A Comparative Analysis of the Location behaviour of Japanese and European Semiconductor Manufacturers.

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1. *Introduction*

Market mechanisms are mediated via a range of different types of institutions, which can be of an economic, political or legal nature. In situations where institutional environments differ significantly between locations, the overcoming of such differences may incur non-trivial transactions costs. From the perspective of innovation and entrepreneurship, the existence of such transactions costs can lead to reduced firm efficiency, and where such costs are very significant, they can lead to missing markets and an absence of new dynamic and entrepreneurial developments.

Recent developments in economics (Krugman 1991) and management science (Porter 1990, 1998) have highlighted the role that geography can play in engendering localized increasing returns to scale, thereby leading to consistent variations in the spatial patterns of new firm foundations, new product developments and new process innovations. In particular, variations in local information externalities (Jaffe et al 1993), labour hysteresis effects (Simpson 1992; Audretsch and Feldman 1996), and location-specific input sources, can generate conditions under which such economic developments are localized. Under these kinds of conditions, factor price adjustments are not sufficient to ensure that all areas are equally attractive for risk-taking and investment locations, either for a single sector, or for all sectors.

In order to help discuss how these explicitly geographical issues relate to the generation, growth and behaviour of firms, the notion of 'industrial clusters' (Porter 1990, 1998) has recently been added to the familiar set of regional analytical tools, which already includes the product-cycle models. Discussions of the potential advantages of industrial clusters as locations for risk-taking, entrepreneurship and investment are now widespread. Unfortunately, however, employing the notion of industrial clusters in order to motivate discussions of the entrepreneurship, innovation and investment is not at all as straightforward as it may at first appear. The reason for this is that much of the clusters literature is based on very stylised institutional notions of or the relationships between firms. From a transactions costs perspective, it can be shown that the notion of industrial clusters, in it simplest and most familiar form (Porter 1990, 1998), itself cuts across three quite different analytical concepts of industrial location behaviour, each of which is predicated on different assumptions about the nature of transactions costs, the nature of information exchanges, and the institutional frameworks through which these are mediated. Each of these three different cluster concepts has quite different implications for entrepreneurship, innovation and risk taking, and understanding the various assumptions behind the cluster notions is necessary in order to make sense of these interrelationships.

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The purpose of this paper is to explain the three different types of institutional frameworks underlying the various notions of industrial cluster, and then to discuss how we might interpret observed entrepreneurial and innovative behaviour under various conditions. In order to illustrate the issues at stake, we discuss two examples from the global semiconductor industry. Both of these examples initially appear to reflect simple industrial clustering arguments, but on closer inspection, organizational insights show that the geographical issues are much more complex than at first they appear. Different types of clusters have different advantages for different types of firm innovation and risk-taking behaviour, and distinguishing which type of firm will benefit from which particular cluster will require consideration of organization, information and institutional issues, many of which are ignored by the simple clusters literature.

2. *Industrial Cluster Types: A Transactions Costs Approach*

If we adopt a transactions-costs perspective we can define three distinct types of industrial clusters, according to the nature of firms in the clusters, and the nature of their relations and transactions within the cluster (McCann and Gordon 2000; McCann 2002; Simmie and Sennet 1999). These three distinct types of industrial clusters are the *pure agglomeration*, the *industrial complex*, and the *social network*. The key feature which distinguishes each of these different ideal types of spatial industrial cluster, is the nature of the relations between the firms within the cluster. The characteristics of each of the cluster types are listed in Table 1, and as we see, the three ideal types of clusters are all quite different.

characteristics	**pure agglomeration**	**industrial complex**	**social network**
firm size	atomistic	some firms are large	variable
characteristics of relations	non-identifiable fragmented unstable	identifiable stable trading	trust loyalty joint lobbying joint ventures non-opportunistic
membership	open	closed	partially open
access to cluster	rental payments location necessary	internal investment location necessary	history experience location necessary but not sufficient
space outcomes	rent appreciation	no effect on rents	partial rental capitalisation
notion of space	urban	local but not urban	local but not urban
example of cluster	competitive urban economy	steel or chemicals production complex	new industrial areas
analytical	models of pure	location-production	social network

approaches	agglomeration	theory input-output analysis	theory (Granovetter)

