

TECHNOLOGY GEOGRAPHY: A NEW AREA OF SCIENTIFIC INQUIRY

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Abstract: Operations management, international management, public policy and economic geography are four scientific areas, which come together in the study of international technology transfer. This paper shows how each of these four areas has its own central issues but also have specific parts that are relevant for research on international technology transfer. It is essential for companies to thoroughly understand the issues of productivity of production technologies employed by them, and for international companies the relationship of productivity of a specific production line and the environment in which this production line operates. Simultaneously, it is essential for governments to understand the productivity of its work force and therefore to understand the relationship of its country characteristics and the productivity of specific industries (or production technologies). A recommendation is made to add a new focus to the research on international technology transfer called: Technology Geography. Its primary purpose is to investigate the linkages between technology and its location, and its consequences for technology transfer and international production operations.

Keywords: International technology transfer, technology management, operations management, international management, public policy, economic geography.

Introduction

Businesses are faced with an international market place. It is apparent that most companies have to make their decisions in the context of global changes. One of the critical decisions for companies is to determine where it should locate its activities. Virtually every textbook on operations management covers this topic, see e.g. (Stevenson, 2002). However, these typically cover location in a national context rather than an international context and may therefore appear to be largely outdated in the current situation.

The international location of activities is an important issue for companies because there are misconceptions about the economics of international operations. Ferdows (1997) showed that there are three strategic reasons to manufacture goods abroad. These reasons are: access to low-cost production, access to skills and knowledge, and/or proximity to market. It is therefore implicitly assumed that companies have rational strategic reasons to operate in foreign countries. It turns out, however, that the economic side of having

foreign operations are by no means clear cut. Some theories exist that claim that, especially for mature products, producing in low-cost countries is cheaper and therefore offers cost benefits (Vernon, 1966), the general applicability of this must be seriously questioned.

Baranson (1967, p. 83) showed that, despite low Indian wages, producing a Cummins engine in India, with essentially a copy of the US production line, cost about 4.1 times more than producing the same engine in the United States. This difference is not caused by changing the production technology, for example by using more labor intensive techniques. Van Hasselt et al. (1977) compared the production of a metal test-piece in machine shops in Indonesia and the Netherlands, using essentially identical processes. The comparison showed that producing in Indonesia cost between 1.6 and 1.8 times more than in the Netherlands. Similar findings were also reported more recently for example by aircraft industry officials who stated that producing a MD90 aircraft in China, also well known as a low labor cost country, at the end of the 1990s cost approximately \$10 million more than the corresponding aircraft built at Boeing's American plant (U.S. International Trade Committee, 1998, p. 5-12). This shows a hefty cost increase when moving production towards a low labor cost country.

These examples illustrate that moving production to low labor cost countries does not automatically reduce cost. Since this is the case, there is a need for companies to understand the economic implications of carrying out operations in international locations, i.e. regardless of strategic motives, a sound economic basis should exist before companies get engaged in international operations. The question to be raised is how much does it cost to produce in a foreign location? Or, even more importantly, why are there production cost and/or productivity differences for international locations? And how can this knowledge be applied to determine the best location for a companies' operations?

Existing disciplines

A scientific base that deals with the previously posed questions and that supports companies with international location issues is still in its infancy. This is due to the fragmented attention that has been given to international operations by scholars. Research carried out in four existing disciplines, operations management, international management, public policy, and economic geography, contributes to our understanding of production cost and productivity related to an international location. Operations management and international management are both concerned with management of companies, and overlap with regard to the development of companies' international operations strategies. Public policy and economic geography are focused on governments, i.e. they aid government decision making with regard to industrial policy. None of these disciplines explicitly focuses on the international comparison of production cost and/or productivity. Most of the available research either did not focus on the economic issues or it did not provide a focus on the company level, e.g. actual production cost. In addition, the current research is characterized by the different perspectives taken. As a consequence, not only does each particular perspective chosen have severe drawbacks, but, most importantly, it has impeded a full understanding of international factors that influence cost and productivity.

