Rich Trades, Scarce Capabilities: Industrial Development Re-visited[*]

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Abstract

What economic mechanisms underlie the polarisation of the world economy into the 'high wage' industrialised countries, and the less developed 'low wage' countries? Should we expect the two groups to converge over time, or to diverge? What economic mechanisms come into play as LDCs attempt to 'catch up'? How does the current liberalisation of world trade, or 'globalisation', impinge on these countries, and how does it affect the prospects for 'convergence'?

In this paper I bring together two recent economic literatures which have developed independently of each other over the past decade. The first is the 'Geography and Trade' literature, which has cast new light on how the dichotomy between 'rich' and 'poor' countries evolves. The second literature is the modern 'market structure' literature, which examines how global industries may of necessity be dominated by a relatively small number of leading producers.

At the heart of this discussion is what I shall label 'scarce capabilities': just as the Golden Age of the Dutch republic was founded on the establishment of its dominance of the 'rich trades' (the maritime sea-routes to the Indies and the Caribbean), so the wealth of modern industrialised economies rests on the network of firms that enjoy 'scarce capabilities', the rent from which manifests itself primarily in the form of high real wages in their domestic labour markets. How this comes about, and how it persists, is my central theme.

Keywords: globalization, scarce capabilities, geography and trade

JEL Classification: O00

Introduction

In the last decade of the sixteenth century, the Dutch republic underwent a dramatic economic transformation that laid the foundation of the country's Golden Age. At the heart of this process was the rise of the 'rich trades', the network by which Dutch shipping came to dominate the lucrative trade routes to the East Indies, the Americas and the Levant (Israel (1990)). The rise of the 'rich trades' provides me with an archetypal example of the economic process which I want to explore in what follows. Many of the themes which I develop below emerge clearly in the Dutch story: the steady displacement of an old and well established bulk-carrying trade in which the Dutch had so long excelled by this hugely more lucrative new activity; heavy fixed outlays in building up a network of supporting facilities; the growth and development of a series of domestic industries that could benefit from the export opportunities opened up by this new shipping activity; and, most importantly - a huge rise in real wages in the Dutch Republic, relative to levels in neighbouring countries.

It is this last feature of the process, the rise in real wages, which forms my point of departure. It would seem that some kinds of economic activity are more lucrative than others; and countries specialising in such activities will enjoy a higher level of real wages than their neighbours. From the viewpoint of classical economic analysis, this line of argument invites a number of immediate objections. If some activities are more lucrative than others, will not new entrepreneurs, firms or countries flock to these activities, driving their net returns back to some 'normal' level? If free movement of labour across countries is possible, then labour flows will offset the wage differential; while if labour is not free to move, firms will shift their 'lucrative activities' to low wage regions, thus again offsetting the wage differential. At the heart of my story lie two ideas: the first concerns 'scarcity', the second 'immobility'.

The notion that some activity remains lucrative demands a story about scarcity: I will locate this scarcity in the capabilities of firms (Nelson and Winter (1982)), where 'capability' can be thought of as comprising two elements: a measure of the maximum quality level that the firm can achieve, and a measure of its cost of production (productivity), for each product line. It is a firm's relative capability vis-a-vis its rivals that will turn out to matter in what follows. In fact, there is a 'window' within which a firm's capability must lie, if it is to earn any sales revenue at all. Competition between firms to enhance their relative capabilities, moreover, will involve, inter alia, an escalation of their spending on R&D and other fixed outlays, and the effect of this will be to shake out all but some limited number of active firms in any market (independently of the size of the global economy). It is in this sense that capabilities become 'scarce'.

Now if a single firm can improve its capability relative to all its rivals, it will enjoy a 'rent of ability' in the form of enhanced profits. If, however, several firms attain a similarly high level of capability, this rent is dissipated in part via price competition, to the benefit of consumers. Now suppose this group of 'highly capable' firms are clustered in some geographic area, and suppose labour is imperfectly mobile across areas. Then the effect of this enhancement in the firms' capabilities, relative to those of firms outside this region, is to push up the demand for labour in the region. I will argue that the primary beneficiaries of local firms' enhanced capabilities are not the firms themselves, but the local workforce on which they rely; their superior capabilities translate into high real wages.

To complete the story, I need to explain why the resulting real wage differentials can persist: why do 'high capability' firms not move to 'low wage regions'? Here, we come to the crux

of the matter: I argue that the 'capability' in question is embodied in the set of workers that comprise the firm; and imperfect mobility of even some individual workers may imply that any re-location of the firm's activities may involve costs sufficient to outweigh any putative gains from lower wages.

But why should the group of 'high capability' firms be clustered in the same geographic area? Why can they not be scattered uniformly across all regions? Here, I appeal to the mechanism that lies at the heart of the recent 'Geography and Trade' literature (Fujita, Krugman and Venables (1999)), which turns on the input-output linkages across manufacturing firms. Two-thirds of manufacturing output consists of intermediate goods, sold by one firm to another. The presence of a rich network of manufacturing firms provides a positive externality for each firm in the system, allowing it to acquire inputs locally, thus reducing the costs of transport, of coordination, of monitoring and of contracting. Once this effect is allowed for, the location decisions of firms become interdependent; a 'divided world' may emerge, in which a network of manufacturing firms is clustered in some 'high wage' region, while wages in the remaining regions stay low.

Now the 'Geography and Trade' literature provides a highly plausible account of how the division into two groups occurs. But what does it imply for the process of 'catching up'? What it places at the centre of the analysis is the interdependence of a network of domestic firms; so that the main 'barrier to development' lies in the diseconomies faced by any single firm in relocating itself (The 'all-at-once' problem). Now this is, I will argue, only one half of the problem. To understand the other half of the problem, I will argue, we need to look once again at the nature of 'capabilities'.

In the second half of this paper I will illustrate some of the ideas involved by looking at the Indian machine tool industry. In this case, the industry is well supported by a well-developed mechanical engineering industry, and the focus of its difficulties following the recent liberalization of India's trade regime lie, not in the 'all-at-once' problem, but rather in the challenge of keeping in step with the international "quality window". It is in the integration of ideas about quality competition, which come from the recent 'market structure' literature (Sutton (1998)), with the ideas regarding clustering which emerge from the new 'Geography and Trade' literature that the novelty of the present analysis lies.

