COMPETING IN CAPABILITIES: AN INFORMAL OVERVIEW*

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* This lecture summarizes, rather informally, some themes developed in my Clarendon lecture of 2004, the text of which is currently in preparation.

In his recent TV series 'The Road to Riches', Peter Jay invited the viewer to join him on a tour of a cashew-nut processing factory in Tanzania. Built some fifteen years before with the financial support of the World Bank, its construction seemed a good idea at the time. Locally grown cashew nuts were being exported to India for processing, and it appeared natural to suggest that they might be processed locally instead. As Peter Jay walks through the factory, it becomes clear that the machinery and equipment is perfectly functional; but the factory stands idle and unused.

The Tanzanian factory stands as a metaphor for what I want to discuss in this lecture: I want to explore a well-motivated shift in our understanding of the process of industrial development that has been evolving over the past decade or so. This improved understanding leads to an emphasis on the kind of nitty-gritty hand-holding assistance to individual companies in developing countries that is nowadays characteristic of the work of USAID, the IFC and others. My aim is to sketch an analytical framework within which we can capture the key issue involved in the story of the Tanzanian factory: if you don't start out with a firm that has the appropriate capabilities, installing capital equipment won't help. The scarce resource most important to the process of industrial development lies in the capabilities of firms.

1. What is Capability?

The term 'capability', used in relation to firms, has been in vogue in the business school community for over two decades yet it has limited impact to date on the economics literature (Nelson and Winter, 1982). My first step in what follows is to pin down this notion in a manner that economists might find useful, by building on some ideas from the Industrial Organization literature (Sutton (1991, 1998)).

At one level 'capability' is no more than an extension of the traditional notion of productivity to a world in which quality matters. At this level, we might define a firm's ('revealed') capability in terms of two numbers: For each (narrowly defined) product line, we define (i) the unit variable cost of production, c, as the number of units of labour input required per unit of output and (ii) a measure or index of 'perceived' quality, u, defined in terms of buyers' willingness-to-pay for a unit of the firm's product, as against rival firms' products.[1]

Underlying this 'revealed' capability is the firm's 'underlying capability', which consists of the set of elements of 'know-how' or 'working practices' held collectively by the group of individuals comprising the firm. Throughout the first part of the present lecture, I will simplify this latter aspect by treating the firm's investment in capability building as a 'black box', viz. I simply suppose that there is a mapping from the firm's fixed and sunk outlays on 'capability building', denoted F, and resulting levels of quality and productivity.[2]

2. Competing in Capabilities

To motivate the discussion that follows, we begin with a simple example. Consider a single market in which a group of n firms offer competing products to a population of identical consumers, each of whom is equipped with a utility function of the form

$$U = (ux)^{\delta} z^{1-\delta}$$

where x is the quantity of the good consumed, u is a quality index for this good, and z is the quantity of some outside good available at an exogenously given price. From the (Cobb-Douglas) form of the utility function, we can see that a fixed fraction δ of total consumer income will be expended on the quality good. Different firms offer different qualities at different prices; it follows again from the form of the utility function that each good which commands positive sales at equilibrium must sell at the same quality-price ratio, u/p.

[1] It is worth noting that this index of 'perceived quality' can be raised not only by improving the physical attributes of the product, via R&D or otherwise, but also through improvement in reputation, brand image, and so on.

[2] More generally the determinants of a firm's productivity and quality range from inventiveness in finding new methods of production, to the mixture of luck and judgement involved in successful product development. But all that matters, from my present point of view, is that among the factors in this list, there should appear one which plays a crucial role: if one of the various ways of improving capability is the use of enhanced fixed outlays by the firm – in the form, say, of R&D spending devoted either to product innovation (i.e. raising u) or process innovation (i.e. lowering c) – then results described in the text will follow.

Each firm is characterised by a quality index u and a productivity index c which measures the unit cost of production in units of labour input. We set the (exogenously given) wage rate to unity so that c represents the marginal cost of production. We aim to characterise a Nash equilibrium in quantities (a Cournot equilibrium).

The discussion that follows takes as its point of departure two basic propositions that emerge from this model. The first proposition says that competition between firms will lead to the endogenous determination of some lower bound or threshold to capability, which must be reached in order for firms to achieve viability:

Proposition 1

> Given any configuration of capabilities
>
> $$(c_1, u_1), (c_2, u_2) \ldots (c_n, u_n)$$
>
> there is an associated critical level of u/c: and any firm with capability (c, u) such that its value of u/c lies below this critical level will have zero sales (revenue) at equilibrium.

It is worth noting that a special feature of the present example is that the equilibrium profit of each firm depends upon u and c only through the ratio u/c, as illustrated in Figure 1.

This first proposition leads to a natural question: if a low level of capability imply a firm's exclusion from the market, what are the implications of this for firms' investments in capability building? With that question in mind we consider a two-stage game, the second stage of which is the game just described. In the first stage of the game, firms choose their levels of u and c and incur a sunk and fixed cost F, where:

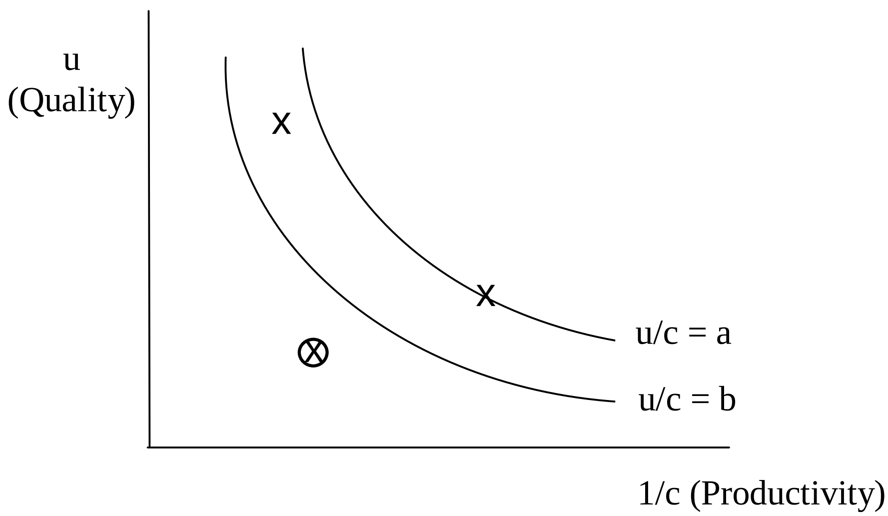
$$F(u, c) = \left(\frac{u}{c}\right)^{\beta}$$

where $\beta(\geq 1)$ measures the effectiveness of investments in capability building, i.e. a lower value of β, or equivalently a higher value of $1/\beta$, implies that investing in capability is more effective. This leads to:

Proposition 2

> Given any value of β, there exists an associated bound $n^*(\beta)$ such that at most $n^*(\beta)$ firms can co-exist at equilibrium.

