

---

## Technology geography: studying the relationships between technology, location and productivity

---

No author  
queries

### Harm-Jan Steenhuis\*

Eastern Washington University, College of Business and Public Administration, Department of Management, 668 N. Riverpoint Blvd. Suite A, Spokane, WA 99202-1660, USA  
E-mail: hsteenhuis@mail.ewu.edu  
\*Corresponding author

### Erik J. de Bruijn

University of Twente, School of Business, Public Administration and Technology, Technology and Development Group, PO Box 217, 7500 AE Enschede, the Netherlands  
E-mail: e.j.debruijn@utwente.nl

**Abstract:** Operations management, international management, public policy and economic geography are scientific areas which come together in the study of international technology transfer. This study shows how each of these areas has its own central issues but also has specific parts that are relevant for research on international technology transfer. It is essential for companies to 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 line operates. Simultaneously, it is essential for governments to understand the productivity of their work force and, therefore, to understand the relationship of their country's characteristics and the productivity of specific industries. 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, location and productivity differences.

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

**Reference** to this paper should be made as follows: Steenhuis, H.-J. and de Bruijn, E.J. (0000) 'Technology geography: studying the relationships between technology, location and productivity', *Int. J. Technology Transfer and Commercialisation*, Vol. 00, No. 00, pp.00-00.

**Biographical notes:** Harm-Jan Steenhuis is an Assistant Professor of operations management at Eastern Washington University. He received his MSc in industrial engineering and management and his PhD in international technology transfer from the University of Twente, the Netherlands. He is currently involved in research on international manufacturing and R&D-level technology transfer in industry-university cooperative research.

Erik J. de Bruijn is a Professor of business management in non-western countries. He received his MSc from the University of Massachusetts and a PhD from the

2 *H.-J. Steenhuis and E.J. de Bruijn*

University of Twente. Since 1971 he has worked as Project Coordinator and Consultant for the Netherlands Government in various industrialisation projects in developing countries. He currently teaches international business management and is Chairman of the Technology and Development Group, School of Business, Public Administration and Technology, University of Twente.

---

## 1 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 a company 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. No matter what the strategic motives are, companies must also have a good understanding of the cost of international operations to facilitate the decision-making process. It turns out, that the financial side of having foreign operations is by no means clear cut. Many companies have lost huge amounts of money in trying to move closer to a market or getting access to low-cost production.

For example Renault from France lost \$750 million in the USA and Imperial Tobacco (British) lost over \$300 million with its acquisition and subsequent sale five years later of Howard Johnson (USA) (Willman, 2003). Recently MMO<sub>2</sub>, a UK company, sold its Dutch arm for \$25 million. Since its acquisition in 1996 it had invested approximately \$2.2 billion (Budden, 2003). Another example is Numico, a Dutch company which bought Rexall, a US-based company in 2000 for \$1.8 billion and subsequently sold it in 2003 for \$250 million (Bickerton, 2003). Finally, in 1999 US-based Reliant bought Una, a Dutch company, for \$2.4 billion. It was sold in 2003 for \$1.3 billion (McNulty and Bickerton, 2003). These examples illustrate that getting closer to a market may come at a high price.

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. For example 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 USA. 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 an MD90 aircraft in China, also well known as a low

*Technology geography: studying the relationships between technology* 3

labour cost country, at the end of the 1990s cost approximately \$10 million more than the corresponding aircraft built at Boeing's US plant (US International Trade Committee, 1998, p.5–12). This shows a hefty cost increase when moving production towards a low labour cost country. In 2003, the vehicle manufacturing costs in China were among the highest in the world. It cost 20–30% more than in the US according to General Motors (Mackintosh and McGregor, 2003). These examples illustrate that moving production to low labour cost countries does not automatically reduce cost.

