DOMESTIC MARKETS AND INTERNATIONAL COMPETITIVENESS:{PRIVATE }
Generic and Product-Specific Competencies in the Engineering Sector

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DOMESTIC MARKETS AND INTERNATIONAL COMPETITIVENESS

This paper develops a theoretical and empirical model to analyze the effects of the size and nature of domestic markets on the international competitiveness of national industries. We validate our theory using data on the more than 20,000 plants in the sector producing engineering services for petrochemical plants. Our analysis suggests that the (relative to the US) competitiveness of European or Japanese industries is greater in activities whose underlying competencies can be utilized repeatedly across products instead of being confined to well defined product category. Put differently, the cost penalty due to the fragmented European markets is the least in the case of activities based on generic competencies, and the greatest for activities based on product specific competencies.

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INTRODUCTION

The question of how economic and other characteristics of national markets shape the competencies of firms and industries has become a prominent one in economic and business strategy research. Michael Porter [1990] has noted that these factors can be an important source of distinctive advantages. A number of scholars have argued that a "national system of innovation" is a useful conceptual construct for thinking about why countries differ in the way firms approach technological development, and in their technological performance (see Nelson [1993]).

This paper focuses on a specific question within this broader context. We examine how the size and nature of the internal market influence the international performance of firms, and how these effects differ across firm activities according to the nature of the competencies that form the basis of those activities. Our use of the term "activity" rather than "product" or some synonym is deliberate. Although it may be analytically convenient to identify firms with products, such an identification also obscures the idea that firms are better identified with competencies and capabilities rather than with product markets. Moreover, competencies are typically difficult to change, and they can be of different types. In particular, while some of them are product-specific, others are applicable across a variety of products.[1]

That larger domestic markets may have beneficial effects on the competitiveness of national industries is not surprising.[2] The typical explanations have appealed to firm level increasing returns (e.g. learning by doing). We focus on the case where increasing returns at the level of the firm are unimportant. We

find that large domestic markets still have beneficial effects. However, we shall argue, that in smaller markets, the competitiveness of national industries is more strongly penalized in the case of activities that require competencies that are product-specific vis-a-vis competencies that are more generic. We use "generic" to mean that the competency is applicble to a variety of products. The natural comparison is between the large, integrated US market, and the comparably sized but fragmented continental, market of Western Europe. Our argument is that, other things being equal, market fragmentation in Europe hurt domestic industry, but in the case of more generic competencies, the relative disadvantage was smaller. Using the language of economics, whereas a larger market may bestow an absolute advantage across a variety of activities, "smaller" markets have a comparative advantage in activities underpinned by generic competencies.[3]

We examine these issues by studying an important, yet very much neglected, sector of modern economies -- the sector supplying engineering and construction services for oil refining and petrochemical plants. We base our analysis on a comprehensive data set of more than 20,000 oil refining and petrochemical plants constructed during 1970-1990 all over the world. The key point is that the competitive advantages of firms in the engineering sector depends on different types of assets and competencies. Some of these competencies are product specific, whereas others applicable across a variety of downstream products. Thus, at one end, one can think of the development of proprietary technologies for licensing, which depends on know-how and experience that is specific to particular process technologies. At the other extreme, plant construction rests on more generic skills, like project management, organization of work and co-ordination of sub-contractors, etc.

Although our discussion (and our evidence) pertains to the engineering sector, the distinction between product specific and generic competencies is a general one. For instance, in pharmaceuticals, Henderson and Cockburn [1996] show that large pharmaceutical firms focus on relatively few therapeutic classes, indicating that product specific competencies are important. By the same token, generic competencies are important as well, because they find evidence of spillovers across therapeutic classes. Similarly, while leading firms in many US industries are increasing their focus on core products areas, leading European firms in the same industries are maintaining a certain degree of diversification.[4] We argue here that these patterns can be understood as a consequence of the differential impact of market size on product specific competencies and generic competencies.