Operations management

Operations management is concerned with the management of processes or systems that create goods and/or provide services. It encompasses a range of decision areas which includes location decisions and one of its main concerns is productivity, see e.g. (Stevenson, 2002). Roth et al. (1997) showed that the international aspect of operations is poorly represented in the total field of operations management. International operations management is concerned with two categories (Chakravarty et al, 1997). The first category is issues that have implications for an international network of facilities, suppliers, and markets: configuration and flow of goods, people, technology, and information. It deals with the management of international operations. In this category a number of studies have surfaced that examine in particular international manufacturing networks. Examples of such studies are (Shi and Gregory, 1998) which looks at the configuration of international manufacturing networks and (Nassimbeni, 1998) which looks at the coordination in international manufacturing networks. The second category is related to comparison of production and operations in different countries. This one deals with international comparisons of operations practices. Examples of such studies are given in (Whybark and Vastag, 1992) in which a number of production planning and control techniques are compared for different countries.

In the last number of years scientific awareness of the international aspects of operations management has increased which led to the establishment of a scientific forum in the first category, International Manufacturing Network based at the University of Cambridge, UK and a scientific forum in the second category, Global Manufacturing Research Group, currently based at Texas A&M University, USA.

The operations management academics realize that there are significant differences in domestic versus international operations. Yet, despite the increasing attention towards international operations issues, the international perspective in the operations management discipline faces a serious drawback: the economic consequences of involvement in international operations are hardly investigated. The insights gained about managing international manufacturing networks and how different cultures handle production tasks differently are insightful and provide valuable clues towards understanding cost implications. However, the actual economic implications of the international differences on the 'bottom-line' are by no means understood.

International management

In contrast with the operations management perspective, international management has had a heavy emphasis on the economic side of international involvement. International management is concerned with the organizational and strategic response to continued differences across nations in mindset, in prices, costs, regulations, standards, distribution methods, and valuation measures (Contractor, 2000). This involves investigating four types of activities: arbitrage, foreign market entry or the internationalization process, working around or reducing the regulatory, economic or social barriers to entry in the host nation, and the transfer of firm-specific advantages to other locations. International management focuses on more than just operations issues alone.

In the context of operations, the attention of international management researchers is oriented towards the internationalization process. This means that much attention is given to export (and trade flows), see e.g. (Éthier, 1982; Hummels and Levinsohn, 1995; Marin and Schitzner, 1995; Noussair et al., 1995) and foreign direct investment strategies (and multinational companies), see e.g. (Teece, 1981; Dunning, 2000; Moon and Roehl,

2001). Although many of these studies address economic issues, the level of detail of economic analysis is limited. For example Eden and Miller's (2001) study on the cost of doing business abroad addresses many of the already known elements of doing business abroad such as for example transportation costs. But the study neglects the findings from the operations management discipline namely that operations practices are different in different countries. Another example includes several articles on outsourcing by Kotabe and others (Kotabe, 1989; Swamidass and Kotabe, 1993; Kotabe and Swan, 1994). These studies examine outsourcing strategies and benefits but neglect the different operations practices in different countries and hence do not give an adequate economic analysis of outsourcing.

International management research has contributed much to our understanding of differences in doing domestic and international business. In instances where international management research focused on operations the contributions from this perspective have been limited. Much of the international management literature deals with high levels of aggregation, for example trade analysis, without looking at the essentials, i.e. the individual companies and their cost figures and motives for internationalization.

Public policy

Public policy is concerned with decision making in and about societies. It is a complex area with complex decision making (Patton and Sawicki, 1993). One of the important areas for public policy is technological development and, coupled to this, economic development. Governments are interested in knowing how to achieve economic growth and to increase standards of living for their populations. Technology development has proven to be an important contributor towards economic growth (Rosenberg et al., 1992; Mowery and Rosenberg, 1995), hence its importance for government officials.

Typical studies which address economic and technological development include (Raz et al., 1983; Sharif, 1986a; Sharif 1986b; Technology Atlas Team, 1987; Sharif, 1988; Glass and Saggi, 1998; Kumar et al., 1999). Each of these studies addresses technological development, in particular for industrially developing countries with an emphasis on economic development and catch-up with the industrialized nations. These studies are interesting in and of themselves but they remain at a high level of aggregation, i.e. typically at an industry level. These studies also do not address productivity or cost differences for similar technologies in different locations, e.g. it is assumed, often implicitly, that if a technology is transferred, similar levels of productivity can be achieved at the new location. This is often not the case. It would be beneficial for public policy research to add this new dimension to its research because it has important implications with regard to policy choices.