It has been pointed out that many international divestments were the result of investment decisions that were made without a careful preliminary analysis (Boddewyn, 1979, p.23; Torneden, 1975, p.103). As part of the preliminary analysis companies need 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 company's operations? These questions are crucial for companies that operate in international environments. Answers to these questions provide companies not only with insight into the cost of doing business in international environments but they provide insight into the factors that lead to certain cost structures. This is particularly important since this provides insight into the linkages between international environments and a range of topics that are considered in international operations decisions such as; quality, technology, culture, communication and transportation.

## **2 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 the 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 characterised 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.

### *2.1 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 recent years scientific awareness of the international aspects of operations management has increased and has 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 realise that there are significant differences in domestic versus international operations. Yet, despite the increasing attention paid to 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 into 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 fully understood.

## 2.2 *International management*

In contrast with the operations management perspective, international management has laid a heavy emphasis on the economic side of international involvement. International management is concerned with the organisational 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 internationalisation 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 operations issues alone.

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

### *Technology geography: studying the relationships between technology* 5

2001; Teece, 1981). 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; Kotabe and Swan, 1994; Swamidass and Kotabe, 1993). These studies examine outsourcing strategies and benefits but neglect the different operations practices in different countries 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 internationalisation.

#### *2.3 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 (Mowery and Rosenberg, 1995; Rosenberg et al., 1992), hence its importance for government officials.

Typical studies which address economic and technological development include (Glass and Saggi, 1998; Kumar et al., 1999; Raz et al., 1983; Sharif, 1986a, b, 1988; Technology Atlas Team, 1987). Each of these studies addresses technological development, in particular for industrially developing countries with an emphasis on economic development and catch-up with the industrialised 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.

#### *2.4 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 organised. Economic geography is heavily concerned with the locational analysis of productive activities. Four major sets may be defined (1985, p.207).

6 *H.-J. Steenhuis and E.J. de Bruijn*

- 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 a managerial or control-function activity associated with decision making in large organisations.

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 quite possible that jobs, and therefore activities, are performed in a region without offering cost advantages compared to other regions, as was demonstrated above. 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.

### 3 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 international environments can be much more expensive than in domestic environments and that companies may underestimate the true cost of international operations. It can even be more expensive to produce in low labour cost countries than producing similar goods in industrially developed countries. Furthermore,

*Technology geography: studying the relationships between technology*

7

especially in the Operations Management and International Management disciplines, the accepted methodology is predominantly quantitatively, hypothesis-testing orientated, see e.g. journals such as the Journal of Operations Management, Production and Operations Management, the International Journal of Production Economics, the Journal of International Business Studies, the International Business Review and the Journal of International Management, which are considered high-ranked journals in these disciplines (Barman et al., 2001; DuBois and Reeb, 2000).

It is important to get a better, in-depth understanding of the proposed relationship because it leads to an understanding of the differences in cost and, therefore, ultimately aids companies' and governments' 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 types 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.

Although the focus is on a production technology's cost and/or productivity and location characteristics, the implications reach much wider. Issues such as quality, culture, communication between countries, transportation, corruption, etc., are all related to international environments. These issues are included in Technology Geography because they affect the cost of producing in international environments. In other words, in order to study the relationship between technology and location it is also necessary to study a range of other factors because these factors are expected to differ in international environments and these differences are expected to influence the cost of operating a technology. For example Baranson (1967, p.82) compared the cost of producing an engine in India versus the US. He found that the cost in India was \$6022 versus the cost in the US at \$2100. Furthermore, he estimated that the engine produced in India did not reach the same quality level as the engines produced in the US and therefore he estimated that to reach similar quality levels in India as in the US would increase the cost of Indian engines to \$8600. Another example is illustrated by Steenhuis and de Bruijn (2004) who showed the consequences of information inaccuracy. This inaccuracy affects productivity and although Steenhuis and de Bruijn (2004) did not quantify this effect, it would be worthwhile to do this for the area of Technology Geography. These examples show that the comparison of manufacturing cost in different locations by necessity has also to include a range of other factors such as quality levels and communication infrastructure.