Table 1. Industrial Clusters: A Transaction Costs Perspective

In the model of pure agglomeration, inter-firm relations are inherently transient. Firms are essentially atomistic, in the sense of having no market power, and they will continuously change their relations with other firms and customers in response to market arbitrage opportunities, thereby leading to intense local competition. As such, there is no loyalty between firms, nor are any particular relations long-term. The external benefits of clustering accrue to all local firms simply by reason of their local presence. The cost of membership of this cluster is simply the local real estate market rent. There are no free riders, access to the cluster is open, and consequently it is the growth in the local real estate rents which is the indicator of the cluster's performance. This idealised type is best represented by the Marshall (1920) model of agglomeration, and is the notion of clustering underlying models of new economic geography (Krugman 1991; Fujita et al. 1999). The notion of space in these models is essentially urban space in that this type of clustering only exists within individual cities.

The industrial complex is characterised primarily by long-term stable and predictable relations between the firms in the cluster. This type of cluster is most commonly observed in industries such a steel and chemicals, and is the type of spatial cluster typically discussed by classical (Weber 1909) and neo-classical (Moses 1958) location-production models, representing a fusion of locational analysis with input-output analysis (Isard and Kuenne 1953). Component firms within the spatial grouping each undertake significant long term investments, particularly in terms of physical capital and local real estate, in order to become part of the grouping. Access to the group is therefore severely restricted both by high entry and exit costs, and the rationale for spatial clustering in these types of industries is that proximity is required primarily in order to minimise inter-firm transport transactions costs. Rental appreciation is not a feature of the cluster, because the land which has already been purchased by the firms is not for sale. The notion of space in the industrial complex is local, but not necessarily urban, in that these types of complexes can exist either within or outside of an individual city. This complex model is actually the single explicitly spatial element in the transactions costs approach of Williamson (1979), where the focus is on the types of flow-process scale economies which firms can realise by being part of vertically-integrated production complexes. This type of thinking has often been the basis of policies aimed at the fostering of industrial enclaves, particularly in developing economies (Isard and Vietorisz 1955).

The third type of spatial industrial cluster is the social network model. This is associated primarily with the work of Granovetter (1973), and is a response to the hierarchies model of Williamson (1975). The social network model argues that mutual trust relations between key decision making agents in different organisations may be at least as important as decision-making hierarchies within individual organisations. These trust relations will be manifested by a variety of features, such as joint lobbying, joint ventures, informal alliances, and reciprocal arrangements regarding trading relationships. However, the key feature of such trust relations is an absence of opportunism, in that individual firms will not fear reprisals after any reorganisation of inter-firm relations. Inter-firm cooperative relations may therefore differ significantly from the organisational boundaries associated with individual firms, and these relations may be continually reconstituted. All of these behavioural features rely on a common culture of mutual trust, the development of which depends largely on a shared history and experience of the decision-making agents. This social network model is essentially aspatial, but from the point of view of geography, it can be argued that spatial proximity will tend to foster such trust relations, thereby leading to a local business environment of confidence, risk-taking and cooperation. Spatial proximity is necessary but not sufficient to acquire access to the network. As such, membership of the network is only partially open, in that local rental payments will not guarantee access, although they will improve the chances of access. The geographical manifestation of the social network is the so-called 'new industrial areas' model (Scott 1988;), which has been used to describe the characteristics and performance of areas such as the Emilia-Romagna region of Italy (Piore and Sabel 1984; Scott 1988; Storper 1997; Castells and Hall 1995). In this model space is once again local, but not necessarily urban.

In reality, all spatial clusters will contain characteristics of one or more of these ideal types, although one type will tend to be dominant in each cluster. Therefore, in order to understand the advantages to the entrepreneurial firm of being located in any particular cluster, it is first necessary to determine which of the ideal types of industrial cluster, described in Table 1, most accurately reflects the overall characteristics and behaviour of the firms in the cluster. With this knowledge, we can then consider how the organizational characteristics and objectives of our entrepreneurial firm relate to the characteristics and behaviour of the other clustered firms. This form of analysis, whereby the decision-making and organizational characteristics of the firm are considered explicitly with respect to the firm's environment, is a standard methodological approach in industrial organisation research (Caves 1982; Aliber 1993). However, these organization and decision-making issues are largely ignored in the simple clusters literature, and as such, the relationships between firm location, innovation, entrepreneurship and regional development are little understood.