The next section presents a brief history of the evolution of the engineering sector in oil refining and petrochemicals. The next section describes our data, and shows the extent of the division of labor between engineering firms and downstream manufacturers. In the following section, we discusses the "technological" and "organizational" competencies of engineering companies. It uses our data to show that the former are more product-specific than the latter. This serves as the basis for our discussion on the comparative performance of the US, Western European and Japanese engineering sectors. The next section provides empirical validation. We show that the leading US firms have a greater advantage in licensing (which requires product specific competencies) relative to construction (requiring relatively generic competencies). The concluding section briefly discusses the extensions of our theory to other sectors.

THE ECONOMICS OF THE SPECIALIZED ENGINEERING FIRM

Petroleum refining and the petrochemical sector are characterized by large scale, continuous production technologies. In the 1930s, and especially during the postwar period, process innovation, both major and incremental, had been an important factor in determining the competitive dynamics of these industries (e.g. Enos, [1962], Stobaugh [1988]). A major process innovation is followed by incremental innovations. Very often, these are aimed at increasing the scale of production, in an attempt to take advantage of the fact that capital costs increase less than proportionally with a rise in the scale of output. Other areas of incremental innovation have included the optimization of energy consumption, increased selectivity of output, and higher yields.

The complex nature of the process of design and construction of continuous plants, and the large size and high growth rates of markets created the possibility of specialization and division of labour. Indeed, from very early in this century, petroleum and chemical firms used specialized firms in various capacities: to procure or manufacture equipment such as pumps and compressors, valves, and heat exchangers, and to provide specialized sub-systems such as piping and the electrical system. Although the petroleum and chemical firms tended to do process development and design work in-house, " ... contractors would be called in to handle constructions, piping and mechanical work, electrical work, and other separated facets of the project" (Landau and Brown, 1965, p. 7:35). As these engineering-construction firms grew in their ability to handle more sophisticated tasks, process design too came to be a part of their activities. In what follows we shall use the term Specialized Engineering

Firms (SEFs) to refer to these specialized contractors whose business is the design, engineering, and construction of oil refineries and chemical plants.

SEFs had varied backgrounds. Some, such as Bechtel, started as civil engineering contractors. Others, such as Lurgi, and Lummus, were equipment makers for the chemical industry. Later on, some firms, like Zimmer or Scientific Design, grew out of process developments by innovative chemical engineers. The first SEFs were formed as early as the 1920s. They were mostly American, and typically, their clients were large oil companies (Landau and Brown, 1965, p. 7:35)[5] In the years before World War II, the chemical companies did not rely as much as the oil companies on SEFs for the design and engineering of entire production processes. In part, this was due to the long standing tradition of secrecy that characterized some of the chemical companies. But it was also due to the fact that these companies often had fairly large and established in-house departments for design-engineering.

However, by the 1960s, SEFs had come to occupy an important place in the industry. Freeman notes that for the period 1960-66, " ... nearly three quarters of the major new plants were "engineered", procured and constructed by specialist plant contractors" (Freeman, 1968, p.30). As with any division of labour, the rise of SEFs in the postwar period was made possible by the rapid growth in the market for chemical products, a growth rate which was about three times that of GNP in the advanced western economies (Freeman, 1968).[6] This implied that even a small reduction in the manufacturing cost meant large profits. Producers were therefore willing to employ specialist firms which would provide them with improved processes and cost efficient plants.

The specialist firms - the SEFs - worked for a number of clients. Based on their accumulated experience, SEFs were often successful in designing better processes and plants. In plant construction, they could accumulate expertise in project-management and become better than chemical companies at the organization and co-ordination of large projects. At the same time, a few SEFs even became important innovators in their own right (See for instance Mansfield et al., 1977.) Most SEFs, however, were not major innovators.[7] Most major new processes then came from the chemical and oil companies themselves. As Spitz (1988) notes, the first large plant for a new process would typically be built by an operating company (producer). But once an SEF was provided the relevant information about the plant, it could run "copies" for a number of clients, and thus learn about, and improve the process.