1. Capability, Quality and Wages

The first step in the argument is best illustrated by sketching out a simple example involving two countries, 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 industry comprises a number of firms producing distinct substitute goods of varying levels of quality. All consumers have the same tastes; consumers devote one third of their incomes to the products of each industry[1]. Higher quality products command a higher price at equilibrium: relative prices are such that consumers are indifferent between any two products which command positive sales at equilibrium, given the qualities and prices of these products. 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.

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 v_A and those in Country B at quality level v_B. In industry 3, all firms in both countries produce at the same fixed quality level.

Now if $u_A = u_B$ and $v_A = v_B$, 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 and v_B fixed, let u_A and v_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

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[1] The details of this kind of model are developed in Sutton (1991,1998). In particular, Chapter 3 of Sutton (1991) provides a simple example in which consumers are equipped with a Cobb-Douglas utility function, and so divide their income in some fixed proportions between the various goods, independently of their relative prices.

lower it in country B. Meanwhile, more production of the third industry shifts to country B; real wages remain the same in both countries.

As u_A and v_A rise further, however, all production of these industries shifts to country A. A key property all models of this kind is that if the ratio u_A/u_B is sufficiently high, then (so long as two or more firms offer quality u_A) at equilibrium prices all consumers will choose the high quality good. The equilibrium price of this good will be so low that, even if producers of the low quality rival good offered it at a price equal to its marginal cost of production, consumers would still prefer to buy the higher quality good. In other words, given u_A, there is some threshold quality $\underline{u}$ below which country B will earn no sales revenue from this good.

As u_A and v_A rise, 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)[2].
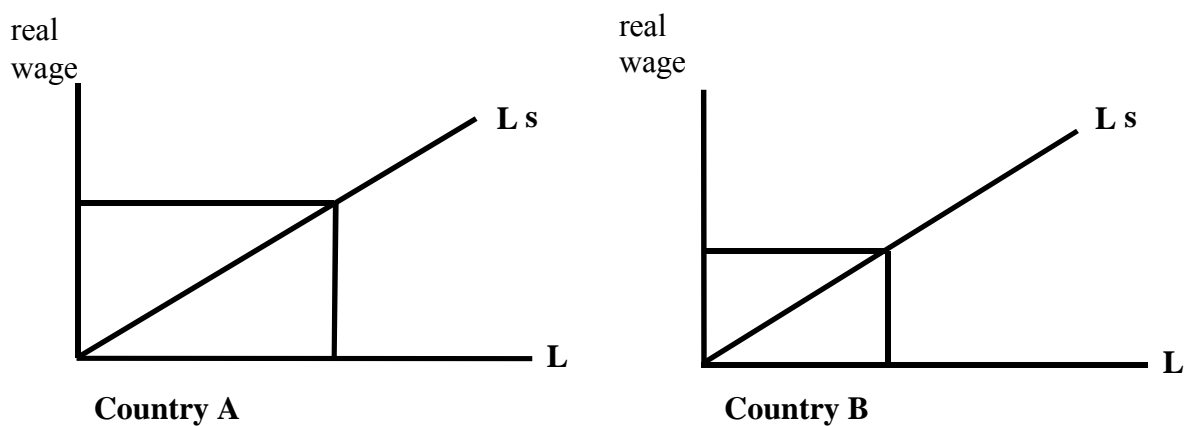

Figure 1.   Quality and wages in the two-country model, where $u_A \gg u_B$, $v_A \gg v_B$.

This notion of a 'quality window' generalises easily to a setting in which each firm is described by a 'capability' expressed as a pair of numbers (u,c), representing the (maximum) quality level it is able to offer, and its productivity, i.e. the number of units of labour input required per unit of good produced[3] (Figure 2). A further generalisation lies in introducing several different markets (or submarkets), so that the firms 'capability' is now expressed as a vector, specifying a (u,c) pair for each 'technological trajectory' along which it develops expertise, and so for the market (or submarket) in which it sells goods embodying that capability[4].

The notion of the 'window' carries over directly to this more complex setting (Figure 4): firms whose (quality, productivity) combination falls below a threshold in (c;u) space will not achieve any sales in the associated market[5].

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[2] As this number rises, we may approach a zero profit equilibrium, in which the number of firms is such that gross profit exactly covers the fixed outlays (R&D etc.) incurred by each entrant in achieving its quality level u_1.
[3] For the equivalence between the 'quality' (product innovation) model and the 'productivity' (process innovation) model, see Sutton (1998), Appendices 14.1, 15.1.
[4] For details regarding this more complex setting, and a definition of 'technical trajectories' and their associated 'submarkets', see Sutton (1998), Chapter 3.
[5] Readers interested in the technical details may wish to consult Sutton 1998, Appendices 14.1 and 15.1, where an example is developed within which a firm's capability can be expressed simply as a ratio u/c; I have used this example in drawing Figure 3.
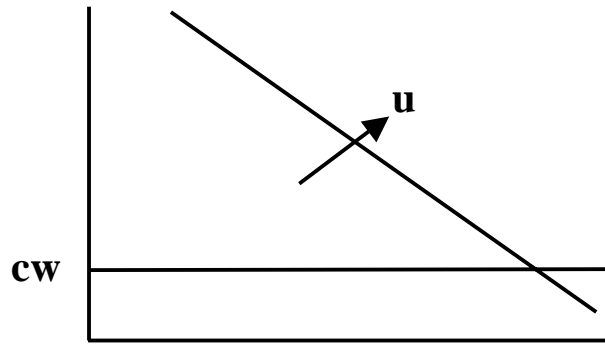
Figure 2.   A firm is represented by its capability (u,c) along each technological

trajectory.   The parameter c measures its productivity, its unit cost of

production being cw, where w is the local wage rate.   The parameter u

measures 'quality'.   A rise in u shifts demand outwards, given any level of

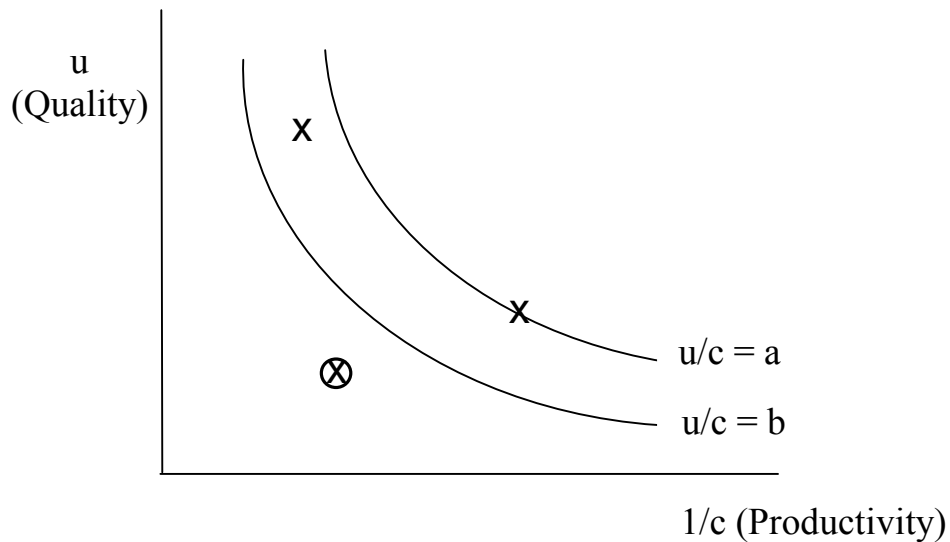prices and qualities offered by the firm's rivals.

