proprietary.

Table 3 Proprietary assets and capabilities of Reliance, Cemex and Mittal

Firm	Proprietary Assets	Proprietary Competencies
Reliance	Vertically integrated petrochemical complexes. World-scale manufacturing plants - largest single-stream ethylene cracker in the world. Degree of vertical integration among the highest in the world- translates into significant cost savings	Project execution capability- builds global-scale plants in record time. Over-utilization of capacity a regular feature of all plants- translates into ability to maintain globally comparable operating ratios even in slack periods.
Cemex	500 plants in 30 countries with over half of assets outside Mexico. Marketing operations in 60 nations. Highly profitable dominant market position in Mexico and Venezuela.	Moved from 28th to 2nd position in the cement industry in the last decade. Ability to maintain the highest OPM in the industry. Provides a delivery guarantee to customers building itself a strong brand value. Aims to complete its global supply chain initiative by 2001. Demonstrated ability to develop new products and services – eg. cement for extreme temperatures and the one-hour delivery window
Mittal	Manufacturing facilities in sixteen countries and a customer base in 150 countries. Many assets acquired at prices much below replacement cost. Biggest and most globalized producer in the world steel industry.	Ability to turn around poorly managed plants into efficient low cost units- achieving some of the lowest costs per ton for certain kinds of steel. One of the pioneers in the cost-efficient DRI and meltshop technology. Ability to spread best practices world-wide.

Going proprietary through product innovation

In many industries, at some point the ability to add value through process innovation reaches limits, and there is a move towards product innovation. As Lundvall puts it: 'What seems to characterise both Japan and the Asian Tiger economies – as compared with other less successful developing economies – is that they have moved massively into new product areas where it was far from obvious that they had an original comparative advantage' (Lundvall, 2000, p100).

For example, since 1991, as India's economy has opened up, firms there have been forced to make processes more efficient to survive. New manufacturing methods have been introduced, and manufacturing efficiency has risen significantly. But change at the product-end has often come through selling out to foreign firms or by licensing new product technology, which has become more difficult. Only in some exceptional cases has change at the product end come in the form of investment in R&D and building proprietary product development capability aimed at the international market. Indian attempts at product innovation are Bajaj Auto and Titan Watch.

Titan is India's largest digital watch company. Titan entered the Indian watch market in 1987, and in five years had become the leading Indian watch firm, mainly through design. The watch movement was imported for many years, though Titan now makes its own and is one of just six global watch manufacturers that are completely integrated. It benchmarks all parts of its value-chain, including its after-sales service. It has consistently been awarded brand prizes and Designer of the Year awards. Titan releases an average of 100 new designs a year and now has a total of 1,600 designs. Middle-class Indians went from wearing a smuggled Japanese watch to wearing a Titan, and the watch went from solely utilitarian to a multiply-owned fashion accessory. In the late 90s, Titan entered the European watch market, attempting to establish its own brand in secondary markets, in Europe and the Middle East. In 2005 it had 60% of the Indian market and exported to thirty countries.

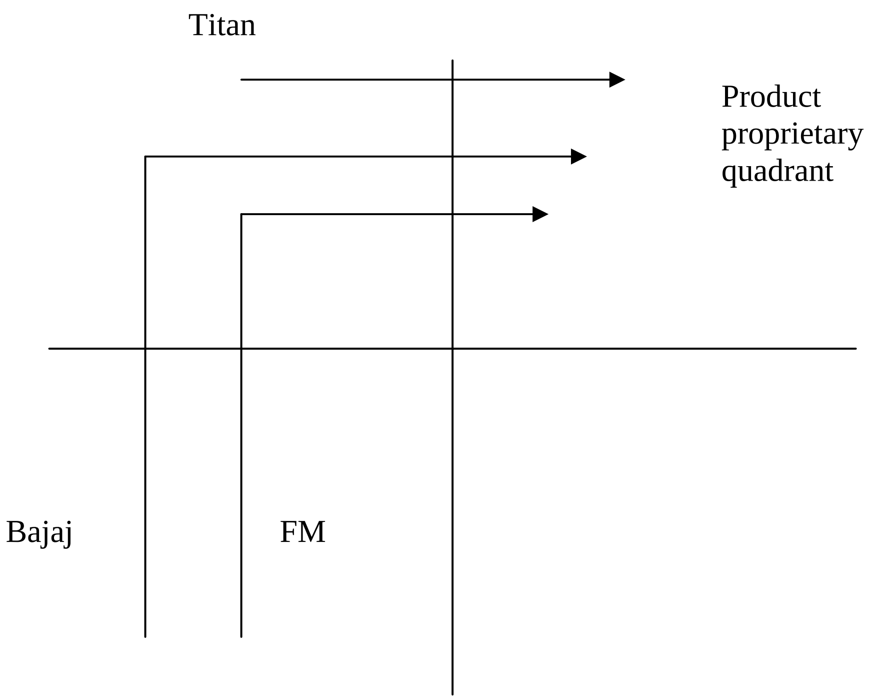
Bajaj Auto (BAL) is India's largest two-wheeler manufacturer and the third largest two-wheeler manufacturer in the world. It licensed scooter technology from Piaggio in the 1960s, and then continued to make essentially the same model, with cosmetic changes. Bajaj claims to be the world's lowest cost two-wheeler manufacturer, and has demonstrated its ability to innovate considerably in making its manufacturing process more efficient. The Indian market has moved away from scooters to motor-cycles, where BAL was second to Hero Honda and BAL saw its market share fall. The pressures forced BAL to invest heavily in product development in the late 90s, through both technology licensing and in-house development. As the President of