### 3.1 Characteristics of technology geography

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

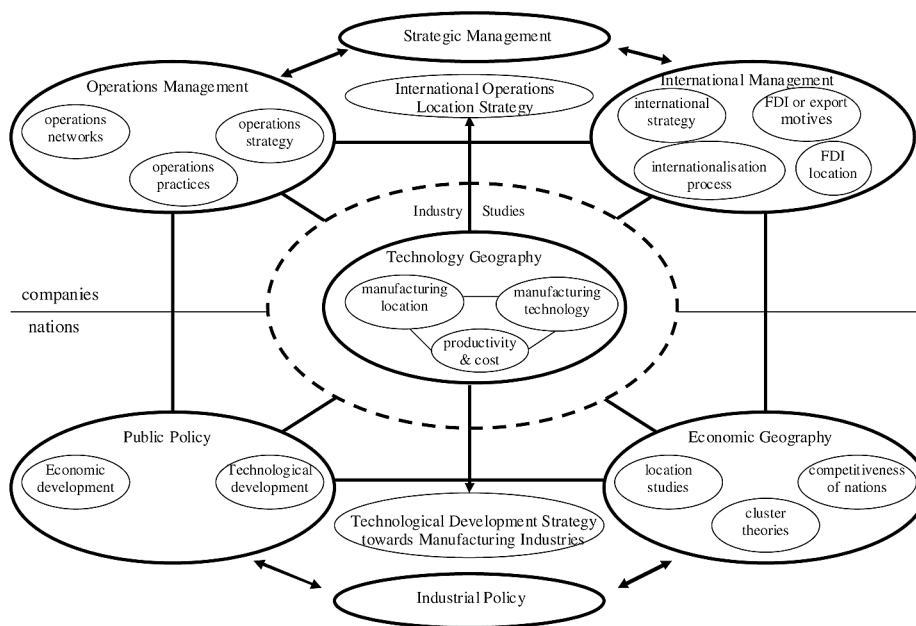
8 *H.-J. Steenhuis and E.J. de Bruijn*

- 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 industrial 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** 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



*Technology geography: studying the relationships between technology*

9

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 or real measurement of cost and productivity are important but also the relative measurement is significant, e.g. the cost adjusted for quality differences. This was shown in the earlier provided example of Baranson (1967) in which he compared the production cost for engines in the US and India where the absolute cost comparison per engine is respectively \$2100 versus \$6022 but if adjustments are made for quality differences a relative comparison shows respectively \$2100 versus \$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.

It is proposed that, due to the limited knowledge in this particular area, the drawbacks of the predominantly quantitative hypothesis testing approaches in such instances, and the emphasis on exploring and explaining type questions, initial studies should utilise in-depth case study approaches (Swanborn, 1996; Verschuren and Doorewaard, 1999; Yin, 1994). Case studies offer the advantage that data are grounded in empirical analysis and although they have limited external consistency, they can, through pattern-matching and similar techniques, provide a better internal consistency than, for example, survey research (Hutjes and van Buuren, 1996; Miles and Huberman, 1999; Yin, 1994).

Table 1 provides an overview of the main characteristics of technology geography.

**Table 1** Characteristics for technology geography

Goal	To provide empirical knowledge on the relationship between the cost and productivity of technologies, and the location characteristics of where the technology is employed. This knowledge should be aimed at governments and companies so that they can make better informed decisions on where to locate particular technologies.
Specific objects	Manufacturing location, manufacturing cost and productivity, and (manufacturing) research technology transfer.
Methodology	Case studies to provide empirically grounded and in-depth data to derive hypothesis and propositions on the relationship between location and technology. In particular horizontal technology transfer studies can provide valuable insight since in these instances often exactly the same technology is used in different locations.
Example research examples	The goal is a fundamental understanding of how location-related factors influence the cost and productivity of technology deployment in different locations. The following are questions of research questions that contribute to this overall goal: <ul style="list-style-type: none"> <li>• How does national culture affect productivity and/or cost?</li> <li>• How does infrastructure affect productivity and/or cost, e.g. electricity shortages, bad roads, etc.</li> <li>• Can similar quality levels be reached at any location? If so, what is the effect on cost?</li> </ul>
Specific outcomes	<ul style="list-style-type: none"> <li>• A definition of location, i.e. the characteristics of a location that influence cost research and/or productivity of a technology.</li> <li>• A definition of (manufacturing) technology, i.e. the characteristics of technology that influence its cost and productivity.</li> <li>• A set of relationships that link location with technology.</li> </ul>