Figure 3.   The window of capability (a,b). The firms denoted by x are viable; the firm

denoted by $\otimes$ 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.

Scarce capabilities: the escalation mechanism

So what is capability?   What determines the levels of attainable quality, and productivity? The list of proximate causes 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 among 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 certain fundamental results will follow[6].

The central idea is that in this kind of setting, there will be a lower bound to market concentration[7]; the number of firms that survive in the 'window' will be limited - and this limit or 'bound' on the number of active firms will remain constant, irrespective of how large the global market becomes.   As the global market grows, the effect is not to draw in an ever-increasing number of active firms; rather, it is to enhance the efforts made, and the fixed outlays spent, by a relatively small   number of active firms, whose efforts raise their capabilities, and so raise the 'window' within which any viable firm must operate.   This carries some serious implications for the analysis of the effects of globalization, as we will see in what follows.

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[6] 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). 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.

[7] The term 'market concentration' relates to the degree to which the market is dominated by a few large firms; it is conventionally measured as the combined market share of the largest 4 (or so) firms in the market.

So what determines the number of active firms, or the level of market concentration? The answer turns on the following question: suppose that some firm was to enter the market, whose capability exceeded that of all currently active firms by some factor, which we may label as 'k'. How great would be the gross profit[8] earned by such a firm in the new post-entry equilibrium, expressed as a proportion of the industry's current (i.e. pre-entry) sales revenue? Label this ratio a(k)[9]. To complete the picture, we ask: how effective are fixed outlays (such as R&D, say) in raising capability? Specifically, denote by β the elasticity of response of u (or of 1/c), to increases in fixed outlays[10]. The bound to concentration in the market is a simple function of these three numbers; it is increasing in a, and decreasing in k and in β[11].

To show what is implied by all this, it is useful to move to a concrete and realistic setting in which firms face a number of alternative routes along which they might proceed in developing their capabilities.

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[8] i.e. profit prior to the deduction of fixed outlays incurred.

[9] To be more precise: the answer to this question will depend upon the way in which existing firm's capabilities are distributed, relative to the existing 'top' level of capability; so in defining a(k), we need to choose a 'worst case', in order to be able to guarantee that our new entrant will earn a profit at least equal to a(k) times current industry revenue. In choosing k, ('the size of jump') on the other hand, this is a parameter under the entrant's control, and so we can choose the value that yields the highest resulting profit. Readers interested in a precise statement of this basic 'nonconvergence' result may wish to consult Sutton (1998), Chapter 3. The basic idea can be traced in the literature to Dasgupta and Stiglitz (1980) and Shaked and Sutton (1987).

[10] i.e. a 1% increase in u (or in 1/c) requires a β% increase in fixed outlays.
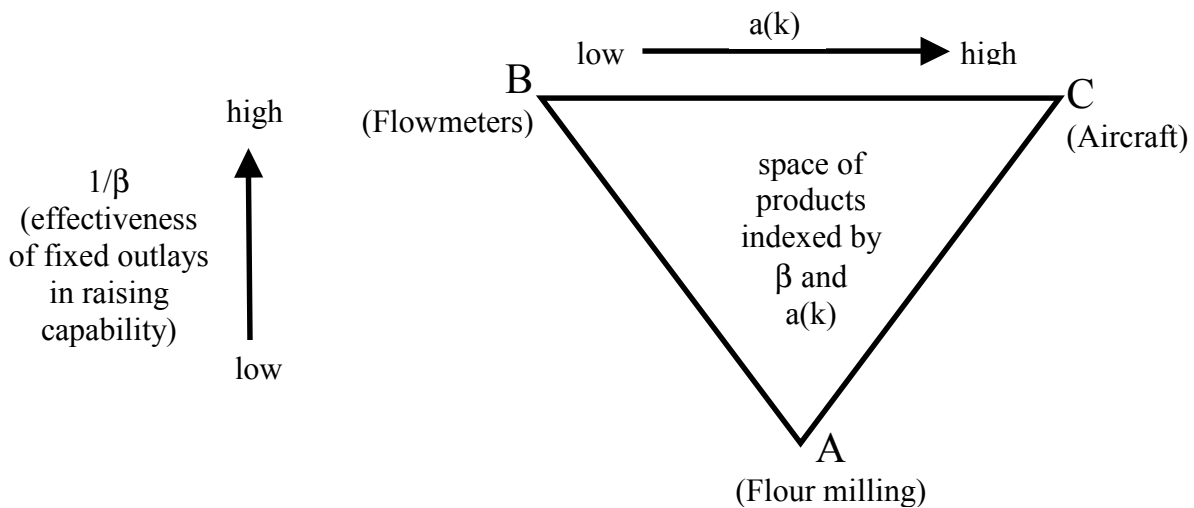
Figure 4.   A figurative illustration of the way in which the pattern of industry evolution

is driven both by the effectiveness of fixed outlays in raising capability

(measured by $1/\beta$), and by the gross profits generated by raising u along any

single trajectory, expressed as a fraction of industry sales revenue (measured

by $a(k)$).   Concentration is low at both A and B, in the figure, and high at C.

Spending on fixed outlays (as measured, say, by the ratio of R&D outlays to

industry sales) is low at A, but high at B and C.