BAL put it, 'after eighteen years with one model, BAL released eighteen models in eighteen months'.

Moving to product innovation - building design capabilities

Design provides the potential to innovate in products without pushing out the technology frontier). Firms have invested in design capabilities in different ways to move up the value-chain. Titan began as a product innovation based firm, has strong design capabilities, and is now developing proprietary products - it is selling internationally through its own brand (figure 4). Bajaj is developing a steady stream of new products after decades of variants on a single model. In motor-cycles, it has gone from licensing new designs from Kawasaki to undertaking joint design and development of new products. Bajaj set up an assembly plant in Brazil to enter the market with a Kawasaki-branded (but Bajaj-Kawasaki designed and owned) motorcycle. In scooters, Bajaj bought technology for new engines and shapes from various sources to integrate into a range of proprietary new designs. Exports, very limited in 2000, have increased six-fold to almost 200,000 machines (12% of value) in 2004-5. It has a dominant presence in two-wheelers in Mexico, Columbia, Peru, Iran and Indonesia, as well as Bangladesh and Sri Lanka.

Fig 4 Building design capabilities to add value



Moving to proprietary – special role for R&D

We have shown (Forbes and Wield 2000, 2004) that the R&D task for a follower firm is different to that in leader firms. R&D is a multi-faceted activity: in an environment of rapid catch-up, it can mean enhancing shop floor innovation; learning from other firms; it can mean improving existing products; building independent product development capability; it can in some circumstances be *the* business, as an contract R&D firm; it can also mean coordination of the separate parts of a knowledge system. All of these could push firms towards the technological frontier.

A number of firms have built new proprietary technology without expensive R&D units. Reliance is a good example of a company that has developed proprietary technology via process Innovation (see figure 5). Reliance has R&D units that operate closely with implementing units. Reliance has also sponsored research at Indian national laboratories - on catalysts, for example. Its in-house R&D units have the responsibility to coordinate work done at these laboratories with in-house effort. Reliance had by 2000 emerged as India's second-largest corporate spender on R&D. But growth in R&D only came in the 1990s, after Reliance had established its pre-eminence in project execution and manufacturing efficiency.

Hindustan Lever used R&D to deliver small improvements in product technology (shampoo sachets) and process technology (cheaper packaging machines for sachets).

These small improvements have led to major gains in market share and penetration of the Indian rural market (Forbes and Wield, 2004).

Indian pharmaceutical firms began by manufacturing bulk drugs and then followed by developing capabilities to produce and market branded formulations for the domestic market, thus moving quadrant from process to product, but still non-proprietary (trajectory A in Fig 6) (Kale and Wield, 2006). Generic product R&D, which occupies the process-proprietary quadrant involves creating non infringing processes or in some cases invalidation of an existing patent (trajectory B). This gave Indian firms a novel and innovative element and grounds to apply for a patent. The knowledge base underlying generic product R&D builds on organic and synthetic chemistry skills acculated in reverse engineering but adds a patentable innovative element. In parallel with that trajectory, a few Indian firms invested in risky innovative activities to develop new chemical entities represented by the product-proprietary grid.