3. *The Semiconductor Industry and Clusters: Current Popular Wisdom*

In terms of industrial clustering, innovation and entrepreneurship, there is one industry whose spatial and organizational issues have been discussed at length, and this is the semiconductor industry. The advantages of industrial clustering for internationally competitive sectors such as the semiconductor industry, have been extensively surveyed in the literature (Piore and Sabel 1984; Best 1990; Porter 1990), with the focus of these arguments being primarily on the geographical aspects of the US, and in particular the Silicon Valley, semiconductor industry (Larsen and Rogers 1984; Piore and Sabel 1984). The benefits of industrial clustering for the semiconductor industry have been analysed in terms of the role played by informal local information spillovers (Jaffe et al. 1993; Almeida and Kogut 1997) and also in terms of the advantages associated with a high quality and highly flexible local labour market (Angel 1991). In these clusters, the means by which both firms and the local industry evolve are largely non-price mechanisms, in the sense that information and labour market externalities play a key role, as do certain 'trust' relationships between local firms, if and where they exist. In terms of our cluster characterizations in Table 1, the Silicon Valley example is therefore primarily a 'pure agglomeration', with possibly also some aspects of a ‘social network’ (Saxenian 1994), although the latter is difficult to prove. In spite of the fact that the empirical validity of some of these arguments has been questioned (Arita and McCann 2000; Audretsch and Feldman 1996; Suarez-Villa and Walrod 1997), in many quarters the Silicon Valley example of industrial clusters is perceived to be the ideal spatial and organizational arrangement for 21st century innovative industries (Castells and Hall 1995; *The Economist* 1997). It is argued that in the case of the semiconductor industry, hierarchically organized firms are incompatible with the entrepreneurship and innovative dynamism associated with modern industrial clusters, because rigid organizational boundaries and corporate control prohibit the continuous redevelopment of dynamic local relations (Saxenian 1994; Turok 1993). These arguments have also been applied to other sectors (Best 1990).

Beyond the (questionable) example of Silicon Valley, the currently popular arguments outlined here, regarding the presumed incompatibility between the existence of hierarchical firms and the development dynamic of entrepreneurial and innovative clusters, are actually very limited in their general applicability to most sectors or locations. The reason for this is that the clusters literature is based on a very narrow and stylised description of the optimal relationship between spatial and industrial organization. In particular, such clusters assume that there are many co-located small firms, which are highly dynamic, entrepreneurial, and innovative in response to local information spillovers. In cases where such conditions do not exist, proponents of these theories (Saxenian 1994) argue normatively that they *should* exist. Yet, as we have seen from Table 1, these cluster models are characterized by a combination of the model of ‘pure agglomeration’ along with possibly some aspects of the ‘social network’ model. Yet, the simple cluster literature generally ignores the possibility that other institutional arrangements, such as the ‘industrial complex’ arrangement described in Table 1, may not only be optimal in many innovative industries, but may also be widespread in reality. Risk-taking, innovation and entrepreneurship may be significant in quite different spatial-industrial arrangements. The importance of this oversight is that the ‘industrial complex’ model provides an obvious rationale for industrial clustering on the part of multiplant and multinational firms in cases where the firm wishes to use location as a means of maintaining control and internalising information within a defined group rather than sharing it with the local industry in general. In other words, industrial clustering can be a means of internalising externalities and avoiding non-market signals within the well-defined organizational boundaries typical of multiplant and multinational firms, and yet can still be entirely compatible with the existence of a locally dynamic and innovative industry.

4. *The Organization of the Semiconductor Industry*

In order to understand the organization of the semiconductor industry it is first necessary to understand the different activities which take place within the industry (Nishimura 1995, 1999; EIAJ 1994). The nature and relationships between the different activities within the semiconductor industry are actually very similar to the different activities which take place in the book publishing industry (Arita and Fujita 2001; Arita and McCann 2002a,b). These are described In Fig.1.

Fig.1 Production Process of Semiconductor: Comparison with Book Publishing and Printing

The reason we use the example of the book publishing industry for comparison purposes, in order to help describe the organization the semiconductor industry, is that while the nature and range of activities in the book publishing industry are generally understood, the activities of the semiconductor industry are not. As we see in Fig.1, the first stage of the semiconductor production process is the silicon chip design stage, in which the functional logic of the chip, and three-dimensional circuit layout of transistors and capacitors within the silicon wafer is determined. This activity is carried out primarily using computer aided design (CAD) systems. The result of this stage is the production of masks, which are the three-dimensional templates of the chip. This stage of the process can be compared to the planning, editing and layout stages of the book publishing process.