A figurative illustration of the way in which the three parameters impinge on market structure

is sketched in Figure 4. The story goes as follows: if the effectiveness of fixed outlays, as

measured by $1/\beta$, is low, then the fraction of industry revenue devoted to such spending will

be low.   This situation corresponds to those 'low-tech' industries where methods of

production, and product design, are standardised (Point A in Figure 4). This is the setting

captured by the monopolistic competition models used in the current 'Geography and Trade'

literature.   Where, by contrast, the effectiveness of such outlays is high, we will see firms

vying to enhance their relative capabilities.   The resulting outcome depends on $a(k)$ and it is

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[11] Formally, at equilibrium at least one firm in the market must have a share of industry sales revenue that

useful to look at two polar cases. There will, in general, be various directions in which capabilities can be advanced (i.e. "alternative technical trajectories" along which R&D outlays can be spent), and associated with each of these will be a different set of products that can be offered (Figure 5). One polar case arises when, for a given 'size of jump' k, the returns (as measured by a(k)) are small relative to industry sales revenue: here, the different trajectories lead to alternative types of product each of which commands a certain share of total demand, even if it lags in quality behind the others. The 'flowmeter' industry is an archetypal example of this scenario: flowmeters come in various types, each associated with a different form of technology (electromagnetic, ultrasonic, etc.). Different groups of users will strongly prefer one of these to another, depending on the nature of the application (oil pipelines; general chemical plant; etc.). The evolution of this (kind of) industry is characterised by a proliferation of new product types as new technological trajectories are explored. The result is that the global market can support a large number of players, and relatively small firms can achieve viability by specializing in a single product type.

(a) the 'Flowmeters' case   **(b) the 'Aircraft' case**
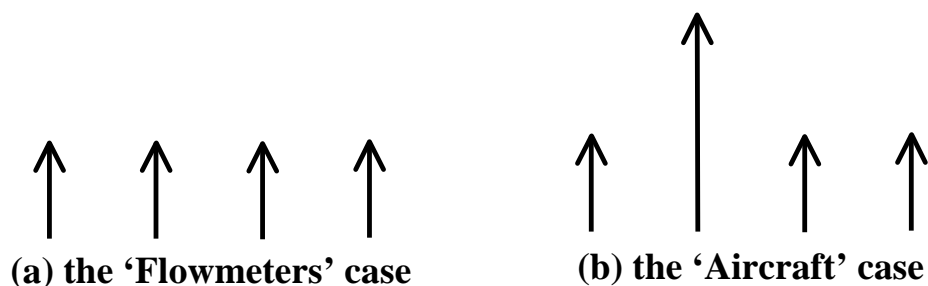
Figure 5.   How industries evolve: two polar cases.

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exceeds a(k)/k^β (Sutton (1998) Chapter 3). A lower bound to concentration is obtained by taking the value of k which makes this ratio as high as possible.

The other polar case is illustrated by the early history of the aircraft industry. In the early 1930s, various technical trajectories were followed, and alternative designs proliferated (monoplane, biplanes, and triplanes; planes of metal and non-metal construction; land planes and seaplanes). The objective function of the various airlines was, however, identical: they wanted a plane that could achieve a high level of operating efficiency, as measured by the 'cost per passenger mile'. By 1936, the launch of the Douglas DC-3 established the superiority of one particular trajectory; from this point forward almost all efforts would be focused on the launch and improvement of single wing all-metal monoplanes, with a particular ('cantilevered') form of wing design.

In terms of the theory, this polar case corresponds to a situation where, for a given k, the value of a is high. If higher quality (here, lower costs-per-passenger mile) can be attained along any one trajectory, buyers will readily switch their allegiance from other forms of product: all that matters is a single criterion. Industries of this kind will necessarily move towards a highly concentrated market structure, in which a small number of players dominate the global market.

So what does a(k) measure? In terms of the present example, it can be seen as a measure of the degree to which the products associated with different technical trajectories are good substitutes: the degree of substitutability of these goods in buyers' eyes is one determinant of the value of a(k). More generally, what matters is the strength of the linkages between these trajectories, both on the demand size (product substitutability in the eyes of buyers), and on the supply side (the presence of scope economies in capability building, which allow advances in capability on one trajectory to automatically enhance capability on another trajectory, or to reduce the cost of enhancing that capability).

So what does this imply for the evolution of market structure? Where the effectiveness of fixed outlays is low (point A in Figure 4), we can have a fragmented industry structure, with many small firms; here, the levels of capability of all firms can converge to a similar level. As we move up the diagram, however, firms' fixed outlays, and so their capabilities, rise: and to achieve viability, a firm must be in the relevant 'window'. What distinguishes outcomes B and C in the diagram is the mechanism just noted, according to which we may move to a fragmented structure (proliferation; point B) or to a concentrated one (escalation; point C). In both cases, however, achieving viability within any product category requires a capability that lies within the relevant 'window'. Once fixed outlays constitute <u>one</u> of the available routes to improving capability, the number of viable players in the global market will be bounded.

In this section, I have drawn on the recent Industrial Organization literature to show how competition in 'capability building' will shake out all but a limited number of competitors in the production of final goods in any (narrowly defined) product group. This begs the question: if there are many trajectories and related product groups, why can we not have a 'homogenous' world economy in which these 'viable' firms are scattered evenly across all geographical regions? It is at this point that I turn to the recent 'Geography and Trade' literature, whose main focus over the past decade has lain in tackling this question.

2. Clustering

The answer proposed by Krugman and Venables turns on the notion of supply-side linkages between firms. Specifically, it depends on the degree to which a firm can reduce its costs through buying and selling intermediate goods (materials, components and sub-assemblies) from local firms, as opposed to firms operating in other regions. Translating the Krugman-Venables argument into the present context, what it supposes is that our 'high quality' firms enjoy a positive externality from the presence of other 'high quality' firms within the same region.

Using the Krugman-Venables diagram, we depict in Figure 6 one kind of pattern that may develop. If the links are weak, a 2-country world will have an equilibrium in which our 'high capability' firms are uniformly spread across the two countries. Once the linkages become stronger, however, a split develops, with one or other country emerging as the 'high-wage' country. This 'externality' provides one reason why, once the pattern has emerged, no one 'high capability' firm will find it profitable to migrate to the lower wage region. Only if a whole cluster of interdependent firms migrate together, will the wage-cost gains outweigh the cost increase caused by the loss of the relevant linkages.
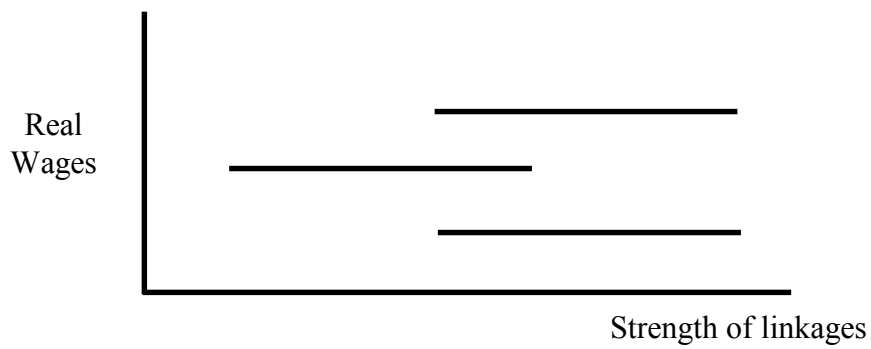
Figure 6. Clustering (Krugman-Venables). The case illustrated here is one in which, when the strength of linkages takes an intermediate value, there are two types of equilibria (homogenous world/divided world).