Figure 1: A Window of Capability



The window of capability (a, b). The firms denoted by × are viable; the firm denoted by ⊗ is not. The curves on the diagram represent lines of constant capability along which u/c is a constant. The constant b corresponds to the threshold level of capability, while the constant a corresponds to the highest level of capability.[3]

The important point to note in Proposition 2 is that the value of n* is independent of the size of the market: what happens as the size of the market increases is that firms increase their

[3] Readers interested in the technical details may wish to consult Sutton (1998), Appendices 14.1 and 15.1. Readers familiar with the 'capabilities' literature will notice that I am defining capabilities here in a static way ('current capability'). An important extension lies in introducing the idea that firms may differ in their ability to improve their levels of c and u over time ('dynamic capability'; see for example Bell and Pavitt, (1993)). This can be incorporated into the present setup by allowing the form of the fixed cost schedule, linking c and u to R&D spending, to vary across firms; an exploration of this theme lies beyond my present scope.

outlays in capability building, in step with market size. The result is that increases in market size do not lead to the familiar process of entry; rather, the number of firms remains constant while their capabilities increase. (For a fuller discussion of these ideas see, for example, Sutton 1998, chapter 3).

3. Capabilities and Trade

Now a natural question to ask in a 'Trade and Development' setting is this: if two countries differ in their levels of capability, this difference will be reflected as a difference in their real wage levels: and this will in turn affect a firm's viability. This leads to the question: can low wages compensate for low quality? To address this question, it is useful to look at a simple general equilibrium example.

The example involves two countries of equal size, each endowed with the same labour supply function. Labour is immobile across countries, but goods are traded freely in a single global market.

Suppose there are three industries, each of the kind considered in the introductory example above, viz. each industry comprises a number of firms producing distinct substitute goods of varying levels of quality. As before, all consumers have identical tastes, represented by a Cobb-Douglas utility function, and all consumers devote one third of their incomes to the products of each industry[4].

Each product is produced using c units of labour per unit of good produced, and so at constant marginal cost cw, where w is the wage rate.

[4] The details of this kind of model are developed in Sutton (1991,1998).

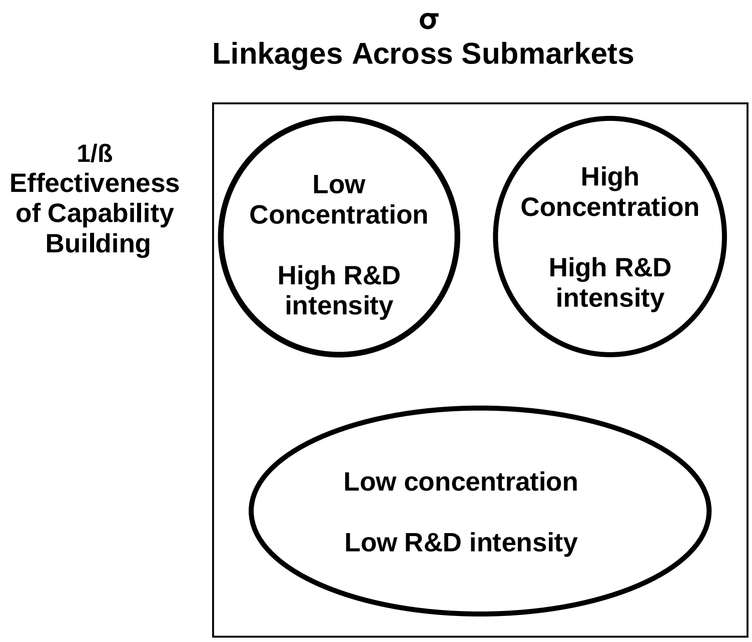
Box 1 **Industry Characteristics**

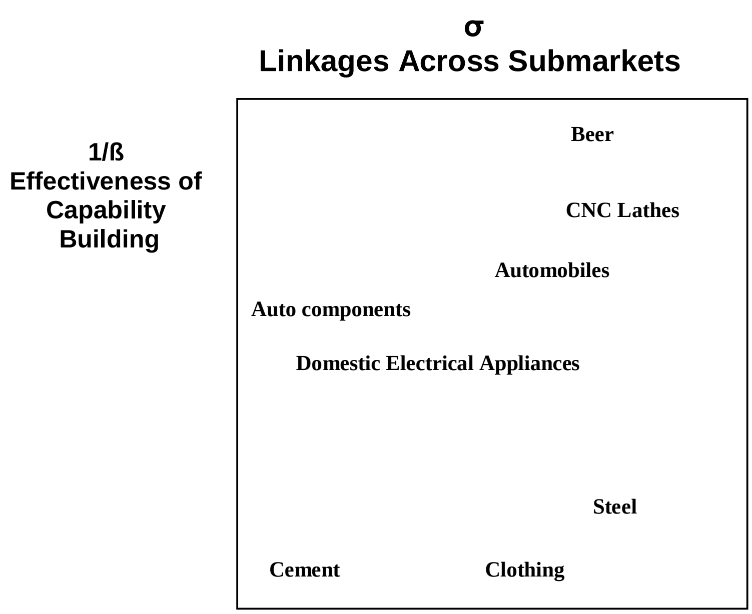
While the example in the text is rather special in character, Propositions 1 and 2 carry over to a very broad class of oligopoly models (see Sutton, 1998, chapter 3). A key question of interest in this wider context is: what are the industry characteristics which determine the minimal level of concentration that can be attained, or equivalently, the maximal number of active firms that can survive at equilibrium in an arbitrarily large market? The answer depends upon two parameters: The first parameter of interest is $1/\beta$, which measures the effectiveness of investments in capability. If, for example, an increase in fixed outlays on capability building (via R&D for example) leads to a substantial rise in product quality ('product innovation'), or a substantial fall in the unit cost of production ('process innovation'), then $1/\beta$ will be high. The second parameter, labelled σ, measures the extent to which a high capability firm can capture market share from low capability rivals. Insofar as products are close substitutes, or insofar as there are scope economies involved in R&D, for example, σ will be higher. More precisely, what σ measures is the degree to which a high capability firm's market share can be eroded by the arrival of a (large) number of lower capability rivals. Explicitly, we consider one high capability firm facing competition from n equally (less) capable rivals. If the market share of the high capability firm falls to zero in the limit where the number of rivals, n, increases to infinity, then the parameter σ takes a value of zero. (Sutton (1998), Chapter 3).

It is worth noting that when either 1/ß falls to zero, or when σ falls to zero, then the lower threshold of capability consistent with survival falls to zero, and an arbitrarily large number of firms can co-exist when the market becomes 'large'. Many of the standard models considered in the recent Trade literature are of this special kind.

Figure 2 shows the pattern of outcomes associated with different combinations of $1/\beta$ and σ. What the figure indicates is as follows: when the effectiveness of capability building is low, the lower bound to concentration is low: it will be possible to sustain a fragmented market structure. As we move up the vertical axis, two alternative patterns emerge, according as σ is low or high. When σ is low, we can still sustain a fragmented market structure, but now the levels of effort devoted to capability building by firms will be intense, and the R&D to sales ratio will be high. But as we move across the diagram to the top right hand corner (high $1/\beta$, high σ), concentration must necessarily be high, independently of the size of the market. The figure also indicates where various industries lie, by reference to measurable 'industry characteristics' following Sutton (1998).