Economic geography

De Blij and Muller (1985, p. 33) define economic geography as being concerned with the various ways in which people earn a living and how the goods and services they produce in order to earn that income are spatially expressed and organized. Economic geography is heavily concerned with the locational analysis of productive activities. Four major sets may be defined (de Blij and Muller, 1985, p. 207).

- Primary activities: the extractive sector of the economy in which workers and their environment come into direct contact, especially mining and agriculture.
- Secondary activities: the manufacturing sector, in which raw materials are transformed into finished industrial products.
- Tertiary activities: the services sector, including a wide range of activities from retailing to finance to education to routine office-based jobs.
- Quaternary activities: the fast-growing sector involving the collection, processing, and manipulation of information; a subset, sometimes referred to as quinary activity, is managerial or control-function activity associated with decision making in large organizations.

In the context of international operations, economic geography provides many valuable insights. For the aircraft industry a study by Cunningham (1951) provides an early example of the location and build up of the US aircraft industry. A more recent study by Eriksson (1995) shows the global location of aircraft manufacturing activities. By taking a multiple-year time frame, trends in international manufacturing location can be detected, see e.g. (van Liemt, 1992). Economic geography also shows how operations activities tend to cluster together and how this may lead to competitive advantages of regions or countries, see e.g. (Porter, 1990).

Economic geography studies are very relevant for governments because they show the location of income and how this relates to a population. This is at the same time the weakness for the application sought here: economic geography is concerned with the spatial division of income of people without comparing the economics of specific operations activities across locations. Economic geography has a focus on people's incomes but for our purpose we need a focus on operations activities economics. Although these two may be considered to be connected, i.e. if the activities can be more economically performed in another region, the jobs, and hence activities, will move to that other region, this is not the case. It is very well possible that jobs, and therefore activities, are performed in a region without offering cost advantages compared to other regions, as was demonstrated earlier. Economic geography can be used to identify trends in locating operations activities but in addition analysis aimed at the economics of these activities connected to the location are required to determine the cost efficiency and productivity of technologies in specific locations.

Technology Geography

Research in each of the four existing disciplines contributes to the knowledge base on international operations. However, none of the existing disciplines explicitly or implicitly studies the relationship between on the one hand a production technology's cost and/or productivity and on the other hand, location characteristics. Empirical findings have shown that producing in low labor cost countries can be more costly than producing similar goods in industrially developed countries. It is important to get a better understanding of this proposed relationship because it leads to understanding the differences in cost and therefore ultimately aids companies' and government's decision making. It is a new area, which we called: Technology Geography. This area concerns the study of *the relationship between technologies and location*. An example of this is a study to determine a particular production technology's cost differences across different locations. Another part of it is research to determine a particular production technology's productivity differences in different locations. This research is important both for companies and for governments. For companies, these type of studies aid with location decision making. Strategic decisions with regard to where to locate a company's activities can only be sensibly made once the total cost for different locations can be assessed. For governments, these studies are important because they aid governments in industrial decision making. Strategic choices with regard to which industries to foster can only be sensibly made once the total cost for different industries can be assessed.

In the context of production, technology geography aims at answering the following questions, for any A and B:

- What is the productivity of a particular production line in location A?
- What is the cost of producing with this particular productivity in location A?
- What is the productivity of an exact copy of this production line in location B?
- What is the cost of producing with this particular productivity in location B?
- Which location associated factors cause the differences in cost and/or productivity between the production technology at A and B?

A and B can be regions within a country as well as locations within different countries. The ultimate result of technology geography research should be a comprehensive model that shows how different location factors affect operation activities cost and/or productivity with the aim of providing companies and governments with an assessment instrument to aid their strategic decision making for respectively locations and industry development.

The field of technology geography is depicted in figure 1. Figure 1 illustrates the core areas for technology geography in the particular context of manufacturing activities, as compared to other operations activities. It shows that the core relates to three research areas: manufacturing location, manufacturing cost and productivity and (manufacturing) technology transfer.