My focus here lies, not in re-stating the arguments of Krugman and Venables to explain how we get to a bipolar world[12], but rather in asking: 'once we are in a bipolar world', is it stable? More particularly, what barriers lie in the way of firms in the 'disadvantaged' region, when they attempt to catch up?

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[12] For these arguments, see Krugman and Venables (1995) and Fujita, Krugman and Venables (1999).

3. High Quality Firms, Low Wage Workers? A Question of (Im)mobility

Why does any individual high-quality producer not move to the low-wage country? The answer given in the 'Geography and Trade' literature rests on the notion of interdependencies among firms: each firm relies on suppliers of intermediate inputs. A wholesale move of all firms would simply raise wages in the country of destination; a move by a single firm would deprive it of sources of (accessible, local) supply, which would result in its incurring transport costs (and perhaps other 'coordination' or 'contractual' costs) with distant suppliers.

Here, I want to suggest an additional mechanism. This mechanism rests on the notion that a firm's capability is embodied, not only its property rights (by way of patents, etc.) but, more importantly, on the 'tacit knowledge' possessed jointly by those individuals who comprise the firm's workforce.

To illustrate what I have in mind here, let me invoke a simple schema, illustrated in Figure 7. Imagine a set of discrete tasks that may need to be accomplished in the course of developing the next generation of products produced by the firm, along some given R&D trajectory. So long as one employee knows how to do task i, this knowledge can be passed to others at negligible cost. On the other hand, if we remove all those individuals who can do task i, then the firm incurs a cost (of delay, or otherwise) as the lost knowledge has to be (re-)learned or (re-)invented.

Now imagine a firm in which a large number of employees each carry out a small number of 'standardised' tasks (Panel a). Here, a small fractional reduction in the workforce deletes no 'knowledge'. By contrast, take a firm where certain tasks/elements of expertise are the

preserve of a small number of workers; now the loss of a small fraction of workers can result in a substantial loss of know-how (Panel b).
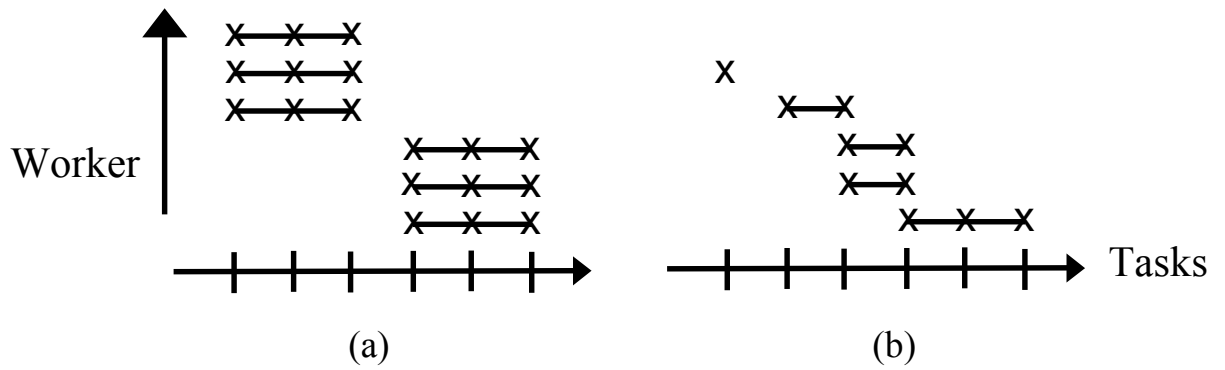

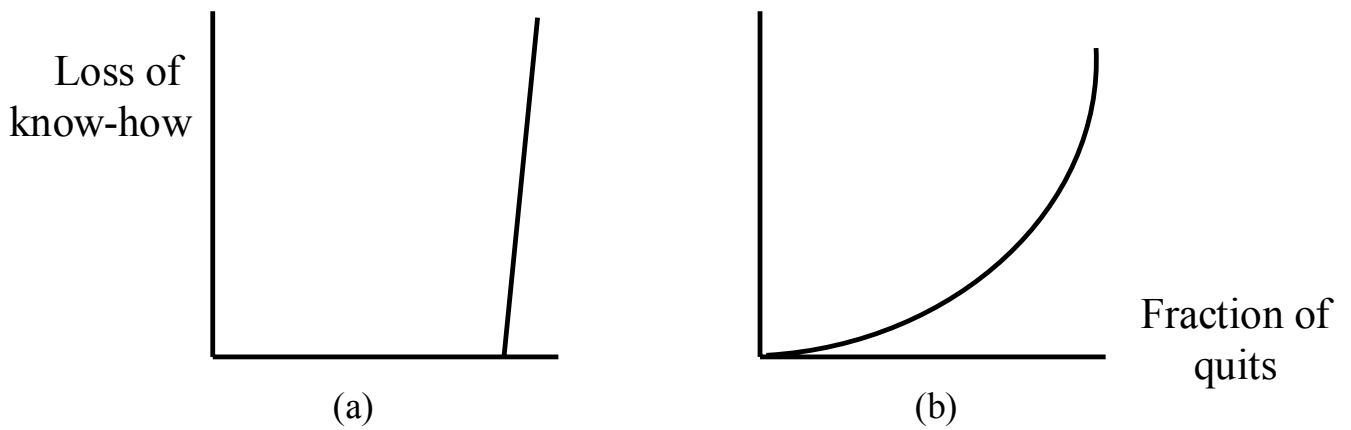Figure 7.　　The spread of expertise: two extreme cases.