As a specific example, Ranbaxy, the Indian drug firm, used various types of R&D to move up the value chain. Ranbaxy was until recently in the non-proprietary/product quadrant as the bulk of its products were generic and reverse-engineered drugs. It built an effective R&D capability focused on reverse engineering. More recent investment in research under its new drug discovery programme was to find new molecules - an attempt to move to proprietary and product (and internationally patented) technology. Its efficient FDA-approved manufacturing plants for generics are a useful complementary asset for this new drug development programme. Among Rambaxy's strategic moves have been: establishing an R&D base in the US for early stage R&D; licensing a drug to Bayer; and then buying Bayer's generics business to give it access to the European market; and building a wide range of drug trial collaborations with Indian, US and European firms.

Figure 5 Building R&D capabilities

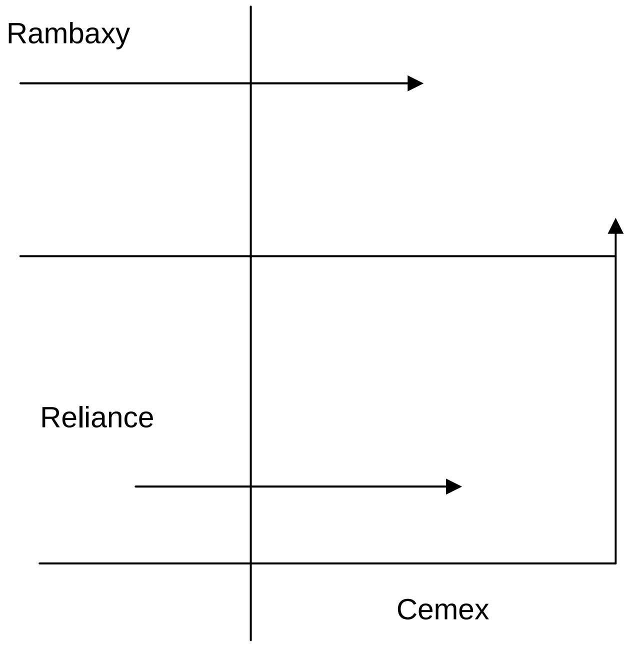
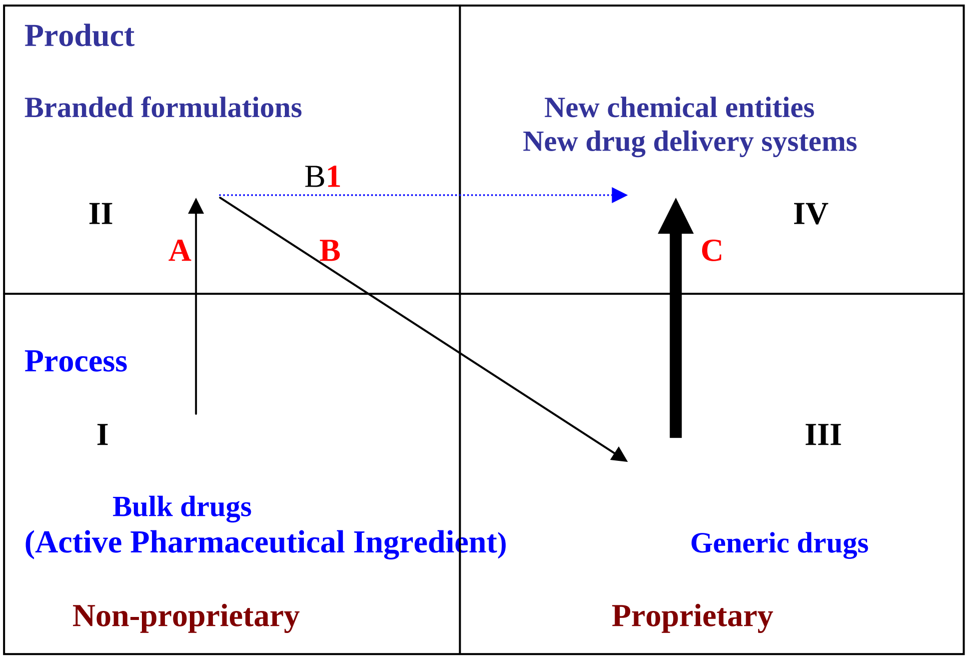


Figure 6: Proprietary-product-process grid for Indian pharmaceutical



Source: Kale and Wield, 2006

Building a Technology Strategy for innovation

In building new capabilities, strategic perspectives can help firms understand their choices. Our argument has been that, for firms to move up the value-added ladder requires the hard slog of gradual improvement but then graduation to proprietary and product innovation. This process requires both old and new assets and capabilities.