The second stage of the process is the wafer process, the technology of which is determined by materials science. At this stage of the production process the circular silicon wafers, produced by specialist chemicals firms, are subjected to lithography. This is a process whereby ultra-violet light is used to illuminate certain parts of the wafer, according to the mask design, in order to bring about chemical changes within certain parts of the wafer. The wafers are then etched and treated, thereby removing the parts of the wafer subjected to the lithography. After as many as fifteen stages of lithography and treating, the result is a three-dimensional silicon structure. This stage of the semiconductor production process can be compared to the plate-making and phototype process which takes place in the book printing industry.

The final stage of the wafer production process is that of the wafer assembly process. Here, the circular wafers which have been subjected to lithography and treating are extracted and dissected into many small square chips, each of which is then framed in plastic or ceramics for insulation and protection. This stage of the chip production process is the equivalent of the book binding process within the book publishing industry.

Different firms and firm types and different locations tend dominate in different stages of the semiconductor industry (Arita and McCann 2002b). Some firms are specialized only one of the three semiconductor production stages, whereas other firms integrate more than one of the production stages. Small firms, which are involved in just the first stage of production tend to be concentrated in places such as Silicon Valley. Unfortunately, however, it is only these small-firms involved in this first stage of the semiconductor production process which have been the focus of so much of the recent interest in clustering, and it is this concentration of small firms which has been presented as the ideal stereotype of the industry. Yet the majority of the global semiconductor industry is actually comprised of large vertically-integrated firms which carry out both of the first two activities, and in many cases, all three stages of the semiconductor production process (Arita and McCann 2002b). Moreover, it is these firms which actually produce the majority of patents and new product and process innovations within the industry. However, the spatial and organizational behaviour of these firms, which represent the majority of the global semiconductor industry, has been almost entirely ignored. These vertically-integrated firms sometimes arrange their establishments in geographical clusters, but the reasons for such behaviour are very different from the clustering arguments outlined in section 3 describing the spatial organization of Silicon Valley. Therefore, in the next section we briefly discuss two examples of industrial clustering which reflect the typical behaviour and objectives of the multiplant and multinational vertically-integrated parts of the semiconductor industry. These two examples are the Japanese semiconductor producer Toshiba, and the US semiconductor producer Texas Instruments. The spatial organization of these two firms is discussed in order to demonstrate counter examples to currently popular simple clustering models.

6. *Examples of Corporate Clustering: Toshiba and Texas Instruments*

For the Japanese example of Toshiba, we have compiled data from two sources (*Sangyo Times* 1995; *Press Journal* 1995), which document all of the industry's plants by location, activity, and position within the corporate organizational hierarchy. All of the data for each of plants is 1995 data, which is the latest date for which all of the data is available.

The domestic organization of Toshiba is typical of all Japanese vertically-integrated semiconductor producers (Arita and Fujita 2001; Arita and McCann 2002a,b). The firm is strictly organized into a simple vertical hierarchy, with groups of plants performing the third stage activity of wafer assembly reporting directly to a single plant carrying out second stage activity of wafer processing. Each of the wafer processing plants itself will report directly to the firm's headquarters, in this particular case located in Tokyo, at which a range of first, second and third level activities take place.

Fig.2 The Spatial Organization of Semiconductor Plants at Toshiba (1995)

As we see in Fig.2, the firm's individual plants are often arranged in small geographical clusters, in which several third-tier wafer-assembly plants are located very close to the particular second-tier wafer-process plant to which they report directly. The second-tier wafer-process plants each report directly to one of the first-tier design plants. Each of the plants in the hierarchy has a controlling shareholding interest in all of the plants which are subsidiary to it, as is typical in such keiretsu types of business groupings (Clark 1979). Each individual cluster of plants, together as a group, produces a different type of silicon chip, the overall development of which is controlled from a particular first-tier plant. Although it is beyond our means here, by observing the location of different vintages of technology, it can also be shown that there is no simple centre-periphery product-cycle logic to these spatial patterns (Arita and McCann 2002c). Clusters of plants are set up to produce a particular type of technology, rather than technology vintages being pushed through a given spatial system. The reason for this type of spatial organization is to facilitate and maintain strict control over inter-plant information flows, as well as to minimise the shipment costs of goods between plants. Japanese vertically-integrated semiconductor producers are renowned for their extreme secrecy. Local external information spillovers play no part in the organization of these wafer process and assembly plant clusters; which are designed specifically to militate against such phenomena. Moreover, it can also be shown that the extreme secrecy surrounding the first-tier plants suggests that the location of these facilities is also unrelated to local informal information exchanges (Arita and McCann 2002b). Similar behaviour is also observed in the pharmaceuticals sector (Simmie 1998).