Figure 8.　　The loss of know-how, expressed as a fraction of tasks, which follows when every second worker quits (Panels (a) and (b) correspond to panels (a) and (b) of Figure 7, respectively.

What is striking about mobility patterns of multinational firms is that they show a high propensity to shift to low wage countries those kinds of activity illustrated in panel (a) of Figures 7,8; but to retain in their domestic market those activities which demand the 'core competencies' embodied in scarce know how, illustrated in panel (b) of the figures. In this latter case, while a slow rate of turnover of labour involves no substantial cost (in any one 'period', the loss of a single worker involves no loss of collective know-how; next period's incoming workers can be trained at minimal cost), moving the firm to a new country will involve the loss of a significant fraction of 'immobile' individuals who will quit rather than move[13], and so will imply a costly loss of collective know-how. So what I want to argue here, is that once the capabilities are embodied, via 'domestic' firms, in 'domestic' employees, the firm is no longer (perfectly) mobile in the face of real wage differentials. The 'divided world' scenario becomes an equilibrium.

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[13] The introduction of 'compensating payments' to such individuals leaves my argument unchanged.

4. Globalization Pains

It is time to turn from the description of the model, to some of its implications. Within the framework I have sketched above, the impact of trade liberalization derives from two basic mechanisms:

- an intensification of price competition which squeezes price-cost margins for all firms;

- a consequent narrowing of the capability window in which firms operate, as the minimum level consistent with viability rises.

Firms' optimal responses to these pressures involve an increase in resources devoted to raising capability, leading to a further upward shift in the window. Firms beginning with a lower level of capability now face a dilemma: depending on how low their current capability is, it may or may not be worth investing the necessary effort in re-establishing viability; for weaker competitors, the optimal strategy may be to quit the race.

The nature of these problems is well illustrated by the case of the Indian machine-tool industry, to which I turn in the next section.

5. An Illustration: the Indian Machine-tool industry

To illustrate these ideas, and to develop some of their implications, I would like to focus on an industry which lies in the 'middle' of the triangle diagram of Figure 4 above: the machine tool industry. While reported R&D levels for this industry are moderate, the fraction of a leading firm's manpower involved in machine design ('fixed outlays') is of the order of 10 or 15 percent, so that the industry lies in the middle ground between 'commodity-type' industries (point A of Figure 4) and 'high tech' industries (points B and C of Figure 4). Moreover, the industry's products fall into a modest number of basic non-substitutable machine types that have few design commonalities (lathes or 'turning centres', vertical and horizontal milling machines or 'machining centres', gear-cutting machines and so on), leaving it midway between the polar cases shown by points B and C in Figure 4.

The Indian industry is a long-established one. From the 1950s to the early 1990s, it operated in a protected environment, with tariffs on imported machines running as high as 100%. The industry was, and still is, dominated by some 8-10 leading firms; some 30 firms now account for 70% of industry sales revenue. Up to the early 1990s, these firms exported a substantial share of their output to the (price-sensitive, quality-insenstive) markets of Eastern Europe and the USSR. The changing economic environment of the 1990s led to a collapse in this export activity. The liberalization of trade, from 1992 onwards, has led to a fall in import duties to around 15%, and the industry is now adapting rapidly, and rather painfully, to this new regime.

The Technology

The technology of machine-tools underwent a major change in the 1960s and '70s with the introduction of computer numerically controlled (CNC) machines. The advent of these machines had some interesting consequences: while such machines offered higher productivity and enhanced precision, their production did not - paradoxically - require greater competence in the construction of the machine itself. What was now crucial to the performance of the machine was two elements: the computer controls ('CNC units') themselves, and the 'ball screw' (and ball bearings) that serve to move the tool into position for cutting. A ball-screw is a long threaded cylinder, about 1cm in diameter and over a meter long. The level of accuracy demanded for the threads in ball screws used in CNC machines is at the limits of what can be currently achieved: accuracy is measured by looking at the cumulative error in thread length over a distance of a meter, and is calculated in microns.

What the advent of CNC machines did, in terms of market structure, was to split the production of the machine among three groups of firms: the CNC controls are made by specialist producers, two of whom dominate the global market (Fanuc of Japan and Seimens of Germany). Several machine tool companies make CNC controls in-house, but these controls do not compete on equal terms with those of Fanuc and Siemens in sales to other machine-tool makers. Ball screws come in various quality bands; new CNC machine tools sold in major industrialized countries come equipped with Class 1 ballscrews, and there are only about five firms worldwide supplying these. The number of machine-tool makers who manufacture Class 1 ballscrews in-house is no more than a handful worldwide.

Almost all leading machine-tool firms 'buy in' both their CNC controls, and their ball-screws (and ball bearings) from specialist producers. The cost of these critical elements will

typically constitute about 50% or so of the total production cost of a CNC machine; this figure holds good both for Indian producers, and their leading international rivals.

The Changing Environment

From 1992 onwards, as India moved to a more open trading regime, competitive pressures on Indian industry became more intense. Some industries thrived: events in the car industry were dominated by the rise of the Suzuki-Maruti joint venture that has by now captured 70% of the market. The related growth of the auto-components sector has been no less noteworthy, and the productivity and quality levels achieved in some of the leading component producers are close to those achieved in the US, Japan and Europe.

For the machine tool industry, however the years since 1992 have been difficult. As tariff barriers fell, a surge in the volume of imported machines led to a large loss of market share for India's leading producers. In the mid-90s, the most important pressure came from Taiwanese producers of CNC lathes who undercut the prices of India's main producers by 20% or so. Given the huge disparity in wage costs (a ratio of 6:1), this might seem surprising - or at least indicative of a huge difference in productivity levels.

So how large is the productivity gap? Over the past year, I have been engaged in a World Bank sponsored benchmarking study of Indian firms relative to their counterparts in Taiwan and Japan. The most striking finding to emerge relates to the huge difference in gross labour productivity[14] among Indian producers: the levels range over a factor of 4 or more, with the

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[14] Measured as the annual production of CNC lathes of a specific type, divided by total employment in the lathe business, excluding design staff and sales/service staff.

highest recorded level coming close to the levels achieved by some Taiwanese firms[15].