As noted earlier, SEFs first arose in the US, and moved abroad aggressively after the end of World War II.[8] In a seminal paper, Freeman found that the market for design and engineering of chemical plants was dominated by US firms. (Freeman [1968].) For the period 1960-66, SEFs from the US accounted for 99% of the value of all chemical plants constructed in the US, over 85% in Latin America and Canada, and over half of *all* "exports". But Freeman also noted that SEFs from Western Europe and Japan were developing into major competitors for the US. As in other sectors, there are important distinctions between the structure of the SEF sector in the US, and that in Western Europe and Japan. For one, SEFs in the US are typically independent companies, not affiliated with oil and chemical producers. By contrast, some (although not all) of the leading European and Japanese SEFs

were born as engineering divisions of larger manufacturers.[9] As the market for engineering services grew, they began to serve other clients as well.

THE MARKET FOR ENGINEERING SERVICES

Data set and sample

This essay is based on the analysis of a data set which covers 25,835 plants in oil refining and petrochemicals constructed or planned during 1970-1990. The Hydrocarbon Processing Industry (HPI) data base (Gulf Publishing, Texas) is constructed from a systematic annual survey of the plants in the industry. For each plant, the HPI data base reports a variety of information including the name of the client (operating company), the firms acting as the engineer, the licensor, and the contractor, the product or technology, and the location of the plant.[10] HPI adopts a broad definition of petrochemicals, and classifies the plants in five major technological categories: Natural gas, refining, petrochemicals, offsites and utilities, and coal and other solids.

HPI is a source commonly employed by petrochemical analysts and by the industry itself, and its broad coverage suggests that biases are unlikely. A more important concern is that while all records report the name of the firm that ordered the plant (the operating company), the field of the engineer, licensor, or contractor is sometimes blank. HPI staff told us that this could be either because the appropriate information was not reported, or because the correspoding ngineering or contractor services were provided in-house -- but since the company had not explicitly reported it. In the case of licenses (and partly of engineering services), a blank may also denote that the technology is so commonly available

that there is no need to purchase the technology. These are not simply measurement errors because blank records may not be randomly distributed. As a result, we report our results in two forms - for all plants, as well as for plants where the relevant field is not blank.

From our data we selected sample of 169 SEFs. The criterion used was to select all firms that were engineers or contractors of 20 or more plants in the data base, and operating companies of no more than 5 plants. With 20 years of data, this amounts to defining SEFs as companies that provided engineering or construction services for at least one plant per year on average. We are then discarding firms that supply these services only occasionally. By excluding firms that operated more than 5 plants, we are also ruling out the oil or chemical companies. However, there were only a handful of companies in the data base that were engineers or contractors of more than 20 plants, and operating companies for more than 5. Very few oil and chemical companies appear to be also suppliers of these services on the open market.

Most SEFs in our sample come from the US or Western Europe (about 45, or 30% of the sample, from each of the two regions). Some of the US firms, like UOP, Lummus, Kellog are among the earliest SEFs in the world. Among the Western European firms, British, German, Italian, and French SEFs are the most frequent. The more prominent European SEFs include Lurgi and German Linde (Germany), Snamprogetti (Italy), and John Brown (UK). Our sample also includes 14 Japanese SEFs, with Mitsubishi Heavy Industries, JGC, and Chiyoda being among the more prominent ones. About 10% of our sample consists of companies from other regions.

Division of labor in licensing, engineering, and plant construction

A notable feature of the market of engineering services is the extent reached today by the division of labor between SEFs and oil or petrochemical companies. Table 1 reports the total number of plants in our data base by main regions of the world. For each region, it shows the breakdown of plants engineered by the buyer (staff), by one of the SEFs in our sample, by other engineers. The relevant size of the market for the SEFs is the number of plants constructed in the region. The last column shows that in terms of total number of plants, the US market is larger than the Western European market. Our SEFs account for more than 75% of the engineering contracts in which the engineer is known (about 65% of total contracts). The order of magnitude of this percentage does not differ across regions. This figure is also consistent with Freeman's [1968] results where SEFs accounted for about two thirds of all plants, by value. By contrast, on average 5% of the plants are engineered by the buyers. As expected, the percentage of in-house engineering services is higher, but only marginally so, in more developed regions (USA, Western Europe, and Japan).