For its overseas investments, Toshiba locates a range of activities in various US locations, including a first-tier facility in Silicon Valley. However, while this may be suggestive of popular clustering arguments, it should be noted that as of 1995, Toshiba was the only one of the ten major Japanese semiconductor producers with a Silicon Valley R&D presence. All other Japanese Silicon Valley investments were involved with wafer process and assembly activities. Toshiba's investments in other parts of the world are primarily wafer assembly activities.

Fig.3 The Spatial Organization of Semiconductor Plants at Texas Instruments (1994)

Our second example is that of Texas Instruments. Our data here is based on 1994 observations (INSEC 1995), which is the latest complete data available. As we see from Fig.3, within the US, Texas Instruments has a cluster of plants each of which undertakes one of the three stages of the wafer production process. Texas Instruments has no other US semiconductor facilities. Once again, while this may initially appear to be suggestive of the simple cluster arguments outlined in section 3, the logic of this spatial arrangement is basically the same as that for Toshiba in Japan; namely to facilitate and maintain strict control over inter-plant information flows, as well as to minimise the shipment costs of goods between plants. For this cluster of facilities, the organization of these wafer process and assembly plant clusters is designed specifically to militate against informal information spillovers.

For overseas investments, Texas Instruments locates R&D facilities in Europe and Japan, and wafer process and assembly activities primarily in Latin America and Asia.

7. *Discussion*

In terms of our clustering typologies described in Table 1, we see that the nature of the spatial organization of the domestic plants of both Toshiba and Texas Instruments is primarily characterised by the 'industrial complex' model. In other words, stable and predictable relations exist between the various plants. Informal and external information spillovers between local firms are not the primary rationale for such clustering behaviour. Although it may be argued that trust relations of the 'social network' model may be enhanced by proximity between the plants, the clustering logic here is primarily a function of hierarchy organization and information internalization. While the clustering behaviour of these vertically-integrated firms may well also be related to issues of local labour quality, what these examples definitely do not represent is a combination of the 'pure agglomeration' and 'social network' models, characteristic of new industrial clustering theories (Porter 1990; Saxenian 1994). The reason for this is that new industrial clustering theories are predicated on assumptions about informal information spillovers and highly-flexible firm relations. On the other hand, the clustered location patterns of these vertically-integrated semiconductor firms have much more in common with the 'industrial complex' model of location, and is typical of the information internalization behaviour of MNEs in other locations (McCann 1997) and other sectors (Simmie 1998). Our observations therefore suggest that the opportunities for MNE semiconductor firms to engage with local input supply linkages are rather more limited, and much more dependent on organisational issues, than many other authors assume (Henderson 1987, 1989; Saxenian 1994). Moreover, as with all issues dealing with essentially institutional frameworks, the time period required in order to allow for a level of institutional harmonisation which is sufficient to foster such relationships, may be much longer (North 1990) than some of the current simple clustering theories implies.

Such clustering behaviour will not necessarily offer many advantages to a small firm start-up type of entrepreneurial model. This is because, at least as far as the flexibility of inter-firm relations is concerned, the potential advantages of proximity and smallness will not necessarily be appropriate. On the other hand, however, in terms of the upgrading of local labour skills, and the development of product and process innovations, such clusters may provide regions with major advantages, although such advantages will be mediated only within a clearly-organised and stable system of inter-firm relations.

The major lesson to come out of these examples is that observations of industrial clustering behaviour on the part of high-technology activities, cannot necessarily be taken as evidence of the types of new industrial cluster arguments which are currently popular (Porter 1990; Saxenian 1994). Careful consideration must be given to the institutional logic of the cluster and the nature of the transactions which take place between firms within the cluster. The nature of entrepreneurship must be carefully defined. Strict interpretations of entrepreneurship, which focus solely on the development of small firms and spin-off firms must be expanded to include the dynamic and innovative role of large organisations, and the relationships between firms size, inter-firm relations, innovation and local regional development.