### 3.2 *Relationship with existing disciplines*

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 internationalisation. These are typically embedded within company or even industry analysis, showing how particular companies or industries internationalise. 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 internationalisation 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 of 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 of these patterns is always purely economic. 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 having 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.

#### 4 Conclusions

Past and recent studies, e.g. (Baranson, 1967; Hasselt van et al., 1977; US International Trade Committee, 1998), have demonstrated that for an essentially similar technology, the production cost (and productivity) can be substantially higher in low labour cost countries compared to high labour cost countries. These findings are extremely relevant for companies because they provide the core information that is required for international operations location decisions. The findings are also valuable for governments because it provides them with core information required for selecting technological development strategies. Although there is a high practical relevance, the explanation of these international differences is apparently not well understood. Four existing disciplines, operations management, international management, public policy and economic geography, each research part of this phenomenon but an integrated perspective is lacking. This paper proposes a new field of study: technology geography. The focus of technology geography should be to analyse the relationship between a technology and a location, in particular the differences for a technology's cost and productivity levels for different locations. The knowledge gained from these analyses helps companies with their international operations decisions because, regardless of their strategic motives, it aims to provide companies with a better understanding of the actual cost of operating in international environments and may prevent costly international site location mistakes. This knowledge also helps governments, in particular with two issues. Firstly, their decisions on which technologies (and coupled with that industries) they should invest in. Secondly, it provides information on factors that determine location characteristics which influence the productivity of technologies. In other words, governments can use this insight to upgrade locations in order to achieve higher productivity or lower cost for technologies that are utilised in those 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 still requires a certain amount of further operationalisation, a base is provided for research studies which aim to improve decision making in the current location determination of enterprises and industries.

#### References

- Baranson, J. (1967) *Manufacturing Problems in India. The Cummins Diesel Experience*, New York: Syracuse University Press.
- Barman, S., Hanna, M.D. and LaForge, R.L. (2001) 'Perceived relevance and quality of POM journals: a decade later', *Journal of Operations Management*, Vol. 19, pp.367–385.
- Bickerton, I. (2003) 'Dutch healthfood group sells Rexall Sundown for \$250m', *Financial Times*, June 11, p.15.
- Blij, H.J. de and Muller, P.O. (1985) *Geography: Regions and Concepts*, New York: John Wiley & Sons.
- Boddewyn, J.J. (1979) 'Foreign divestment: magnitude and factors', *Journal of International Business Studies*, Vol. 10, No. 1, Spring, pp.21–27.
- Budden, R. (2003) 'MMO<sub>2</sub> sells Dutch arm for 25m euros', *Financial Times*, April 15, p.24.
- Chakravarty, A.K., Ferdows, K. and Singhal, K. (1997) 'Global operations and technology management: a note from the editors of the special issue', *Production and Operations Management*, Vol. 6, No. 2, pp.99–101.