[Tables 1-3 about here]

Table 2 reports the same data for construction. Again, our SEFs account for a large share of the contracts (73% of known contractors and about 53% of total plants), and the percentage of in-house activities is small. Table 3 shows a similar breakdown for licenses. With respect to engineering and construction, the licensor is known in fewer cases (60% of total plants versus 85% and 73% for engineering and construction), perhaps because a number of technologies are in the public domain,

reducing the need for buying proprietary technologies through licenses. More interestingly, our SEFs account for a smaller percentage of total licenses (49% of plants in which the licensor is known, and 29% of total plants). As suggested earlier, most SEFs are not major innovators, and large oil and chemical companies have been responsible for many innovations in this field. Table 3 also shows that the top 100 operating companies (measured by number of plants in the entire data base) account for an important share of total licenses (28% of plants in which the licensor is known, and about 17% of total plants). The division of labor in licensing appears to be less pronounced than in engineering and construction.[11]

We also examined whether the SEFs serve primarily smaller companies, which are less likely to have in-house capabilities to engineer or construct their plants. Tables 4 and 5 show that the difference between the top 100 and other companies is minimal, with the former showing a slightly higher percentage of in-house activities. This is true for both OECD and non-OECD projects, and in construction and engineering. It appears that the advantages of specialisation are so significant that even large companies, which could in principle produce in-house, find it more profitable to resort to SEFs.

[Tables 4-5 about here]

COMPETENCIES AND STRATEGIES OF SEFs

TECH versus ORG type of competencies

But what are the capabilities and sources of competitive advantages of SEFs? SEFs provide know-how that can be thought of as ranging from generalized engineering services to knowledge of very specific and particular processes, or even sub-processes. This suggests that one can distinguish between two main types of competencies of SEFs. On the one hand, there are competencies that can be broadly defined as "technological" (TECH). They refer to the ability of SEFs to generate technical improvements and innovations in plants and in plant design, and they are typically related to the development of proprietary technologies. On the other hand, there are "organizational" competencies (ORG) which are located further "downstream", and they refer to the ability of organizing and coordinating the design, engineering, and physical construction of plants. The competencies required to design and especially to construct plants depend, for instance, on expertise in coordinating local sub-contractors, and in defining project-management tasks. In developing countries, ORG capabilities may also include organizing project financing, as well as arranging for the sale of output (counter-trade).

Many of the SEFs in our sample have demonstrated competencies of one type or another, and some appear to have both. At the generalized engineering end we have firms such as Bechtel, which are large contractors operating not just in petrochemicals, but also in building, transportation and other sectors. At the other end we have companies like Merichem, and UOP, which have concentrated on selling the technology, with a reduced emphasis on the sale of know-how and engineering services. At the same time, companies like ACSA, German Linde, or Kellog provide their proprietary technology in conjunction with engineering know-how. In some sense, unlike UOP or Petrolite, this group may be

thought of as using the proprietary technology to help the sale of their main "product" -- know-how, and engineering services.

Two key aspects of these competencies are important to emphasize. First, that these competencies appear to be stable over long periods of time. For instance, UOP, an SEF prominent in the area of refining processes was started in the 1930s in an attempt to develop a catalytic cracking process where heavier oil fractions are "cracked" into lighter and more valuable fractions. Alongside, UOP also developed a catalytic reforming process - for forming aliphatic (straight chain) hydrocarbons into aromatic hydrocarbons (with benzene ring structures). Some sixty years since then, UOP is still working these very areas. Kellog, another SEF has been prominent in the area of Ammonia technology. Badger has long been known for its expertise in the area of fluidized bed catalytic processes. By the same token, SEFs such as John Brown, Bechtel, and Parsons are well known for the ability to undertake large scale construction contracts.

The notion that competencies should be relatively stable and difficult for firms to change lies at the heart of much of the research in strategy, as well as evolution of industry structure, and the theoretical underpinnings have been discussed extensively, (e.g. see Nelson [1995] and the references cited therein). A widely accepted supplementary proposition related to the notion of stable competencies is that firms differ in their competencies. In other words, there is both a systematic as well as a random aspect of firm competencies. For instance, Teece et al [1994] have advanced the notion of "corporate coherence", to show how differences in competencies explain the diversification patterns of firms. A

maintained hypothesis for this paper is that some firms are more efficient along the TECH dimensions, while others are more competent in ORG based activities, and these differences persist over time.