Figure 2: Industry Characteristics





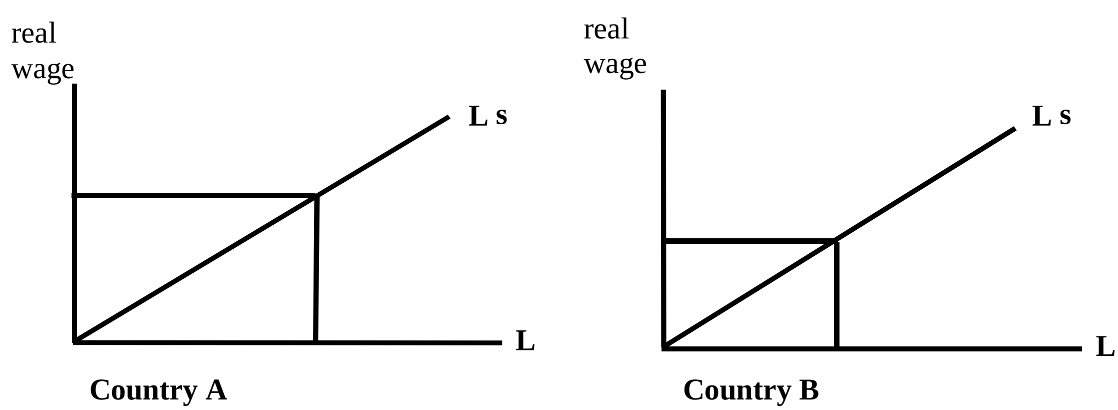
Now suppose all the firms in industry 1 of country A produce goods of the same quality u_A, while their counterparts in Country B all produce at quality level u_B. Similarly, in industry 2, the country A firms produce at quality level u_A and those in Country B at quality level u_B. In industry 3, all firms in both countries produce at the same fixed quality level.

Now if $u_A = u_B$, the setup is symmetric and the equilibrium real wage is the same in both countries. What I want to examine is the effect of a rise in capability among firms in country A. Keeping u_B fixed, let u_A increase. The initial effect of this increase will be to raise the relative volume of production of these two industries in country A, and to lower it in country B. Meanwhile, more production of the third industry shifts to country B; but real wages remain the same in both countries.

As u_A rises further, however, all production of industries 1 and 2 shifts to country A. In other words, given u_A, there is some threshold quality $\underline{u}$ below which country B will earn no sales revenue from these goods.

As u_A rises, then, we will eventually reach a point where only country A produces these goods; u_B lies below the quality window $[u_A, \underline{u}]$. Moreover, all production of the third good shifts to country B. Now 'factor price equalization' breaks down: the demand for labour, and so the real wage, in country A exceed that of country B (Figure 1).

Figure 3: Labour Supply, Employment and wages in the two-country model, where $u_A >> u_B$.



So a rise in capability in country A leads to a rise in real wages; and notwithstanding the wage differential between the two countries, a quality threshold exists below which firms in country B cannot sell products 1 or 2. In other words, the wage adjustment effect in this general equilibrium setting serves to widen the window of quality levels that can coexist at equilibrium, but the message of the first theorem remains valid.

4. Globalization Mechanisms

Up to this point, we have been looking at the way in which the viability of industries and the real wage gap between countries varies with the ratio u_A/u_B . We now hold u_A/u_B constant, and examine the effect of moving from autarky to free trade between countries A and B. We begin with the special case in which the two countries' capabilities are identical, i.e. $u_A/u_B=1$. There are two effects, which relate respectively to the two mechanisms characterized in Propositions 1 and 2 above.

The short-run, or impact effect, of opening up free trade involves price adjustment alone, with quality and productivity levels fixed. Here, prices fall as a result of bringing the firms from each of the countries into competition with each other in the combined market. This will, in general, precipitate the exit of some firms, insofar as prices are now insufficient to allow firms to recover their fixed costs. The result is a rise in concentration, in the sense that the number of surviving firms will be less than the combined number of firms that were active across the two countries prior to liberalization.

The medium-term effect is driven by adjustments in firms' capabilities, as the marginal return to investing in improvements in quality and productivity rises: in the new 'global' market, a firm which invests in quality improvements gains a larger return, since it is now selling to a larger market. This process leads to a further rise in global concentration levels. In the new equilibrium, some firms make additional marginal investments, while others do not. The latter group of firms may or may not survive as a 'low capability' subgroup of firms in the new global industry. Nothing pre-determines the identity of surviving firms; there will be a set of equilibrium outcomes in the global market, in which different firms emerge as survivors.

We now turn to an asymmetric version of the model, in which the firms in Country A have initial capabilities higher than those in Country B. The first new feature that emerges here relates to the short run impact effect: here, it is the low-capability firms in Country B that contract, and – if the capability gap is sufficiently wide - will exit. The real wage gap that exists between Countries A and B can, as we saw above, lower the capability threshold at which Country B's firms can remain viable; but this can only partially offset the impact: below a certain threshold level, Country B's firms will become inactive.

The second feature that emerges here relates to the selection of surviving firms in the medium term. For the less capable firms, the incremental investment required to survive in the global market is greater; and if the initial gap in capabilities is sufficiently wide, then the only equilibrium in the global market will be one in which Country A's firms invest further in capability and survive, while some or all of the Country B firms invest nothing further in capability; these non-investors will again either be inactive in the global market, or will continue to exist as a low capability subgroup.

This brings us to the central theme of this lecture. The two mechanisms we have now seen lie at the heart of the globalization process. The first involves a shakeout of firms in 'low capability' countries. The sunk costs which these firms have invested in creating these ('inferior') capabilities are written off. The second involves a handicap faced by Country B's firms in relation to future investments in capability building, and so in relation to their long run viability.

If the story stopped at this point, then the outlook for less developed countries under globalization would be bleak. Operating against this scenario, however, is the fact that the relatively low wage rates in Country B may induce or strengthen an offsetting mechanism: the (widening of the) wage gap between A and B implies that firms in Country A have an (increased) incentive to marry high capabilities with low wages by way of transferring high level capabilities to firms in Country B; and if this transfer can be effected, then the net impact of globalization will be tilted to Country B's advantage. The net impact of globalization on developing countries turns crucially on the degree to which this offsetting mechanism operates.

While the theoretical framework introduced in Sections 2-4 above rests on a substantial and consistent body of empirical evidence, the transfer mechanisms to which we now turn are much less well understood, and the discussion that follows is necessarily much more tentative and exploratory in nature.

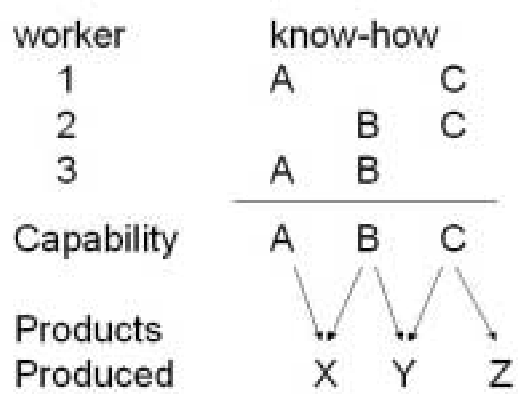
5. Transferring (and Building) Capabilities

It might seem natural to begin by addressing the question of why high capability firms do not adjust by simply relocating to low wage environments. There are two standard arguments in the literature here. The first is that the low wages are offset by a high cost of doing business (in Bank parlance, a poor investment climate). While this is undoubtedly a factor of crucial importance, and one to which I want to return in the final section, I will assume for the moment that we are concerned with a situation in which the quality of the investment climate is not such as to fully offset the differential in unit labour cost. The second argument that is prominent in the literature relates to the mechanism emphasized by Krugman and Venables (1995): the cost of doing business depends inter alia on the local presence of other businesses, and it follows from this that there is a positive externality to operating in the high capability environment. Again, this effect is certainly relevant to the discussion, but the only clear and convincing elements lying behind such a positive externality lie in access to a pool of skilled labour in a local labour market, and in the presence of firms that are part of the same vertical supply chain (i.e. customers or suppliers). These latter considerations will fall into place as part of the story that follows.