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Production Process of Semiconductor
Comparison with Publishing and Printing

Semiconductor		Books	
DESIGN	Planning & Design of Circuits Layout Design Mask Making	Planning & Editing of Manuscript Layout Block Copy	**PUBLISHING**
WAFER PROCESS	Lithography Wafer Manufacturing Process	Plate Making Phototype Process Printing	**PRINTING**
ASSEMBLY	Assembly Testing	Book-binding Testing	**BOOK-BINDING**
	Silicon Wafer (Wafer Manufacturing Makers)	Papers (Paper Manufacturing Makers)	

Fig.1. Production Process of Semiconductor: Comparison with Book Publishing and Printing

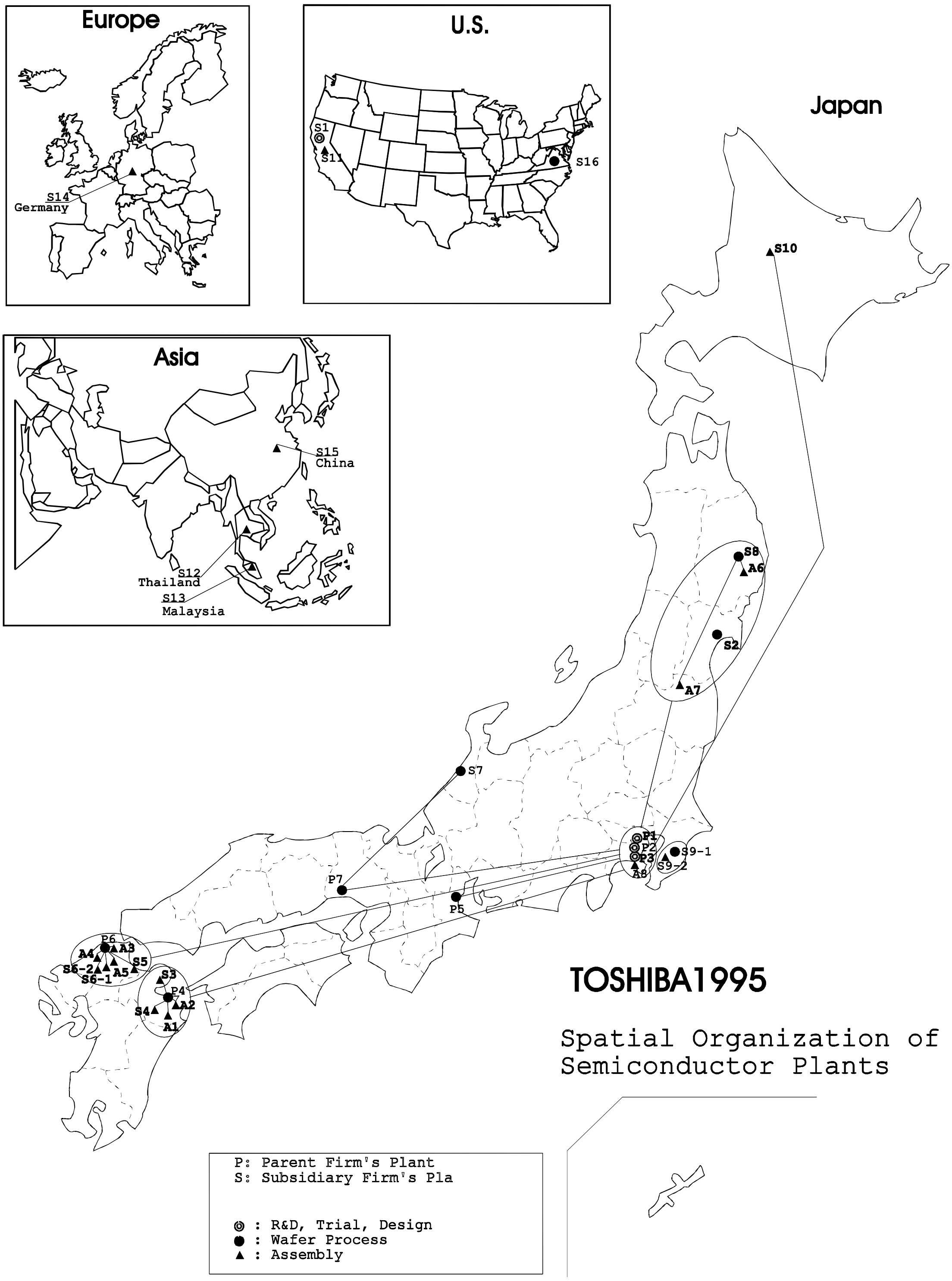

Fig.2 The Spatial Organization of Semiconductor Plants at Toshiba (1995).