The second noteworthy point is that these two types of competencies, TECH and ORG, are differently related to product-specific assets and expertise. TECH competencies are product- (sector) specific. The development of proprietary technology depends to a large extent on specific knowledge and expertise with processes and plants of a similar kind. For instance, even though there are commonalities between the technology underlying a refinery and a urea plant, there are also notable differences among them. Proprietary technologies and related engineering services differ in terms of the types of feedstocks, reaction pathways, or by-products. These differences in turn imply differences in knowledge and expertise along technical dimensions such as the performance of different catalysts. Since a substantial portion of such knowledge tends to be context specific, the more important these details are for the performance of the entire plant, the more difficult it is to take advantage of knowledge or experience gained from other plants or technologies.

ORG type competencies are instead less product specific. The skills required to organize sub-contractors, or to handle project management tasks or financing, do not drastically differ across products. What is relevant here is the ability to manage large projects, and this is fairly independent of the specific plant or technology. For precisely the same reasons, ORG competencies are likely to be region specific. The organization of local work, or of the means of project financing, or the knowledge

about local rules, regulations, and institutions, requires acquaintance with the conditions in which the plant is to be constructed, and these are likely to differ across countries and regions.[12]

The need to capture product -- or region -- specific economies has influenced the strategies of SEFs. SEFs will be more product focussed in their TECH strategies, and more region focussed in their ORG strategies. Having acquired the competencies required to operate in a certain technological area or in a certain region, an SEF will tend to use these competencies repeatedly over a large volume of output. This is evident in the case of licenses. Suppose that an SEF has invested in R&D and developed a new proprietary technology to be licensed. It will have incentives to sell a large number of licenses because, all else held constant, the fixed costs of development can now be spread over a larger number of licensees. While TECH capabilities are therefore limited by technology (product), ORG competencies are typically limited by the region where the company has acquired geographically specialized competencies. Thus, while product specific competencies encourage firms to expand within the same technological classes and across regions, region specific competencies, which are generic with respect to technologies, will encourage SEFs to operate in different technological area within the same region.

Product versus regional focus

TECH competencies are associated with technological activities such as licensing, than with the more generalized engineering and project management activities involved in construction. As a result, we expect that the licensing to be more specialized than construction, with engineering being in between. We examined whether SEFs are more product focussed in their TECH strategies, and more region

focussed in their ORG strategies by constructing indices of product and regional diversification for the SEFs in our sample. We counted the number of licenses, engineering, and construction services of our SEFs in the five product areas of the HPI data base. For each SEF, we computed product diversification across these five sectors -- one for licenses, one for engineering, and one for construction services.[13] Similarly, we measured the regional diversification for each SEF (one for each activity) across the following ten regions: USA, Canada, Central and Latin America, Western Europe, Eastern Europe, Africa, Mid-East, Far-East, Japan, Australia.

Comparisons of arithmetic means, while traditional, are liable to be influenced by extreme values. A more robust comparison can be made by comparing the cumulative distributions. We constructed cumulative distributions, one each for licensing, engineering, and construction, first for our index of technological diversity and then for regional diversity.[14] If companies are more product focussed in their licensing behavior, one will observe that the cumulative distribution of diversity for this activity is always above that of construction. An easy way to interpret this comparison is that for any arbitrary value of the diversity index, the fraction of companies that have a lower index (i.e. that are more technologically specialized) is greater in licensing than in construction.

Figures 1 and 2 show the three cumulative distributions of the technological and regional diversification. As figure 1 shows, the technological diversification for licenses is below that of construction and engineering. Licensing appears to be more technologically focussed than the other two activities. The engineering and construction diversity indexes have a practically overlapping

distribution, which suggests that they are fairly similar in this respect. As is well known in the literature, these curves are evidence of first degree stochastic dominance, which implies, among other things, that the average value of the product diversity index is lower for licensing. Figure 2 shows exactly the same results, but the order of the three activities is now reversed. Licensing is the most regionally diversified activity, whereas construction is the most focussed.