So far we have analyzed and mapped the directions that successful firms have travelled. How can firms build a strategy that takes them closer to the technological frontier? At the beginning of the paper we sketched an approach to strategy using the following concepts: the firms specific *assets,* including intangibles; *capabilities,* those skills that make the firm good at using its assets or putting knowledge to work; *position,* the result of a firms previous building of assets and capabilities; and *path/trajectory,* the direction in which it has been heading.

In this concluding section, we introduce the issue of future trajectory. Firms have choices: they make decisions, albeit constrained by the firm's present position (its current assets and capabilities) and trajectory (how its past assets and capabilities brought it to where it is). There is, however, room for manoeuvre. Choices help shape the firm's future capabilities and assets - and so future competitiveness. The firm can continue to be successful, at least in the short-term, within the same quadrant of the process-product-proprietary map. Jumping quadrants, though riskier, gives the opportunity to capture innovation rents.

We consider the future trajectories of firms and sectors at different positions on the value-added spectrum using cases we have discussed earlier. First, where does Tanzania Breweries, the leading brewer in a small country, go from an 80% domestic market share? Second, how does Hero Cycles, the world's largest bicycle manufacturer, meet Chinese competition? Third, how does Vitro, an emerging player in the global glass industry, continue to close the value-added gap, after it has made many of the early gains? Fourth, is it enough, as with the Indian firms in the software industry, to be an unexpected success story, providing 400,000 plus high paying jobs but with focus on low value added? Finally, how does Reliance, a firm with a dominant position in the Indian petro-chemicals market with low potential for further reverse-integration, keep growing rapidly?

The choice of exports and new products

To grow sales beyond its 80 percent domestic market share, TBL must either export or develop new products for the local market. TBL has higher productivity than the mean for subsidiaries of South African Breweries (Forbes and Wield, 2002). At the level of the firm, it seems that TBL is relatively competitive and could begin export. What is holding it back? Is it perverse state policies that tax local production, including for export, at a higher rate than imports? Or does South African Breweries not permit TBL to compete with it in export markets?

TBL's other possible trajectory is to add more products to its range (figure 7i). That would take a product innovation capability it has not demonstrated in the past, and if TBL chooses this path then it must begin investment in product development and local branding. Investment in design capability and fostering a culture of exploration would complement TBL's shop-floor competence.