Rather than pause to discuss the barriers to relocation, I would like to proceed directly to the much more relevant type of mechanism, i.e. one that involves a transfer of capability from a high capability firm to either a low capability joint venture partner in Country B, or else to a newly-created entity in Country B. Both of these fall under the label of Foreign Direct Investment, though there is an important distinction between the two cases to which I will turn in what follows (Section 7). The central issue, however, lies in the observation that if a low cost transfer of capability were possible under either of our FDI channels, then the incentives to carry out such transfers would be extremely strong. At the heart of my argument is the notion that capabilities are difficult to transfer, just as they are expensive to build. To see why, we need to go beyond the black box formulation which I drew on above, by turning to an explicit representation of the locus of capability.

The central notion in the capabilities literature, as elaborated by Nelson and Winter (1982), among others, is that the carrier of capability is not – in most industries – a piece of knowledge that can be embodied in a blueprint, as would be the case with a pharmaceutical product, say, but rather a set of pieces of 'tacit knowledge' or 'working practices' possessed jointly by those individuals who comprise the firm's workforce. To illustrate what I have in mind here, consider a simple schema, illustrated in Figure 4. Imagine a set of discrete tasks, or 'pieces of know-how', or 'working practices,' that need to be used either in the course of production or in developing the next generation of products. Imagine these items to be possessed by (distributed over) a number of individuals comprising the firm. So long as one employee knows how to do task i, this knowledge can be passed to others at negligible cost. Thus, we may think of the capability of the firm simply as the union of all the items which are possessed by at least one individual within the firm. Our black box function F can now be replaced by a cost function associated with the acquisition of each of these items by some single individual within the firm, together with an ancillary function that maps the set of items which comprise the firm's capability into its 'revealed capability' (c, u) as described above.

Figure 4: Know-how and Capability



Now it easy to see intuitively, by reference to Figure 4, that depending upon the way in which we design the mapping shown in the figure that we can create examples in which the minimal number of individuals that we need to take out of the firm in order to carry the full range of its capability may vary greatly. (In Figure 4, for example, taking two of the three workers is sufficient to carry the full range of capability). At one extreme, we might have an example in which the same set of 'pieces of know-how' are possessed by a very large number of individuals, and selecting any single one of these individuals will be sufficient to carry the capability. At the other extreme, there might be a large number of elements of know-how which are distributed widely across many individuals, so that we would need to draw on the know-how of many individuals in order to capture the full capability of the firm. At the risk of caricature, it might be worth offering the example of certain areas of the textiles industry as illustrating the first case, while we might take the traditional photographic film industry as an example of the second case). What I am suggesting here is that a good first proxy for the cost of transferring capability is given by counting the number of individuals that we need to assemble in order to form a sufficient sub-set of employees who can carry the capability. Where this number is small, as in the clothing industry for example, we have typically seen very fast and efficient patterns of outsourcing to developing countries come into being. My focus of interest in what follows lies in looking at more typical industries in which this process of transfer is much more difficult. In looking at these industries, it is important to note the nature of the elements that must be transferred, and it is in this respect that what I have to say goes beyond many of the traditional analyses of 'technology transfer'. The key things that must be transferred relate not so much to items that can be successfully reduced to a statement in a manual, but rather to complex and inter-related patterns in working practices which are extremely difficult and time-consuming to unravel and redesign. Within this setting, it is important to maintain a distinction between two cases: that in which the element involves a piece of 'know-how' which the individual can choose either to use or not to use ('free disposal'), and that in which the element involves a habit, custom or working practice which needs to be unlearned before it can be replaced - a point to which I return below (Section 7).

The transfer process: two phases

The process of transferring (and building) capability consists of two phases. The first phase involves the initial introduction of a higher level of capability to some single firm or group of firms, either as a result of FDI, or otherwise. The second phase consists of the knock-on effects within and outside the host industry that result from this initial impact. This latter phase has been discussed in the literature under the heading of 'FDI spillovers'. I would like to motivate much of what follows by reference to the FDI literature. It is notoriously difficult to untangle and measure these FDI spillovers, but a series of carefully-executed econometric analyses have, over the past few years, led to a central finding of considerable interest. This relates to the fact that horizontal spillovers (i.e. those that affect firms within the same industry) are small, and possibly insignificant, while vertical spillovers (i.e. those that affect firms in upstream or downstream industries) are substantial and important (see for example Javorcic, 2004). This sharp difference between the role of horizontal and vertical spillovers is precisely what we should expect a priori on the basis of elementary considerations regarding the incentives for firms.[5] While it is clearly potentially damaging to transfer know-how horizontally to rivals, it is easy to show that firms face positive incentives (at least under reasonable assumptions) in transferring know-how to upstream or downstream firms. It is the mechanisms through which these transfers take place that I want to examine here.

Vertical transfer mechanisms

I would like to distinguish between three kinds of mechanisms that appear to have played an important role in a wide range of Chinese and Indian firms during the past decade of liberalization:

1. Equipment Suppliers. The first channel relates to the interaction between a manufacturing company and its equipment supplier(s). This channel is very well understood and plays an important role in many industries.

    - A leading Chinese steel maker developed a relationship during the early 1990s with a German supplier of blast furnace equipment. During the course of three major installations at its plant, there was an important two-way exchange of information as this equipment was being used in a novel environment. The benefits of this interaction accrued to both companies, as the equipment supplier introduced new ideas into the plant's operation, while the experience of the Chinese engineers led to new design modifications incorporated in later versions of the equipment in question.

2. The "Demanding Buyer". This channel is much less familiar, but is very important in some contexts. A nice illustration comes from the clothing industry, where links between suppliers and buyers are developed through a complex and well-functioning network in which buyers search for suppliers, and suppliers search for buyers:

[5] One of the central points to emerge from the capabilities picture I have painted above (but one on which I do not have time to digress during the present lecture) is that every firm faces a trade-off in terms of spreading know-how across its members versus losing individuals or groups of individuals who carry know-how to rival firms or newly created spin-offs. Thus, some level of horizontal spillover emerges endogenously as an equilibrium outcome of the capability building process.

- The Ever-Glory company is a private producer of clothing in South East China. It has grown very rapidly over the course of the past decade, and it exploits all the major channels that are available to it in seeking out buyers. An interesting aspect of the choices it has made is that it has established relations with Japanese department stores, who are regarded as the most demanding buyers in terms of the quality standards which they require. The advantage of forming these links is illustrative of the 'demanding buyer' mechanism: as the quality demands of the global market rise over time, firms that sell to leading edge buyers tend to be a step ahead of the game in terms of the production routines that they are forced to perfect in order to meet their most demanding buyers' requirements, and these improvements in production routines tend to carry over to other lines of their business.

3. The third and most familiar channel relates to situations in which there is a close and continuing contractual relationship between buyer and supplier, which involves a two-way movement of technical and engineering personnel between their respective plants. This is particularly characteristic of the auto sector, to which we now turn.