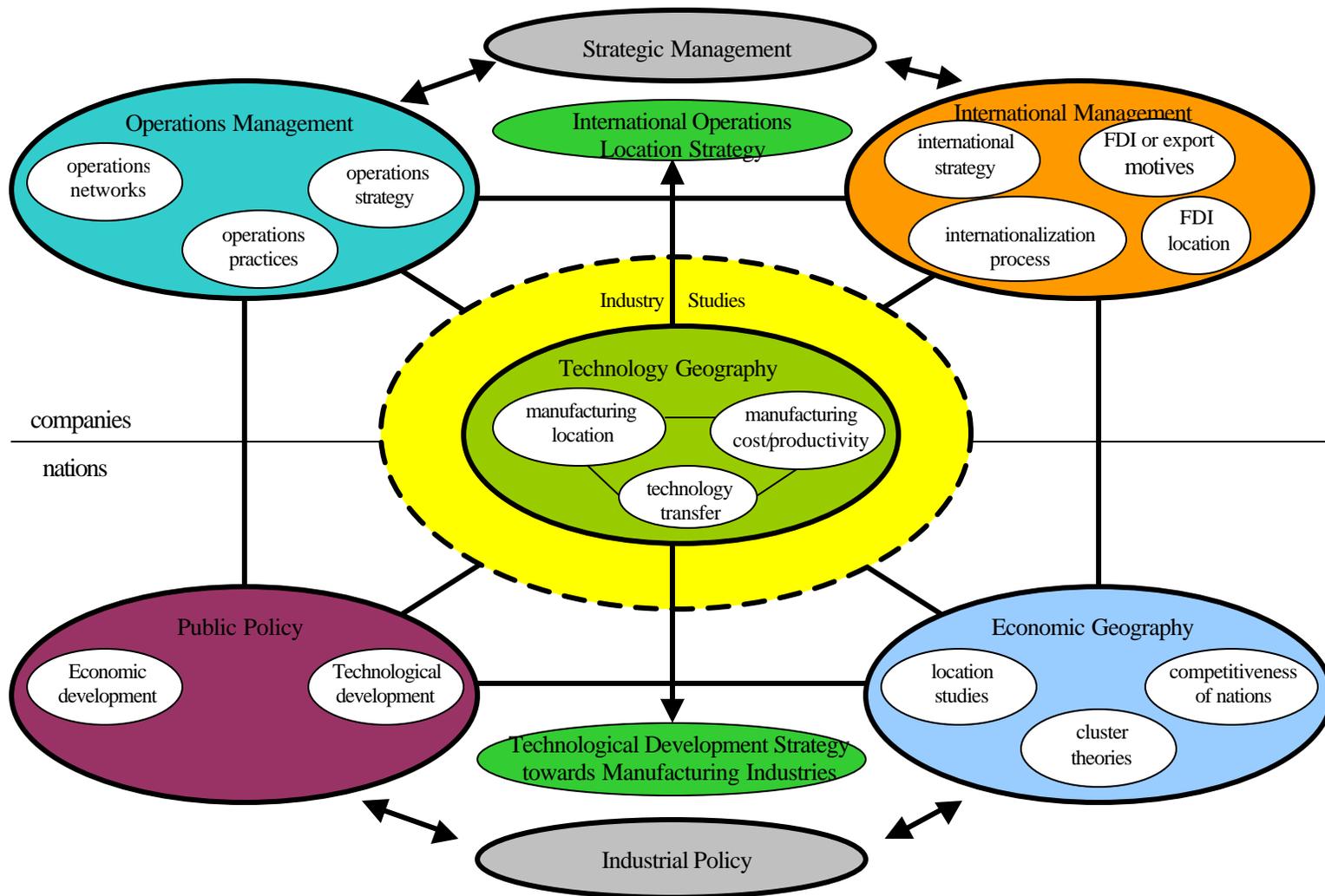


Figure 1: The 'New' Area of Technology Geography

Manufacturing location is important because it is necessary to determine which location characteristics (or variables) play a role in influencing a technology's cost and productivity. Examples of such variables can be the knowledge level of the available workforce at a particular location, the extent to which supplier industries exist at a particular location, or, the ease with which supplier industries elsewhere can be accessed from a particular location. Manufacturing cost and productivity are important because this is what ultimately needs to be compared across locations. The absolute measurement of cost and productivity are important but also the relative measurement is significant. This was shown by Baranson (1967, p. 87) in which he compared production cost for engines in the US (\$2100), UK (\$2986) and India (\$6022). Baranson subsequently adjusted for the poor Indian quality to come up with a more comparable Indian cost figure (\$8600). (Manufacturing) technology transfer has been indicated as another area of interest to technology geography. The motivation for this approach is that it coincides with manufacturing cost/productivity and manufacturing location. Technology transfer studies in particular have the potential of explaining differences in cost and productivity for the same technology in different locations. For example a study by Steenhuis and de Bruijn (2002) showed that manufacturing learning curves are different in international locations. This ultimately affects manufacturing cost and productivity.

The relationships between the existing four disciplines and technology geography are also depicted in figure 1. The relationship between operations management and technology geography is based on understanding operations management in an international context. Operations management scholars can provide many insights about differences that exist in operations practices for international locations. Technology geography contributes to the field of operations management because it provides the economic analysis of differences that result as a consequence of different locations (or practices in locations). This provides important information for managers for developing operations networks and operations strategy.

International management provides technology geography with patterns of international activities such as foreign direct investment and other forms of internationalization. These are typically embedded within company or even industry analysis, showing how particular companies or industries internationalize. Within the field of international management many of these patterns are seen as a consequence of international economic cost differences. As has been shown in this paper, this is not always the case, sometimes other motives or being uninformed may be a cause of internationalization patterns. Technology geography contributes to international management because it provides international management with economic comparisons at lower levels of aggregation. This knowledge is helpful for managers in determining where to locate their activities and what type of international strategies they should follow. The core contribution of technology geography to both operations management and international management is in the area strategic choice of international operations location.