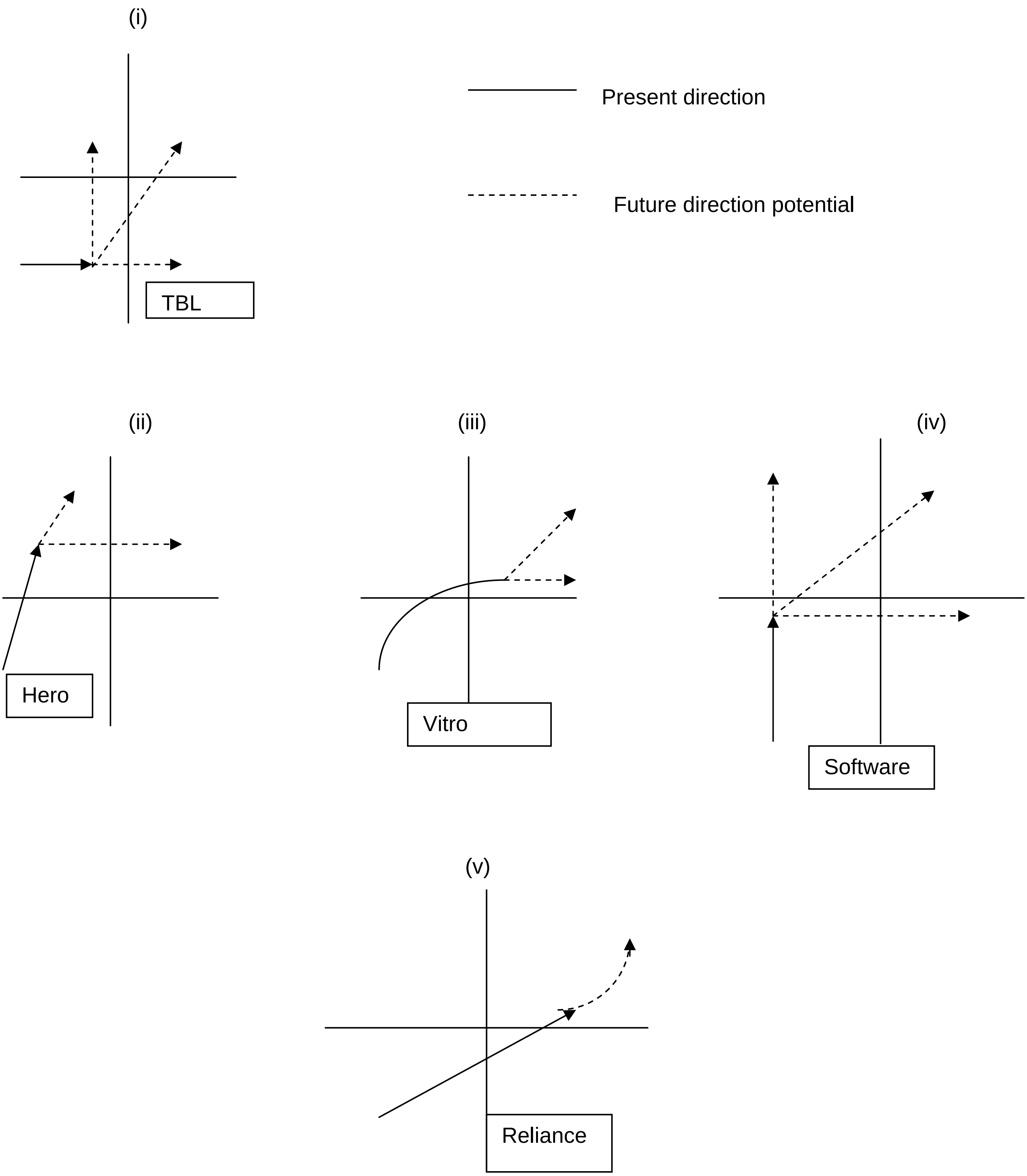
The Choice of Design and Proprietary products

Hero Cycles has the options of moving further up the value-chain with products or of going proprietary through new bicycle designs (Figure 7ii).

Although comparative figures for international bicycle firms are difficult to obtain, there would seem to be a big gap in productivity with the key Taiwanese firms, which now manufacture bicycles mainly in China (Forbes and Wield, 2002). Hero has demonstrated its competence at hard-slog innovation for its standard Roadster and can even compete nationally with imports from China at zero duty. A supply-chain of 400 just-in-time (JIT) suppliers and a distribution network of 3000 dealers is a formidable asset. Being the world's largest manufacturer of bicycles is a useful complementary asset as the basis to innovation in product, process or material technology.

However, the story is not as rosy for either exports or specials. Hero has seen Chinese exports replace its exports in the US and in Africa. India exports one million bicycles each year, of those Hero 400,000. China exports 20 million bicycles a year. China makes over 75 percent of the 10 million bicycles imported into the US market each year, most of which are specials - geared, mountain, or children's bikes. Hero is a relatively recent entrant into the specials market, and China is a threat to it in India itself, let alone overseas. There is a clear need to move up the value-chain with design to higher value-added segments that competitors find difficult to match. Building volume in specials is crucial for exports, and Hero might also consider the expensive but ultimately lucrative option of establishing a brand in foreign markets. Finally, Hero's JIT supply-chain has been enormously effective for the standard Roadster. Can Hero harness this JIT network more effectively for lower-volume specials?

Figure 7 Future trajectories



The choice of design

Vitro is still well behind the industry leader, Owens-Corning, in sales per employee. But Vitro demonstrates that while position is important, it is even more important to be on a good trajectory. Vitro has rapidly been closing the gap - from one-seventh to one-third between 1991 and 2000 (Forbes and Wield, 2002). Our analysis suggests that Vitro is now just within the proprietary-product box, and it has the choice of competing mainly on glass-making or to move more heavily into proprietary products (figure 7iii). The East Asian Miracle option of moving to OBM via Own Idea Manufacturer may be useful in the glass industry, where the new products could be suggested by Vitro as supplier. Another option, that several Japanese and Korean firms used in electronics, was to buy US brands - LG bought Zenith and Acer bought Altos Computer, for example, to help in entering the market with its own branded product.