6. A Case of Rapid Transfer

The 1990s saw a remarkable transformation of the car industry in both India and China. At the beginning of the decade, there had been only a very limited involvement of multinational firms, and total production volumes in both countries remained modest. From the early '90s onwards, a wave of multinational firms entered both markets. In both countries, these entrants were required to achieve a high level of domestic content within a specified period (typically, 70% within 3 years). Achieving this target required the car-makers to switch rapidly from a reliance on imported components to sourcing from local vendors; and this in turn gave the car-makers a strong incentive both to invite multinational component makers to set up plants in China and India, and to work closely with domestic suppliers, to ensure that quality standards were met, within an acceptable price.

A well-established pattern of relationships between car-makers and their (first-tier[6]) suppliers has come into being in all the leading industrialized economies over the past twenty years. This pattern varies from case to case, but many important features of these relationships were first established by Japanese car makers in the 1970s, and were further shaped by the responses of American and European car-makers to Japanese competition in the 1980s. Some key features of the pattern are as follows:

1. The key driver of both productivity and quality is seen to lie in good manufacturing practice. Central to this practice is a move away from the notion of quality inspection at the end of the production line, in favour of a focus on continuous monitoring of quality at each step in the production and/or assembly process, by the operative who carries out each production or assembly step. To establish this process in a plant can require a very substantial change in attitudes and working practices.

2. Achieving and maintaining good manufacturing practice requires constant monitoring of quality and productivity in the plant. The appropriate measures of quality and productivity have been standardized to a remarkable degree across the international industry, and any auto-component plant in any country that sells to a multi-national car-maker will use very similar and highly standardized production methods, and will monitor a very similar series of measures of plant performance.

3. The car-makers will usually recruit at least two suppliers for each (group of) components, and can shift the balance of orders away from a supplier whose quality performance is inferior. While this creates strong incentives, or 'selection effects', that weed out underperforming suppliers, there is on the other side of the coin an active involvement by the car maker in developing the capabilities of its suppliers. This takes two forms: that of direct interaction (where one firm's employees are active in the others' plant), and indirect interaction. The latter can involve, for example, the use of specialist consultant firms, recommended by the car maker to candidate suppliers for whom they can introduce appropriate production standards and procedures in a plant, as a pre-requisite for the car maker's considering the plant as a potential supplier.

[6] A 'first-tier' supplier is one that sells directly to a car maker. Firms supplying components to first-tier suppliers are labelled 'second-tier' suppliers, and so on.

The close two-way interaction between car maker and supplier, together with the strong selection effect that weeds out weaker suppliers, leads to an unusually rapid and effective transfer of capability. The speed and effectiveness of this process in China and India over the past decade can be gauged by reference to a recent benchmarking study, reported as Sutton (2005). One way of gauging the outcome is by looking at the depth and stability of the supply chain. In both countries, the degree of outsourcing to domestically based suppliers by all car-makers is above the required 70% level, and corresponds roughly to the degree of outsourcing found among car-makers in the U.S., Europe and Japan. A more direct approach to assessing progress involves measuring the levels of quality and productivity achieved in the production of specific components. Here, two lines of attack can be used:

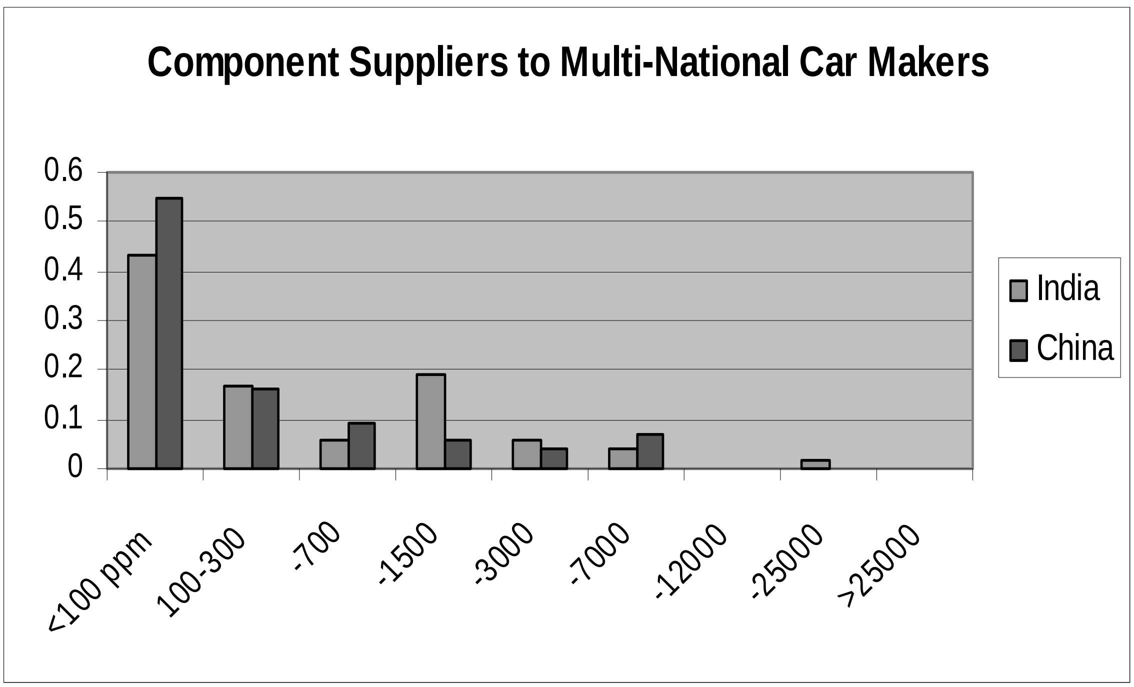
The first line of attack is to take particular car-makers, and examine the quality of parts supplied to them by the full set of their first-tier suppliers. This provides a snapshot of the first tier of the industry supply chain. An example is shown in Figure 5, which relates to a pair of recently established multinational car-makers, one in China and one in India, chosen for their similarity in terms of various characteristics. Having been established less than a decade, each of these firms benefited from the early development of the local supply chain that took place up to the early 1990s in each country. Each firm has taken advantage of the option of inviting some of its home country suppliers to set up joint ventures with local firms in order to ensure supplier quality.

The histograms in Figure 5 show the range of quality, as measured by defects found in incoming components – expressed in 'parts per million' defective. International best practice for car-makers in the U.S., Japan and Europe currently aims to bring the large majority of suppliers under 100 ppm. The histograms for the Indian and Chinese companies are fairly similar. In each case, about half of the suppliers achieve a figure under 100 ppm. The tail of the distribution is also similar: the fraction of suppliers with defect rates exceeding 1500 ppm is about one-eighth.

These distributions confirm the view suggested by discussions in the course of plant visits that, in both India and China, first-tier suppliers to newly arrived car-makers are already operating close to world class standards in terms of incoming component defect rates.

The second approach to assessing progress is to focus on a specific component, and examine the levels of quality and productivity achieved across a range of suppliers of that component. The main difficulty in doing this lies in the fact that each firm has a different product mix, and controlling for differences in the firms' products is difficult. Two producers of gearboxes, for example, would be difficult to compare in a satisfactory way since the differences in design and manufacturing complexity across different gearboxes are very substantial, and since the machine shop producing gearboxes is likely to produce a wide range of (other) components, making the allocation of labour hours to each product line problematic.