## 12 H.-J. Steenhuis and E.J. de Bruijn

- Contractor, F.J. (2000) 'The raisons d'être for international management as a field of study', *Journal of International Management*, Vol. 6, pp.3–10.
- Cunningham, W.G. (1951) *The Aircraft Industry. A Study in Industrial Location*, Los Angeles, CA: Lorrin L. Morrison.
- DuBois, F.L. and Reeb, D. (2000) 'Ranking the international business journals', *Journal of International Business Studies*, Vol. 31, No. 4, pp.689–704.
- Dunning, J.H. (2000) 'The eclectic paradigm as an envelope for economic and business theories of MNE activity', *International Business Review*, Vol. 9, pp.163–190.
- Eden, L. and Miller, S. (2001) 'Opening the black box: multinationals and the costs of doing business abroad', in D.H. Nagao (Ed.) *Proceedings Academy of Management 2001*, Washington D.C.
- Eriksson, S. (1995) 'Global shift in the aircraft industry: a study of airframe manufacturing with special reference to the Asian NIEs'. *Publications edited by the Departments of Geography, University of Gotheburg, Series B, No. 86*. Department of Human and Economic Geography, University of Gothenburg, Sweden.
- Ethier, W.J. (1982) 'National and international returns to scale in the modern theory of international trade', *The American Economic Review*, Vol. 72, No. 3, pp.389–405.
- Ferdows, K. (1997) 'Making the most of foreign factories', *Harvard Business Review*, March–April, pp.73–88.
- Glass, A.J. and Saggi, K. (1998) 'International technology transfer and the technology gap', *Journal of Development Economics*, Vol. 55, pp.369–398.
- Hasselt, R. van, Bruijn, E.J. de and Wirjomartono, S.H. (1977) 'An investigation into the appropriate application of modern methods of production and management in the engineering industry of Indonesia', *Annals of the CIRP*, Vol. 25, No. 1, pp.263–268.
- Hummels, D. and Levinsohn, J. (1995) 'Monopolistic competition and international trade: reconsidering the evidence', *Quarterly Journal of Economics*, Vol. 110, No. 3, pp.799–836.
- Hutjes, J.M. and van Buuren, J.A. (1996) *De Gevalsstudie, Strategie van Kwalitatief Onderzoek*, Second edition, Boom, Meppel.
- Kotabe, M. (1989) 'Hollowing-out' of US multinationals and their global competitiveness', *Journal of Business Research*, Vol. 19, pp.1–15.
- Kotabe, M. and Swan, K.S. (1994) 'Offshore sourcing: reaction, maturation, and consolidation of US multinationals', *Journal of International Business Studies*, Vol. 25, No. 1, pp.115–140.
- Kumar, V., Kumar, U. and Persaud, A. (1999) 'Building technological capability through importing technology: the case of Indonesian manufacturing industry', *Journal of Technology Transfer*, Vol. 24, pp.81–96.
- Liemt, G. van (Ed.) (1992) *Industry on the Move. Causes and Consequences of International Relocation in the Manufacturing Industry*, Geneva: International Labour Office.
- Mackintosh, J. and McGregor, R. (2003) 'A leap over the cliff: are the big profits to be made in China blinding foreign carmakers for the risks ahead?', *Financial Times*, Monday August 25, p.13.
- Marin, D. and Schitzer, M. (1995) 'Tying trade flows: a theory of countertrade with evidence', *The American Economic Review*, Vol. 85, No. 5, pp.1047–1064.
- McNulty, S. and Bickerton, I. (2003) 'Reliant takes \$900m loss on sale to Nuon', *Financial Times*, February 21, p.18.
- Miles, M.B. and Huberman, A.M. (1994) *Qualitative Data Analysis. An Expanded Sourcebook*, Second edition, Thousand Oaks, CA: Sage Publications.
- Moon, H.C. and Roehl, T.W. (2001) 'Unconventional foreign direct investment and the imbalance theory', *International Business Review*, Vol. 10, pp.197–215.
- Mowery, D.C. and Rosenberg, N. (1995) *Technology and the Pursuit of Economic Growth*, Cambridge: Cambridge University Press.
- Nassimbeni, G. (1998) 'Network structures and coordination mechanisms. A taxonomy', *International Journal of Operations and Production Management*, Vol. 18, No. 6, pp.538–554.