Is there an argument for Vitro to have a stronger focus on design? It could certainly acquire design capability easier than technological capabilities.

The choice of longer term over short term benefit

Indian software firms have been a huge success, with a strong asset - India's huge availability of low-cost technical manpower. The key gap has been in moving to higher value-added activities (Athreye, 2005). The most effective Indian firms, such as TCS, Infosys and Wipro, built capabilities within business services, attempting to construct their own 'brand' as a reliable service provider. Narayan Murthy, the head of Infosys has a very prominent presence representing Indian industry at meetings world-wide and so gaining access to the heads of the world's leading corporations, Infosys' target customers (most Indian software firms measure themselves on the percentage of Fortune 1000 firms they count as customers). But value-added per employee growth has been limited, even for these better performers. Growth has come from adding people rather than productivity.

The industry as a whole is still projecting low value-added growth, regardless of talk about moving up the value-chain. What are the options for firms wishing to grow value-added faster (Figure 7iv)?

Opportunities for an Indian software services firm strong in financial services, with a record of developing some improved software development practices might include: expanding within services to integrate more financial service firms; entering new sectors such as telecommunications; through to developing own software products. Another opportunity would be for the software industry to target Indian industry.

Seeing software as a capital good would simultaneously enable software to become more proprietary and Indian industry to become more competitive. This would require that software firms consciously choose less immediately lucrative contracts with Indian customers, and that Indian firms become more demanding and imaginative in the use of IT as a competitive tool.

The choice of a new trajectory in a new industry

So far, we have described choices made within the same industry - of beer, bicycles, glass and software. But firms might also choose to make a much more dramatic - and much riskier - leap into whole new industry. Nokia began in forest products. Wipro still makes the vegetable oil it began with in addition to software. If it had stuck to the standard management-consultancy advice of 'stick to the knitting', Wipro would not be India's second largest software company.

In terms of the map, this choice could be seen as the choice of a completely new map. It could also be seen as exploitation of key assets and capabilities from one quadrant and map as a firm moves into another industry.

From 2001, Reliance made huge investments in IT. Instead of the normal Indian IT focus on software, Reliance invested in IT infrastructure - $5bn in 20,000 km of underground fibre-optic cable around the country. The sheer scale of the investment is beyond the capacity of most firms. Did Reliance have any chance of succeeding? It argued that its key competence was in project execution. Laying 20,000 km of underground cable around the country took considerable project execution competence, including the ability to manage hundreds of local municipalities in every state around the country. Few firms are better placed to do that than Reliance. Having reached a position of dominance in petro-chemicals, Reliance is moving into other attractive product areas: IT as above, power for many of the same reasons, and even bio-technology.

Conclusions

In this paper, we formalised some key concepts of technology strategy and used them to map choices that can be made to build competitiveness. Firm choice is constrained by where it is now - its current assets and capabilities. But firms set on moving from follower to leader must also make choices about where they wish to go, and what investments must be made now in assets and capabilities to get there. This adds up to a technology strategy for innovation.

The process-product-proprietary map gives ways of mapping and analyzing firm-level innovation and innovatory potential. It can illustrate simply what some successful firms have done, what choices they made. Rather than suggesting one best practice, the map suggests that for many firms, there are a series of clear moves to become innovative - to move into the process/non-proprietary grid and to move within it.

After that, the choices are more diverse, but tougher. The key strategic point in all the cases consider above is firm choice.

We have shown that firms can, and do, defy their national environments to become internationally competitive. In their various ways, they are tackling the process of catch-up. We have detailed an approach to innovation dynamics in follower-firms, showing that alternatives are needed to those suggested by the classic innovation literature.

We have deliberately focused on firm innovation dynamics, though our data are from late industrializers and LDC nations wishing to industrialize. We have not attempted to consider in any detail the relationship between firms and their regions and nations. However, the implications of our argument is that industrialization, and adding value to production, is a key component if LDCs are to move from their subservient role in the global economy. Our case studies suggest that firms can change speed and trajectory and that this is important for development. We have also implied that, although infant industry protection must play a role in industrialization processes, it is highly constrained and needs to be constructed differently, to be highly selective and achieve short term results. More important, its role is not uniform and linear, but complex and multi-facetted. A related implication is that there are roles role for policy: improvement of infrastructure and communication, for example; a new approach to R&D that preferences improvement at firm level; and a role in building a clear vision of what citizens might support and work hard for – like better transport, communication systems, education, and so on.