Figure 5: Supplier Defect Rates for a Twinned Pair of New Generation Car-makers



For this reason, we focus on two products that permit a relatively fair and transparent comparison across rival producers: seats and exhausts. In both cases, the component is normally produced in a single specialist plant, which produces at most a handful of major product lines. The design and complexity of the products produced by different firms are fairly similar, and it is possible to identify and make allowances for such differences as do exist. With this in mind, we identified the seat and exhaust producers who supply the leading car-makers in each country. We then chose a representative set of 6 of these seat suppliers and 6 of these exhausts suppliers in each country, i.e. a total of 24 suppliers. These suppliers include some which are joint ventures with, or affiliates of, major multinational seat or exhaust producers who supply international car-makers across the world. Others are domestic producers, some of whom are independent companies, and some of whom are affiliates of the car maker they supply.

In all cases, these firms supply a similar product, or set of products. In the case of exhaust suppliers, the standard product on which we base our analysis is an exhaust, comprising muffler, manifold and tubes. We are concerned with measuring productivity in the manufacture of such an exhaust, beginning from steel tube and sheet steel. This process involves a series of cutting, bending and welding operations.

In the case of seat suppliers, the standard product is a seat set for a passenger car (2 front and 1 rear (bench) seat). We look at productivity in the assembly process, and with two measures of quality. We measure productivity in terms of the number of seat sets, or exhausts, produced per man-hour in the assembly process. Quality is measured at two points. The first relates to the fraction of units found to be defective during the production process i.e. units pulled from the line, or units failing to pass final inspection (the 'internal defect rate'). The second is the 'external' defect rate (used in the previous section, i.e. a measure of the quality of units delivered to the car-maker).[7]

The levels of productivity among seat producers, both in China and India, is close to the 'world class' level of about 1-man hour per seat in the assembly process (Sutton 2005). In exhausts, however, production methods vary more widely, ranging from quite labour-

[7] In comparing levels of labour productivity the most obvious and immediate consideration to address lies in differences in the technique of production, as measured by the degree of capital intensity (or capital-labour ratio) chosen in different firms, or countries. Given that cross-country wage differences are typically far greater than differences in the cost of capital, we might expect that firms in low-wage countries would find it optimal to work at a lower degree of capital intensity, and so a lower level of labour productivity (as defined by the number of units of output per man-hour).

Matters are complicated, however, once the quality of units produced becomes pertinent. It may be, for example, that a low level of capital intensity makes it more difficult to reach acceptable quality standards.

intensive methods at one extreme, up to highly capital-intensive methods at the other, and labour productivity varies accordingly.[8]

In respect of quality performance, Figure 6 shows measures of defect rates. The external rate, which we already saw above, relates to the fraction of defects found by the car maker amongst part supplied, and this is the leading measure of quality as perceived by the purchaser. A threshold figure of 100 ppm is currently regarded by leading international car-makers as a benchmark for world class producers.[9] This threshold is exceeded for 14 of the 21 seat and exhaust firms reporting figures. Of the 14, seven are from China and seven are from India.

Seat makers in both countries achieve relatively good scores. Four out of the six Indian firms had no unit supplied to customers rejected in the past year. Five out of 6 Chinese seat suppliers have scores below 100 ppm, though only one has a score comparable to the top four Indian firms (reporting a level of 10 ppm).

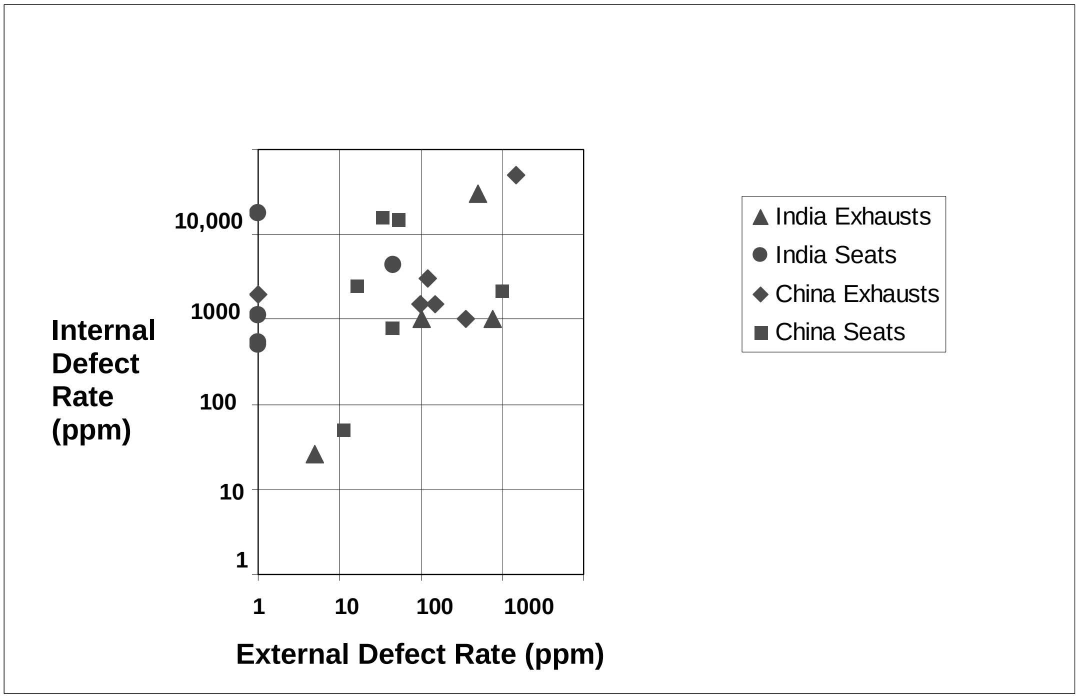
Exhaust producers in both countries have much higher external defect rates: two Indian producers and one Chinese producer attain rates below 100 ppm, while two further producers, (both Chinese) achieve rates in the range of 100-200 ppm. The tail of low performance is longer in India: one firm reported an external defect rate of 1% (10,000 ppm) while two firms were unable to supply a figure (and ancillary information on these firms suggest a figure exceeding 1%).

While this point is obvious, the trade-offs involved in this area can be quite subtle. For a full discussion see Sutton 2004.

[8] The difference in approach between seat makers (who use similar methods everywhere) and exhaust makers (who use widely different techniques) reflects the fact that seats must meet a much higher standard in terms of appearance, whereas for exhausts, the criterion is simply one of mechanical robustness; see Sutton (2004) for details.

[9] The Andersen study of 1996 identified a median level of 500 ppm for seats and 100 ppm for exhausts as the threshold for world class standards. However, industry-wide norms have advanced rapidly over the past 7 years, and a figure of 100 ppm is now regarded as the appropriate norm.

Figure 6: Internal and External Defect Rates



Note: The scale is logarithmic. Rates below 1 ppm are recorded as 1 ppm. Three firms did not report external defect rates. Two Indian seat makers had almost identical internal and external rates and the corresponding points are indistinguishable at (1,600) on the figure.