[Figures 1-2 about here]

INTERNATIONAL COMPETITIVE ADVANTAGES: THE ROLE OF DOMESTIC MARKETS

Nature and size of domestic markets: Implications for TECH and ORG competencies

Having established that TECH competencies are more product-specific than ORG, we can turn to international competitive advantages. As discussed in section 2, the SEF sector in each country was strongly conditioned by its domestic market. The demand and other conditions that SEFs found in their home regions influenced their competencies, and therefore, conditioned their success in the international arena. The question we ask is whether the larger size of the US market provided special advantages of some kind, and particularly whether these advantages were more pronounced for TECH based activities like licensing, as compared to ORG based activities such as construction. To address this question, we discuss below how the conditions that prevailed in the domestic markets influenced the distribution of the TECH and ORG competencies that emerged in domestic industries, and the relationship between the nature of this process and the size of the internal markets.

To build intuition we develop a stylized model, that builds on the model developed in Farrell, Monroe, and Saloner [1994]. While the appendix contains the formal model itself, here we highlight the main features and provide an intuitive discussion. The model assumes that SEFs have two types of cost - a fixed set up cost, and a unit cost. The set-up costs can be thought of as the cost of acquiring the relevant competencies required to enter a market. SEFs differ in their competencies, the differences manifesting themselves in differences in unit costs, distributed across firms according to a certain probability distribution, which is the same for all countries. In other words, to focus on the role of market size, we assume that *countries* do not differ in their technological capacity.

The model has three pivotal assumptions. First, that industry structure is primarily determined by domestic markets - firms decide to enter the industry uncertain of their competencies and base their decisions on the expected profitability of entry. In turn, the size of the domestic market conditions the profitability of entry. We assume that the number of firms that enter the market for a particular activity (licensing, or construction) is such that the expect profit is equal to the (sunk) set-up cost of acquiring the relevant capability.

The second assumption deals with competencies. Firms have different competencies. Since we want to focus on the situation where increasing returns at the level of the firm are not the key factor, we assume that once in place, firms cannot change their competencies. Similarly, we assume that per unit costs are independent of the size of the firm. The third key assumption relates to the differences in fixed costs. Our discussion in the previous section suggests that TECH and ORG competencies have

two different types of fixed costs. TECH requires expertise in a given technological area. ORG requires generalized engineering and construction skills which enable the firms to operate in a number of technological fields. To keep matters simple we assume that once a firm invests in ORG competencies, it can operate as a construction contractor in all product markets (albeit with potentially different levels of costs). By contrast, to operate as a licensor, a firm has to pay a separate (sunk) fixed cost for each market.

This means that, within a given region, and particularly within the domestic region of our SEFs, there is an inherent difference in the size of the market for TECH and ORG based activities. The relevant market size for the former is determined by the number of plants of a given kind that are demanded by the domestic market. By contrast, the relevant market size for the ORG based activities is the total demand for the plants of different types that can be produced after the firm acquires the generalized competencies that are applicable to those products.

Logic of the model

The basic intuition from the model is that a larger market favors a greater number of entrants, and this implies a greater probability that more efficient producers will enter. Furthermore, the model predicts that larger markets will have more efficient (higher quality) producers, but the expected *gain* in efficiency decreases with market size.

To fix ideas, suppose we analyze the licensing market for a given product. The expected profit for an SEF can be written as $(\pi(n)Q$, where Q is size of the market, in this case equal to the number of plants S, and $\pi(n)$ is the expected profit per plant, and n is the number of firms in the market. The expression for expected profits is similar for construction except that the size of the market is given by $Q \equiv S$xV, where V is the number of products (for simplicity we assume that each product has the same number of plants). If we let F_T *and* F_O stand for the fixed costs of licensing (TECH) and construction (ORG) respectively, the expected number of licensors for a given product is given by (1) below. Note that since a firm could operate as a licensor in more than one product, the total number of licensors will lie between n_T and $n_T V$. Contractors, by definition, operate in all products, and their number, n_O is given by (2).