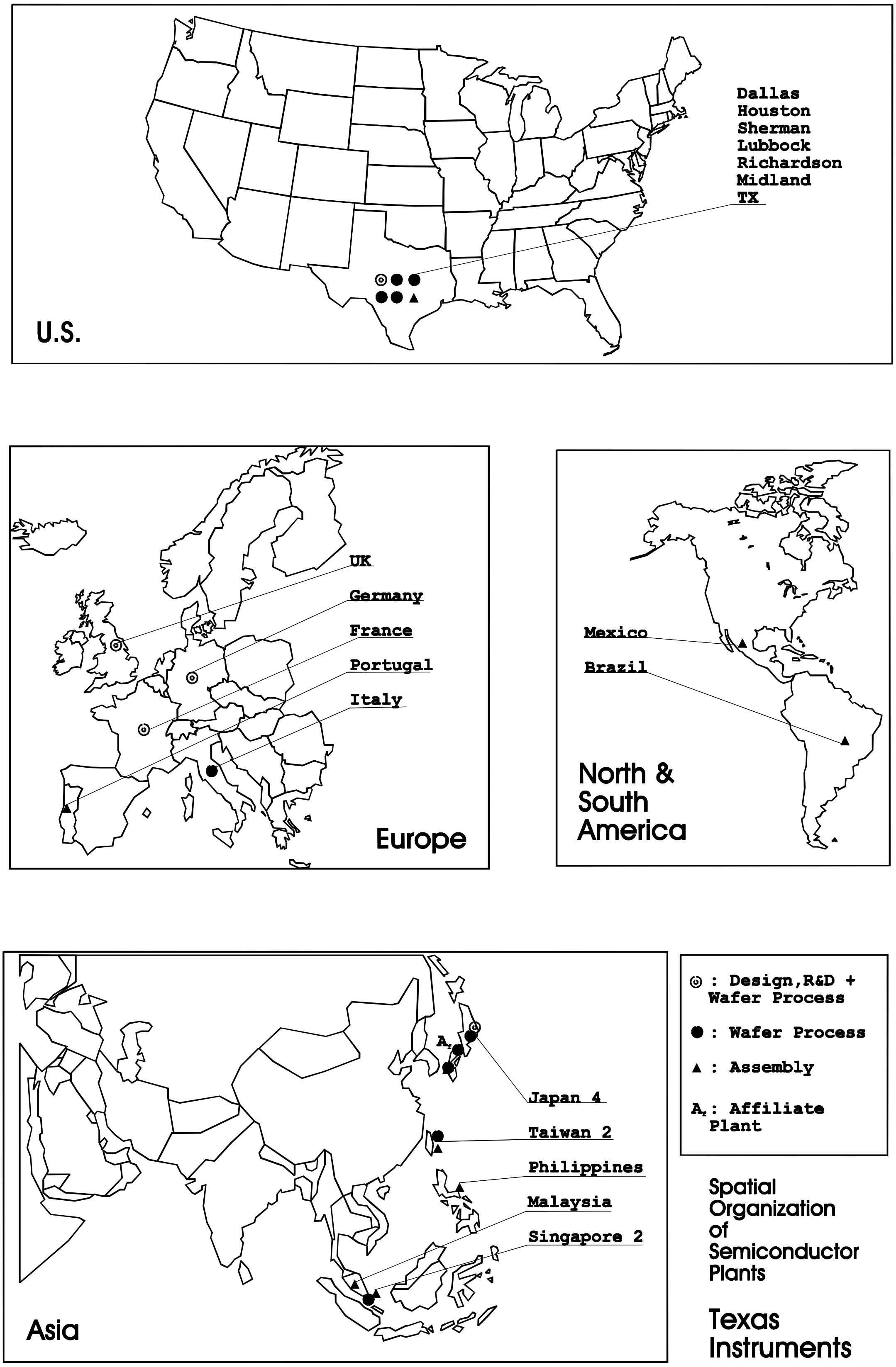

Fig.3 The Spatial Organization of Semiconductor Plants at Texas Instruments (1994).