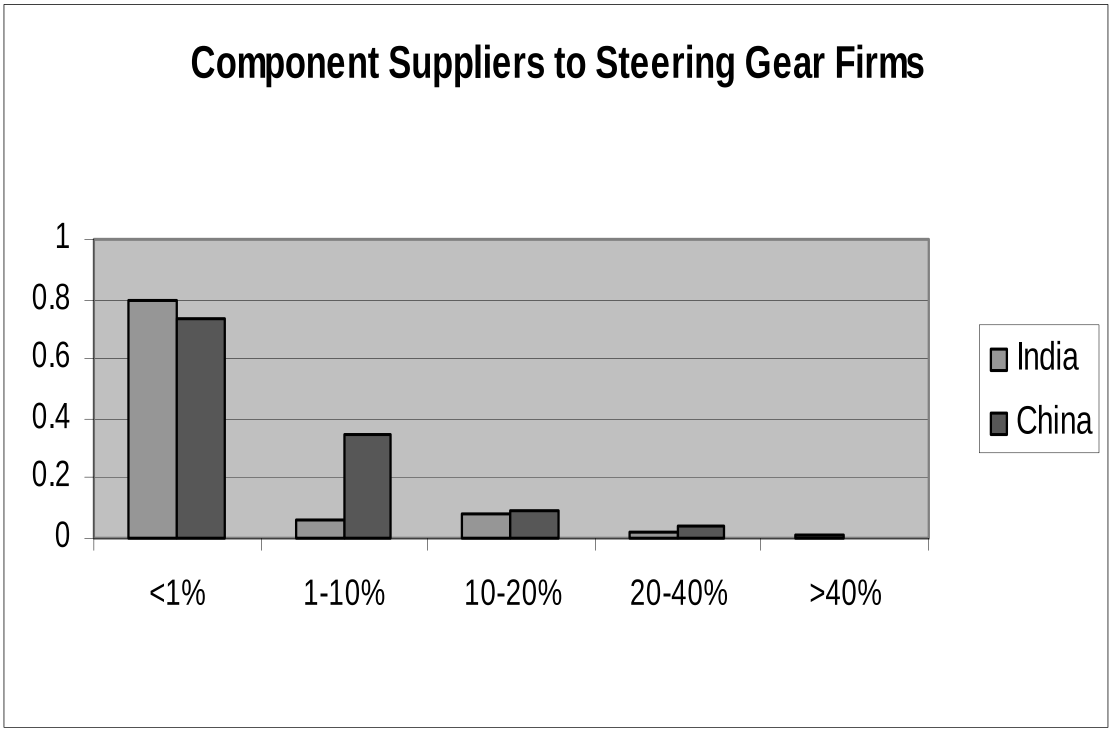
While external defect rates are directly relevant to buyers, the internal defect rate provides a key insight into the tightness of quality control during the production process. The internal rate is based upon a count of all units that are 'pulled from the line' during the production process, or which fail to pass first inspection. (Such units are normally set aside for re-work, though in some cases they may be scrapped). Internal defect rates are typically much higher than external rates. As Figure 6 illustrates, there is a clear positive correlation between internal and external rates; both reflect the tightness of quality control in the production process and in final inspection. External defect rates for both countries lie mostly in the 1000-10,000 ppm range; one-half of the Chinese firms and one-half of the Indian firms have rates of 2000 ppm or less, corresponding to the threshold for world class performance in the influential Andersen study of 1996.

In summary, then, it is clear that the auto-component industry in both countries has moved rapidly towards world class manufacturing standards over the course of the past decade. The speed of this process reflects the unusually well-developed institutional structure that exists between car-makers and suppliers, and in particular, it reflects the combination of a ‘demanding buyer’ with a supportive set of institutions that facilitate capability improvement. Once we move one step down the supply chain, we find a phenomenon which exists across developed industrial economies, but which arises in an acute form in the Chinese and Indian context. The (first tier) suppliers who sell directly to the car-makers source many of their own components from a second tier of suppliers, but in dealing with those suppliers, they tend to accept a more lenient trade-off between the quality of components and the price tendered by the potential supplier.

Figure 7 shows the profile of defective parts received by a matching pair of typical first tier suppliers in China and India. In each country, the firm we look at is a supplier of steering gear and allied components to a range of leading car-makers and other first-tier suppliers. The range of components it produces is broad, and it buys in a range of components and sub-assemblies that require a series of machining and assembly operations. As we move down the supply chain towards producers of this kind in the U.S., Japan or Europe, it is usually the case that the distribution of defect rates for incoming parts becomes less favourable, in comparison with the corresponding distribution for car-makers.

What is striking about the distributions shown in Figure 7, however, is how wide this disparity is both for the Chinese and the Indian suppliers. In each case, the steering-gear manufacturer experiences extremely high rates of incoming defects. These rates are measured, not in parts per million found defective, but rather in terms of the percentage of incoming batches found to be (un)acceptable on first inspection. (Random samples are drawn from each batch on arrival. If the sampled parts are defective, the batch is returned to the supplier, who will carry out a full inspection, and reject or rework as necessary before sending a replacement batch). The threshold of interest is the percentage of batches deemed unacceptable at first inspection. Some 60% of Chinese suppliers and 80% of Indian suppliers achieve a figure of 1%. The tail of the distribution in each case is extremely long. About 4% of each firm’s suppliers have over 20% of their batches rejected on first inspection.

Figure 7: Supplier Defect Rates for Steering Gear Producers



It is here that the main weakness of the supply chain, relative to those of the U.S., Japan and Europe is evident. Manufacturing best practice has spread remarkably quickly to first-tier suppliers in both India and China over the past decade, but these practices have not as yet permeated through the lower tiers of the supply chain. Discussions with firms in the course of this study suggest an explanation. The spread of best practice among first-tier suppliers was driven by pressure from the car-makers during the late 1990s. These first-tier suppliers found themselves under pressure from the car-makers, not only on quality, but also on price. Car-makers worked actively with some first-tier suppliers to achieve low defect rates, while other first-tier suppliers were joint ventures with multinational component suppliers who introduced best practice techniques. But when these suppliers turned to their own ('Tier 2') suppliers they faced a trade-off. Should they stay with a low-cost supplier, and accept high defect rates, or move to a higher cost supplier? High defect rates can be dealt with by spending more man-hours on the inspection of incoming parts, which are sent back to the supplier if found defective. In a low-wage environment, the cost of inspection and of reworking may be more acceptable to the buyer and seller. Only when the first-tier supplier begins to work closely with suppliers, and to de-select suppliers who have high defect rates, is best practice likely to spread. While our interviews with component suppliers suggest that this process is occurring, it is also clear that it is happening only very slowly in both countries, and in contrast to first-tier suppliers, who face tough selection effects in their relations with car-makers, the threshold for de-selection among second-tier suppliers can be very high, as buyers will accept quite high defect rates in return for lower prices.

7. A Timescale for Capability Building

One question of central importance relates to the timescale for capability building: how long does it take to reach world-class levels of quality? Conventional wisdom among multinational component producers involved in the present study is that starting with a new workforce on a greenfield site is a major advantage: one executive based at the world headquarters of a multinational seat maker remarked that he would expect to be able to achieve world-class quality standards at a greenfield plant in any country within one year of its establishment. If, however, he was operating in a joint venture with an established local seat maker, this process might take three years. The difference reflects the slowness of "relearning": if established routines are in place, it is hard to change them; beginning from scratch is easier.[10] While the figures suggested may be optimistic, this key difference is bourne out by the (limited) set of observations we have been able to make of the time profiles of external defect rates in selected participating firms. For example:

- A multinational seat-maker operating on a greenfield site in India experienced an initial level of its external defect rate of 2,085 ppm (as compared to a "world-class threshold" of 100 ppm). In its third year of operation, this rate had fallen to 65 ppm, close to the 50 ppm level regarded as "award class" by multinational seat makers.