Overall, while productivity differences are substantial, they are not so large - given relative

wage levels - to constitute a critical problem for Indian firms. Indeed, the success of

Taiwanese producers in India during the mid-90s was short-lived: the late '90s were marked

by a decline in Taiwanese imports, and a partial recovery of Indian firms. Interestingly, this

recovery was led by the youngest of the Indian producers, Ace Designers. Founded in 1990

by four machine tool design engineers, the firm focuses on a narrow product line (small and

medium size CNC lathes[16]), and employs an unusually high proportion of designers (20%)

among its workforce. In the late '90s, Ace embarked on a new pricing policy, cutting its

prices by 10%, and doubling its sales volume. Currently, the firm accounts for 70% of Indian

sales of CNC lathes, in spite of its being one of the smallest of the eight major suppliers in

terms of total employment.

These shifts in fortune among machine tool producers are typical of the patterns of events

that follow trade liberalization: as price competition becomes more intense, the relative

output levels of more efficient, versus less efficient, producers begin to shift. The long term

consequences of the new pricing environment tend to involve a mixture of consolidation and

exit, and a rise in the level of concentration in the industry.

Beyond productivity

The most important challenge now facing the Indian industry lies in competing, not with low-

price imports, but with imported machines of higher quality. As part of the World Bank

benchmarking study, we identified 50 Indian firms that used an Indian CNC lathe or vertical

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[15] The sources of these differences include, of course, differences in capital intensity (of which more below).

machining centre, side by side in the same plant, carrying out the same operations, as an imported machine of the same type. These users were asked to identify, at a rather detailed level, the relative strengths and weaknesses of the two machines. The key advantages of the imported machine lay in their higher levels of accuracy and reliability[17]. The mean differences were modest[18], and given the price differentials involved (which typically run to 50% or more), it is clear that the price premium customers are willing to pay for modest improvements in accuracy and reliability are substantial. Put another way, the returns to firms from modest quality improvement may far outrun any gains which they stand to make by improving their levels of labour productivity. Indeed, since CNC controls and ball screws account for about half of unit costs, and raw materials, energy costs, and bought-in components such as castings and sheet metal parts, together with overhead costs, make up another 30% of unit cost, only some 20% of unit cost is attributed to (direct) labour costs for the typical producers. A doubling of labour productivity will, under these circumstances, reduce unit costs by a mere 10%. Meanwhile, fairly modest improvements in accuracy and reliability may support a substantially higher price difference.

It is unsurprising, under these circumstances that Indian firms are now increasingly concerned with pinning down the sources of quality differences vis-a-vis imported machines. Improvements in accuracy and reliability are in part a matter of devoting more resources to

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They also include differences in the volume of output.

[16] A sister company, Ace Manufacturing Systems, founded in 1996, makes vertical machining centres.

[17] On the other hand, the relative strengths of the Indian machines, apart from price, lay exclusively in the 'sales and service' area (speed of response to service calls, etc), an area in which a domestic producer tends to have a comparative advantage.

[18] Reliability can be measured quantitatively as the fraction of operating time lost to breakdowns. The striking fact to emerge here was that the majority of the machine-pairs showed no significant differences, but the Indian machines showed a 'long tail' of poor performers.

machine design; equally, however, they depend upon increasing attention to detail in the manufacturing process[19].

The 'Moving Window': Investing in Capability

The quest for quality improvement is made substantially more difficult by the 'moving window' problem. During the 1970s and '80s, most CNC lathes were of a basic type (single spindle, 2-axis machines[20]). These basic machines still constitute over 95% of all CNC lathes sold in India. In the US, Japan and Europe, however, users of machine tools have been moving in increasing numbers over the past decade, to more sophisticated (multi-spindle, multi-axis) machines. These more sophisticated machines are cost-effective for user firms only if they face sufficiently high wage costs; in the Indian market, almost all users find it uneconomical to use such machines.

This situation creases an invidious trap for Indian firms: since wage rates are low, user companies demand 'first generation' technology. But if the general level of industrial development advances, leading to higher relative wages, some part of demand will shift towards 'second generation' machines. The only way the Indian producers can avoid being trapped in a 'last generation' technology is to invest ahead of demand.

This involves the outlay of substantial fixed costs in machine design, in the knowledge that the volume of sales of the machine over its lifetime will never justify the outlay; the return

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[19] Finally they depend upon achieving a substantial volume of output, since the training of machinists in the production of any machine type to achieve uniformly high standards over successive machines is much easier it the plant has a continuous flow of machines through the shop.

[20] Multiple spindles allow simultaneous machining of different surfaces on the machined component. Multi-axis machines allow more degrees of freedom in the orientation of the spindle(s), allowing a complex part to be machined in a single setting - avoiding the need to release and reset the part for successive operations.

lies in the development of capability, on which the indirect, long term returns may be substantial[21]. At least one Indian firm is currently developing its next generation of machines on this basis.

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[21] This problem is not peculiar to Indian firms; one Taiwanese firm has recently entered into a joint venture with a Japanese partner, while expecting to make no net profit on the venture. The payoff comes purely from developing capability in the design and production of 'leading edge' machines.

6. Perspectives and Implications

The analytical framework which I have been sketching in this lecture suggests a number of new perspectives on some long-standing issues in the economics of industrial development. In closing, I would like to comment briefly on four key ideas.

The Limits to Convergence

Over the past decade, a substantial macroeconomic literature has tackled the question of 'convergence': have the differences in real income per capita across countries widened or narrowed over the past few decades? The picture that emerges from this literature is captured in the phrase 'convergence clubs'. Differences among a group of 'high income' countries have narrowed, as real incomes in Europe and Japan have moved towards American levels. Meanwhile, a large group of low-income countries have become relatively poorer. Against this background, there have been some striking 'promotions', as a handful of countries, mostly in East Asia, have moved upwards to join the 'high income' club (Quah (1996)).

The question raised by these empirical findings is: to what extent can we extrapolate the underlying trends? To what kind of configuration are we moving?

One implication of the present analysis is that, as more countries join the 'high income' club, the difficulties facing future promotees become greater. The central theme of the 'market structure' literature is that the 'convergence' of a larger number of firms to similar levels of capability will increase the incentives for some subgroup of these firms to similar levels of capability will increase the incentives for some subgroup of these firms to accelerate their

efforts to draw ahead of the pack. The implication of this for the 'convergence' process is that, the closer we come to convergence, the harder it is to advance further: there are fundamental mechanisms that would constrain the process of convergence, even if all 'intrinsic' differences between countries (in terms of climate, natural resources, etc.) were eliminated.