References

Athreye, S (2005) 'The Indian Software Industry and its Evolving Service Capability', *Industrial and Corporate Change*, 14, 3, 393-418.

Buitelaar, R.M. and Perez, R.P. (2000) 'Maquila, Economic Reform and Corporate Strategies', *World Development*, 28, 9, 1627-42.

Carrillo, J. and Hualde, A (1997) 'Maquiladoras de Tercera Generacion: El Caso de Delphi-General Motors', *Comercio Exterior* 47, 9, 747-757.

Casanueve, C. (2000) 'Globalization and Industrial Restructuring in Mexico: the cases of the electronics and automotive industries'. *Working Paper, Instituto Tecnologico y Estudios Superiores de Monterey*. Mexico City Campus.

Casanueve, C. (2001) 'The acquisistion of fiorm technological capabilities in Mexicos' open economy, the `case of Vitro', *Technological Forecasting and Social Change*, 66, 1, 75-85.

Cohen, W and Levinthal, D. (1990) 'Absorptive capacity:a new perspective on learning and innovation', *Administrative Science Quarterly*, 35, p128-52

Eisenhardt, K.M. and Martin, J.A. (2002) Dynamic Capabilities: What are they?', *Strategic Management Journal*, 21, 1105-1021.

Ernst, D, Ganiatsos, T and Mytelka, L. (1998) *Technological Capabilities and Export Success in Asia*, London: Routledge.

Evans, P (1995), *Embedded Autonomny*, Princeton: Princeton University Press.

Faulkner, W (1994) 'Conceptualizing knowledge used in innovation: a second look at the science-technology distinction and industrial innovation', *Science, Technology and Human Values*, 19, 4, p 425-458

Forbes, N .(2002) 'Doing business in India: what has liberalization changed?' in A.O. Krueger (ed) *Economic Policy Reforms and the Indian Economy*, Chicago, University of Chicago Press.

Forbes, N. and Wield, D (2000) 'Managing R&D in Technology Followers', *Research Policy,* 29, 9, 1095-1109.

Forbes, N and Wield, D (2002) *From Followers to Leaders: managing technology and innovation,* London: Routledge.

Forbes, N and Wield, D (2004) 'R&D in Follower Nations' *Science and Public Policy*, 31,4, 267-277.

Gershenkron. A. (1962) *Economic Backwardness in Historical Perspective*, New York: Praeger.

Gibbons, M., Limoges, C., Nowotny, H., Schartzman, S., Scott, P. and Trow, M. (1994) *The New Production of Knowledge*, London: Sage.

Hewitt. T. and Wield, D (1997) ‘Networks in Tanzanian Industrialisation’, *Science and Public Policy*, 24, 6, 395-404.
Hewitt, T., Wangwe, S. and Wield, D. (2002) ‘Seeing eye to eye: organizational behaviour, brokering and building trust in Tanzania’, *Public Administration and Development*, 22, 97-108.
Hobday, M (1995) *Innovation in East Asia: the challenge to Japan*, Aldershot, Edward Elgar.
Hobday, M (2000) ‘East vs South East Asian Innovation Systems: comparing OEM- and TNC-led growth in electronics’, in Kim, L and RR Nelson (eds) *Technology, Learning and Innovation: Experiences of Newly Industrializing Economies*, Cambridge: Cambridge University Press.
Hobday, M. (2004?) ‘Firm-level Innovation Models: Perspectives on Research in Developed and Developing Countries’, *Technology Analysis and Strategic Management,*
Huff, A.S. and Jenkins, M (eds.) (2001) *Mapping Strategic Knowledge*, Paul Chapman
Humphrey, J., Kaplinsky, R. and Saraph, P.V. (1998) *Corporate Restructuring, Crompton Greaves and the Challenge of Globalisation*, New Delhi: Response Books.
Kale, D (2004) developing knowledge creation capability for innovation:the case of Ondian pharmaceutical industry, PhD thesis, Open University.
Kale, D. and Wield, D (2006) ‘Exploitative and Explorative Learning as a Response to the TRIPS Agreement in Indian Pharmaceutical Firms: Some Implications for Other Developing Countries’, IKD Working Paper No. 11
Kaplinsky, R. (1994) *Easternization: The Spread of Japanese Manufacturing Techniques to Developing Countries*, Ilford: Frank Cass.
Kaplinsky, R (1995) ‘Technique and System, the spread of Japanese management techniques to developing countries’, *World Development*, 23,1, p 156-71.
Kim, L. (1997) *Imitation to Innovation*, Boston: Harvard Business School Press.
Kim, L and Nelson, RR, eds (2000) *Technology, Leaming and Innovation:Experiences of Newly Industrialzing Economies*, Cambridge: Cambridge University Press.
Kline, S. and Rosenberg, N (1986) ‘An overview of innovation’, in Landau, R. and Rosenberg, N. (eds) *Harnessing Technology for Economic Growth*, Washington, DC: National Academy Press.
Lee, J., Bae, Z.T. and Choi, D.K. (1988) ‘Technology Development Processes: A Model for a Developing Country with a Global Perspective’, *R&D Management*, 18, 3, 235-250.