- One of the leading domestic seat makers on the Indian market began in the mid-90s to introduce international best practice procedures. Beginning from an initial external defect rate of 20,000, it took five years of steadily-improving performance to bring this figure down to its present level of 200 ppm.

Among multinational seat and exhaust makers, engineers from high performing plants are regularly transferred to newly formed joint ventures with established domestic producers.

[10] The difference also reflects, in some of the plants visited, the existence of prior contractual agreements on incentive schemes and payment systems, and on working practices, that are hard to change.

One engineer, who had been seconded from a world-class greenfield plant in India to a recently-established joint venture plant in China, remarked that his six-month stint would be “largely a matter of talking”. It was not, he remarked, the obvious alterations to the physical plant that mattered, but rather inducing a shift in work practices. At the most elementary level, this would involve a move away from traditional notions of “inspection at the end of the production line”, to a system in which each operator along the line searched for defects in each seat section as it arrived, and as it departed: the idea of such constant monitoring is in part to avoid “adding value to defective units”; more importantly, it is to set the basis for a system in which the sources of defects are quickly identified and rectified.

8. Going it Alone

The firms in the auto-component supply chains are a mix of independent domestic firms and joint ventures with multinational component producers. Indeed, about half of auto component exports from both China and India are produced by independent domestic companies, who go it alone in building up their capabilities. So how do these firms adapt?

A striking illustration is provided by a long-established Indian manufacturer of mechanical components (steering-gear and related parts). In order to win and service a major new export contract from a multinational car-maker, the firm recently established a new small-scale plant alongside its main premises. Employing a small workforce of male and female operatives, all in their early twenties, and with no prior employment experience, the plant is organized along ‘Japanese’ lines: each operative is responsible for all aspects of his or her work area, including sweeping and cleaning. All shop floor workers, whether skilled or unskilled, spend a month working as cooks in the canteen, in order to instil a sense that everyone is working as an equal member of a team, whose shared aim is to achieve the highest possible levels of quality.

This is an extreme example, but it is illustrative of a broad tendency that was evident in about one-half of the Indian seat and exhaust producers visited in the course of the study: the achievement of high quality standards goes hand in hand with an erosion of traditional patterns of hierarchy within the plant. The emphasis, instead, is on building teams of equals, who work in close cooperation (via ‘quality circles’ etc.) to bring about a steady flow of minor innovations in working methods, whose cumulative effect is substantial.

9. Virtuous Circles: Piggy-backing the Supply Chain

One of the most crucial indirect benefits of the recent wave of international joint ventures in the car industry, lies in the fact that these ventures stimulate the development of capabilities in the domestic supply chain – allowing domestic car-makers to benefit from new possibilities in outsourcing from low-price, high quality suppliers. Perhaps the most striking instance of the mechanism in an Indian context is the case of Mahindra and Mahindra, one of India's leading producers of commercial vehicles and tractors. In 1994, the company went through a major restructuring, one outcome of which was a new policy shift in favour of substantial outsourcing of components and sub-assemblies. Over the following four years, virtually all components, other than engines, transmission systems and body (skin) panels began to be outsourced. For engines, the head and block were bought in from a local supplier in semi-finished form; all transmission components were bought in. For rear axles, the centre bracket was bought in as a casting and machined in-house, but the tubes and shafts were bought in from local suppliers in fully finished form. This shift in reliance on the local supply chain came to a peak with the firm's introduction of the Scorpio van, a light multi-use vehicle launched in 1998. The Scorpio van was designed in-house, using an Italian design house as a consultant on styling, and the outsourcing policy was pushed to new levels, with a network of 110 local suppliers. This permitted unit production costs to be much lower than would have otherwise been possible, and allowed the Scorpio to be sold at an ex-dealer price (including air-conditioning and power steering) of 5.5 lakh rupees ($11,000), which was around 60% of the price anticipated by industry observers at the time of its launch. Sales of the Scorpio transformed the financial fortunes of Mahindra and Mahindra over the five years following its launch.

10. Problems and Policies

The process of transfer of capabilities is at its most rapid and effective in the auto components sector. As we move across the industrial spectrum towards more typical industries such as machine tools, a different picture emerges: one in which adjustment is slower, and in which industries' longest established firms may fail to survive, but in which new entrants with a different approach may sometimes succeed (Sutton, 2001). How can public policy help?

Across the industrial spectrum as a whole, the most central issues of public policy are those related to reducing 'the cost of doing business', or in Bank parlance, 'improving the investment climate'. Measures that improve infrastructure or reduce the regulatory burden on companies are equivalent in their effect to an across-the-board rise in the capabilities of all the country's firms, and so these measures translate, within the present analytical framework, into a general rise in the level of real wages.

What I would like to close with here, however, is a series of remarks on some public policy issues surrounding the transfer of capabilities. I would like to distinguish between indirect methods of attack which aim to induce firms to transfer know-how, as against direct methods in which independent agencies act as a conduit of information to domestic companies.

Among the indirect methods of attack lies the use of domestic content requirements. In the decade prior to WTO entry, both China and India used domestic content restrictions to stimulate development of the component industry, with a view to widening and deepening the benefits accruing from attracting international car-makers. The requirements were stringent, requiring about 70% domestic content within about 3 years, and this led to adverse comment from some of the car-makers who cast doubt on whether this target was feasible or sensible. Policies of this kind are not always appropriate, or successful; but in the present cases the 'infant industry' has been successfully nurtured, and international car-makers show no inclination to turn away from local suppliers following WTO entry. It should be emphasized, however, that the apparent success of this policy rested inter alia on the fact that both of these countries had extremely large domestic markets. The use of such restrictions by smaller countries would be highly unlikely to prove successful.

One of the key benefits from the development of enhanced capabilities in the component supply chain lies in the fact that it can lead to increases in exports of components and sub-assemblies from domestically based firms to overseas car-makers. While the development of the local supply chain in both countries has in large part been driven by the presence of multinational car-makers, component exports are driven equally by multinational and domestic firms. Both India and China have a substantial body of purely domestic firms that have achieved major successes in export markets; of the top ten component exporters in China, six are domestic firms; of India's top 10, half are domestic firms (and three of these belong to a single domestic industrial group).

Finally, I would like to turn to direct methods of support. Here, the key issue lies in establishing an institutional framework within which domestic companies, and newly established companies in particular, can have access to channels of information and training in respect of international best practice in manufacturing. Channels of this kind are notoriously lacking in the developing world, and one of the key levers of a well-designed industrial development policy lies in providing channels of this kind. Sometimes, remarkably successful channels emerge as a result of collaborative work by domestic companies: a good example is provided by the Confederation of Indian Industry, which is almost wholly funded by the private sector, and whose incentives are geared towards providing accessible services of this kind at a level of fees which brings them within the reach of smaller manufacturing companies. Other types of channel have been developed, notably in Eastern Europe and the CIS countries, by USAID, the IFS and the EBRD. The key to these efforts lies in creating networks of companies to whom access to advice on manufacturing practices can be provided on a continuing basis. To choose one (rather arbitrary) example, taken from Azerbaijan, a group of 38 companies operating in the food and drink sector has been assembled, and companies in the group are moving effectively towards achieving international standards in terms of quality and production processes. The close linkage between providing (access to) finance in parallel with active interventions to cultivate improved capabilities is central to the approach, and stands in stark contrast to my opening image of the empty Tanzanian factory.

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