Technology geography: studying the relationships between technology 13

- Noussair, C.N., Plott, C.R. and Riezman, R.G. (1995) 'An experimental investigation of the patterns of international trade', *The American Economic Review*, Vol. 85, No. 3, pp.462–491.
- Patton, C.V. and Sawicki, D.S. (1993) *Basic Methods of Policy Analysis and Planning*, Englewood Cliffs: Prentice Hall.
- Porter, M.E. (1990) *The Competitive Advantage of Nations*, New York: The Free Press.
- Raz, B. Steinberg, G. and Ruina, A. (1983) 'A quantitative model of technology transfer and technological 'catch-up'. The case of developed countries', *Technological Forecasting and Social Change*, Vol. 24, pp.31–44.
- Rosenberg, N. Landau, R. and Mowery, D.C. (Eds) (1992) *Technology and the Wealth of Nations*, Stanford: Stanford University Press.
- Roth, A.V., Gray, A.E., Singhal, J. and Singhal, K. (1997) 'International technology and operations management: resource toolkit for research and teaching', *Production and Operations Management*, Vol. 6, No. 2, pp.167–187.
- Sharif, M.N. (1986a) 'Measurement of technology for national development', *Technological Forecasting and Social Change*, Vol. 29, pp.119–172.
- Sharif, M.N. (1986b) 'Technological considerations in national planning', *Technological Forecasting and Social Change*, Vol. 30, pp.361–382.
- Sharif, M.N. (1988) 'Technology and economics. Basis for techno-economic policy analysis', *Science and Public Policy*, Vol. 15, No. 4, pp.217–229.
- Shi, Y. and Gregory, M. (1998) 'International manufacturing networks – to develop global competitive capabilities', *Journal of Operations Management*, Vol. 16, pp.195–214.
- Steenhuis, H.J. and Bruijn, E.J. de (2002) 'Technology transfer and learning', *Technology Analysis & Strategic Management*, Vol. 14, No. 1, pp.57–66.
- Steenhuis, H.J. and Bruijn, E.J. de (2004) 'Exploring knowledge transfer within manufacturing networks and codified information characteristics: the hidden dangers of inaccurate information', *International Journal of Technology Transfer and Commercialization*, Vol. 3, No. 4, pp.433–453.
- Stevenson, W.J. (2002) *Operations Management*, Boston, MA: McGraw-Hill Irwin.
- Swamidass, P.M. and Kotabe, M. (1993) 'Component sourcing strategies of multinationals; an empirical study of European and Japanese multinational', *Journal of International Business Studies*, Vol. 24, No. 1, pp.81–99.
- Swanborn, P.G. (1996) *Case-Studies. Wat, Wanneer en Hoe?*, Boom, Meppel.
- Technology Atlas Team (1987) 'A framework for technology based national planning', *Technological Forecasting and Social Change*, Vol. 32, pp.5–18.
- Teece, D.J. (1981) 'The multinational enterprise: market failure and market power considerations', *Sloan Management Review*, Vol. 22, No. 3, pp.3–17.
- Torneden, R.L. (1975) *Foreign Disinvestment by US Multinational Corporations, with Eight Case Studies*, New York: Praeger Publishers.
- US International Trade Committee (1998) 'The changing structure of the global large civil aircraft industry and market: implications for competitiveness of the US industry', *Publication 3143, investigation no. 332–384, November 1998*, Washington D.C.: US International Trade Commission.
- Vernon, R. (1966) 'International investment and international trade in the product cycle', *The Quarterly Journal of Economics*, Vol. 80, pp.190–207.
- Verschuren, P. and Doorewaard, H. (1999) *Designing a Research Project*, Utrecht: Lemma.
- Whybark, D.C. and Vastag, G. (Eds) (1992) *Global Manufacturing Practices. A Worldwide Survey of Practices in Production Planning and Control*, Amsterdam: Elsevier.
- Willman, J. (2003) 'In European countries, there are three of four competitors. In the US, there are 10 or 20', *Financial Times*, February 25, p.11.
- Yin, R.K. (1994) *Case Study Research. Design and Methods*, Thousand Oak, CA: Sage Publications.