Lee, K. and Lim, C. (2001) 'Technological Regimes, Catching-up and Leapfrogging: The Findings from Korean Industries', *Research Policy*, 30, 459-483.
Lundvall, B. (2000) 'Commentary', in Kim, L and Nelson, R.R.,   p 100.
March, J.G. (1989) 'Exploration and Exploitation in Organizational Learning', *Organization Science*, 2,1, 71-87.
Morosini, P. (2004) 'Industrial Clusters, Knowledge Integration and Performance', *World Development*, 32, 2, 305-326.
Nelson, R. and Winter, S. (1977) 'In Search of a Useful Theory of Innovation', *Research Policy*, 5, 36-76.
Nowotny, H., Scott, P. and Gibbons, M. (2001) *Rethinking Science, Knowledge and the Public in an Age of Uncertainty*, Cambridge: Cambridge University Press.
Oyelaran-Oyeyinka, B (2004) 'Learning, Organization and Skills: Implications for firm-level performance in African Industry', *Int. J. Technology Management and Sustainable Development*, 3, 2 91-113.
Oyelaran-Oyeyinka, B (2006) *Learning to Compete: Institutions, Technology and Enterprise in Africa,* Ashgate.
Pavitt, K. (1990) 'What we Know about the Strategic Management of Technology', *California Management Review*, 32, 17-26
Penrose, E. (1959, 1995) *The Theory of the Growth of the Firm*, Oxford: Oxford University Press.
Perez. L.A. and Peniche, J. (1987) 'A summary of the principle findings of the case-study on the behaviour of the Mexican steel firm Altos Hornos de Mexico', in J.M. Katz (ed.) *Technology Generation in Latin American Manufacturing Industries*, London: Macmillan.
Prahalad, C.K. and Hamel G. (1990) 'The core competence of the corporation', *Harvard Business Review, May-June,* 79-91
Riggs, H.E. (1988) 'Innovations: a US-Japan Perspective', in Okimoto, D. and Rohlen, R (eds.) *Inside the Japanese System*, Stanford: Stanford University Press.
Samstad, J.G. and Pipkin, S (2005) 'Bringing the Firm Back In: Local Decision Making and Human Capital Development in Mexico's Maquiladora Sector', *World Development*, 33, 5, 805-822.
Semboja, H.H. and Kweka, J. (1997) 'Divestive impact and privatization process in Tanzania', Paper presented at International Conference, Manchester University, July.
Teece, D. and Pisano, G (1994) 'The dynamic capabilities of Firms: An Introduction', *Industrial and Corporate Change*, 3, 537-556.
Teece, D. Pisano, G and Shuen, A (1997) 'Dynamic Capabilities and Strategic Management', *Strategic Management Journal,* 18,7: 509-53.

Tidd, J., Bessant,J. and Pavitt, K. (1997) *Managing Innovation: Integrating Technological, Market and Organizational Change*, Chichester: Wiley.

Wade, R. (1990) *Governing the Market*, Princeton: Princeton University Press.

Winter (2002) 'Understanding dynamic capabilities', *Working Paper, Wharton School*, University of Pennsylvania, PA.