From a country perspective public policy provides technology geography with patterns of economic and technological development. These are typically shown from a country perspective rather than from a company perspective. It provides data on how countries achieve levels of industrial development and how this relates to economic development and income levels. These patterns provide valuable input for technology geography because they show where production is taking place, although it is questionable

whether the cause for these patterns is always a purely economic one. Technology geography contributes to public policy because it shows the relationship between technology productivity/cost and a location. It therefore highlights which location factors affect productivity and cost thereby providing valuable information to governments to determine technological development strategies. For example, it may be crucial to develop supplier industries, such as providing quality materials and machine tooling, before attempting to develop industries which rely on these supplier industries.

Economic geography shows patterns of income and activities related to locations. These are useful for technology geography because they provide the raw data of where certain activities are being carried out as well as have some, albeit at a high level of aggregation, economic indicators attached to it. In addition, economic geography studies provide insights into important characteristics of locations, e.g. being part of a certain industrial cluster may be an important location variable that may influence production cost and productivity. Technology geography contributes to economic geography by providing a more detailed level of analysis and rather than looking at population groups and their incomes, looking at other factors that may influence productivity and hence income levels. The core contribution of technology geography to both public policy and economic geography is in the area of strategic choice of technological development, i.e. selection of core industries to develop.

Conclusions

Past and recent studies, e.g. Baranson (1967), van Hasselt et al. (1977) and (U.S. International Trade Committee, 1998), have demonstrated that for an essentially similar technology, the production cost (and productivity) can be substantially higher in low labor cost countries compared to high labor cost countries. These findings are extremely relevant for companies because they provide core information that is required for international operations location decisions. The findings are also valuable for governments because it provides them with core information that is required for selecting technological development strategies. Although there is a high practical relevance, the explanation of these international differences are apparently not well understood. Four existing disciplines, operations management, international management, public policy and economic geography, each research part of this phenomena but an integrated perspective is lacking. This paper proposes a new field of study: technology geography. The focus of technology geography should be to analyze the relationship between a technology and a location, in particular the differences for a technology's cost and productivity levels for different locations. The existing four disciplines each form an important input for technology geography studies and at the same time technology geography enhances understanding in each of these four areas. With this developed framework, which requires still a certain amount of further operationalization, a base is provided for research studies which aim to improve decision making in the current location determination of enterprises and industries.

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