Shifting Trajectories

Some of the most dramatic changes in market structure, and in industry leadership, occur when the technological trajectory followed by an industry shifts. devaluing old capabilities and creating an 'equal opportunities' framework for some group of potential entrants. The advent of the transistor effectively wiped out the group of businesses that manufactured electrical valves; the transistor was a superior replacement for the valve in almost all applications, but expertise in valve design and manufacture conferred no advantage to these incumbents relative to new companies that quickly developed expertise in silicon-based technology. The same kind of shift has happened at the level of national markets: the rise of Germany as an industrial power in the late nineteenth century was underpinned by its advances in the new science-based chemical industries, and in the newly developing electrical sector. Are there lessons here for the process of industrial development[22,23]?

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[22] Any attempt to address this issue brings us to the question of whether there are some natural 'hierarchies' of capabilities. Those countries that migrated upwards to join the 'high-wage' club over the past 50 years have tended to follow a sequence that begins at point A of the triangle diagram of Figure 4, and then moves upwards. Thus Japan excelled in textiles in the 1950s, in machine tools in the 1960s, and in consumer electronics in the 1970s. The several East Asian economies that rose to prominence in the 1980s followed similar paths. The idea of such a hierarchy of capabilities makes good sense, for two reasons: first, as each firm develops its capabilities, the natural turnover of labour generates externalities for all firms who recruit staff in the same industry, and in cognate industries, insofar as all skills are in part transferrable. Secondly, firms operating at any level in our putative hierarchy will draw some of their input from firms with 'lower level' capabilities: thus the development of a machine-tool industry is facilitated by the presence of a network of basic engineering shops capable of producing castings, sheet-metal work, and basic machine components at low cost.

[23] One idea that has been widely canvassed in recent years is that the information technology sector is 'different', in that it relies to a negligible degree on inputs other than well-educated software designers. IT is

The 'accumulation of capital' revisited ...

The view I have elaborated above stands in sharp contrast to the view that the process of growth and development is driven by the flow of savings, via capital investment, so that real wages rise as a result of an ever-increasing capital-labour ratio; given more capital per head, the marginal product of labour, and so the real wage, is correspondingly greater. (- a view widely canvassed as an explanation of the rapid growth in East Asian economies.)

On the view I have set out above, things work almost exactly in reverse: the primary driver of growth is the gradual build-up in firms' capabilities, which raises the economy-wide real wage. Capital accumulation now appears as a complementary effect: the higher real wage makes it profitable for each firm to shift to more capital-intensive techniques. As the firm makes that shift, the rise in its capital-labour ratio further raises the marginal revenue product of labour at the firm level; and so underpins the rising real wage level.

The idea emerges clearly on looking at India's machine-tool producers. These firms operate with a much lower capital-labour ratio than their Japanese or Taiwanese competitors[24]. Yet their different capital-labour ratios are an optimal response to current Indian wage rates; a rise in capital investment would indeed raise productivity, but not by a sufficient amount to generate a normal rate of return on the capital employed. On the other hand, an economy-wide advance in the levels of firms' capabilities will imply a rise in real wages; not until

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also different in another key respect, in that it can - to some degree - operate with teams who may be dispersed across different geographical areas, thus avoiding the (im-)mobility problem addressed in Section 3 above.

[24] Differences in the capital-labour ratio are primarily effected by changing the mix of 'conventional' (non-CNC) machines as against (CNC) turning centres and machining centres, in the production of components. It also involves, at the extreme, a move to a highly automated production process, in which much of the machining

such a shift begins to occur will the machine-tool makers find it attractive to make substantial changes in their capital-labour ratios.

The 'wealth of nations' question

On my present interpretation, the proximate cause of differences in the 'wealth of nations' lies in the capabilities of firms[25]. It does not lie in 'capital per head', which - in the modern world of (near) perfect capital mobility - is simply an endogenous variable that responds to shifts in relative levels of capability: capital flows towards capable firms, and towards the countries that have more capable firms. The enhanced capital stock enables these firms to further increase their levels of labour productivity, laying the basis for further advances in capability.

But if this is the proximate cause, then what is the ultimate cause? What factors encourage the entry of firms, and the development of capabilities? Here, the institutional and legal background within which firms operate is the key. A central theme in recent literature has

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and assembly process is carried out on a fully automated production line that can be run with minimal supervision.

[25] The process of industrial development, of course, requires a large number of conditions to be present, all of which must be satisfied. To speak of any one element being the proximate cause may seem inappropriate, but what I have in mind here is the idea that, in certain kinds of country at certain times, one of the necessary conditions becomes a binding constraint. My claim is therefore limited to the context of those "middle group" countries such as India in which the pre-conditions for the development of an industrial base are already satisfied and in which we may, to some approximation, regard capital markets are being well functioning. This argument does not apply, for example, to the eighteenth century environment in which Adam Smith first posed his question: there, the institutional and legal environment that facilitated the formation of the limited liability company lay in the future; mobilizing capital via the stock market was much more difficult; and the system of property rights pertaining to invention and innovation was primitive in the extreme. In that setting, the assembling of financial (working) capital to underpin a firm's operations was a binding constraint. Meanwhile, production techniques were advancing less rapidly, and achieving a 'relatively' high level of capability was arguably less difficult.

Similar conditions apply to many less developed countries today: as de Soto (2000) has argued, the absence of secure property rights in land, and real estate, is a serious barrier to the mobilizing of financial capital to underpin the growth rate of the corporate sector.

concerned the key role of these factors[26], and a consideration of these (more basic) factors lies beyond my present scope. What I would, however, like to remark upon is the way in which these - and related - factors fall within the analytical framework I have set out above. One of the most striking factors that handicap firms in developing economies lies in the additional costs which they incur as a result of excessive and inappropriate regulatory controls, and in the petty corruption that develops around their compliance - or non-compliance - with such restrictions. Further examples of such cost-increasing features of the setting in which firms operate abound: inefficient public power supplies, for instance, will force firms to operate high-cost in-house backup plants to cover periods of power blackouts. A catalogue of such factors would be a lengthy one; but from an analytical viewpoint they can be rolled into a single concept: the 'cost of doing business' in the country - which could be expressed, say, as the (typical) percentage increase in the unit cost of production associated with such 'local' disadvantages. Attempts to quantify various elements of these costs are still in their infancy, but few measurement exercises in economics could be more worthy of attention: for it is here that we can move from benchmarking firms, towards benchmarking the effectiveness of governments in providing an environment in which the growth of capabilities will be facilitated.

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[26] On the importance of personal property rights, see for example, Pipes (1999). On the property rights of firms, and their role in underpinning the flow of capital to firms, see North (1989,1990).

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