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There are two points to be noted about this characterization of the problem. First, for a given region such as the US or Japan, the market for engineering-construction services, and hence the one related to the ORG competencies, is larger than that of licensing (TECH). Second, the difference in market size between the US and other countries depends primarily on S. In principle, each European country, or Japan, produces the same "variety" of products as the US does, or at least this difference is likely to be small. But the US has a larger market for each of these products. As a result, the US have a larger market for both engineering-construction and licensing services. This implies that n_L, n_C are both higher in the US than elsewhere. In turn, this implies that the costs of the leading US licensors and contractors will be lower. Put in more general terms, it implies that the efficiency of the leading US firms will be higher.

Proposition 1. *The US engineering industry has more efficient leaders both in licensing and in construction.*

The key to proposition 1 is that larger markets have a larger number of producer. A well known result in order statistics states that the maximum of a sample is bigger, the bigger is the size of the sample (see appendix for formal statement). Intuitively, the idea is that if one draws a card from a deck, then upon repeating the experiment several times, the lowest value of card drawn from a deck with 10 cards is likely to be lower than that drawn from a pack with only 5 cards. The bigger the deck, the lower the expected value of the smallest card. Thus the US market will nurture lower cost leaders in both licensing and construction.[15]

How sensitive are the advantages of market size to the size of the market itself? The model also shows that the expected gains in efficency due to market size diminish with the size of the market itself -- that is, there are diminishing social returns to market size. This has implications for the comparative efficiency of licensors and contractors coming from different countries. The size of the domestic market for US licensors is S, while that of the licensors from other countries is smaller, say βS, $\beta < 1$. For contractors, the US and non-US markets are then respectively $Q = S \times V$, and βSV. If $V > 1$, this implies that non-US contractors face a larger domestic market than non-US licensors. If efficiency increases at a declining rate as market size is scaled up, the difference between the expected cost of the leading US and non-US contractors is then smaller than that between the leading US and non-US

licensors. Thus, Western Europe and Japan have a comparative advantage in construction with respect to licensing, even though both US licensors and engineer-contractors have an absolute competitive advantage. This yields the following proposition:

Proposition 2. *The penalty associated with the smaller domestic markets of Japanese and European SEFs is larger in activities that depend on product-specific competencies (licensing) vis-a-vis those based on more generic competencies (construction).*

ABSOLUTE AND RELATIVE ADVANTAGES OF THE LEADING US, EUROPEAN, AND JAPANESE SEFS

Number of licenses, engineering and construction contracts of the leading firms

Our primary comparison is based on the three leading US, Japanese, French, Italian, German, and British SEFs in licensing, engineering and construction in two sectors -- natural gas and refining, on the one hand, and petrochemicals, on the other.[16] These are the top three SEFs in our sample from each of these countries in terms of total number of licenses, engineering and construction services in the two technologies.[17] Our story is that these are the companies that emerged early on in their national markets as the most efficient domestic producers.

We then compare their performance in the worldwide market. Our prediction is that the leading US licensors, engineers and constructors, display absolute advantages in each of these three activities, but the leading US constructors show a smaller relative advantage compared to the leading US licensors.

Since comparisons of performance of the top firms is potentially sensitive to merger and acquisition activity, we also analyze the aggregate export performance of all SEFs from a country. Even this is sensitive to international acquisitions, but with one major exception, international mergers and acquisitions are relatively rare amongst SEFs.[18]

In comparing the performance of these firms, the question arises about which is the relevant market to be used for comparison. In principle, one would like to pick a market in which our companies would compete only on the basis of their efficiency, and there is no bias in favor of SEFs from one country or another. This implies that one should disregard markets that include any of the countries of our firms, as domestic companies would enjoy advantages due to location or other reasons. The non-OECD market is a candidate market. However, in these markets performance often depend on factors other than purely efficiency considerations. As suggested earlier, political influence, the nature of the relationships between governments, and financial resources may favor SEFs from certain countries. To avoid limitations of one type or another, we present our comparisons using different "international" markets. We look at the worldwide market as a whole, OECD exports (total OECD market excluding the home region), and non-OECD countries.[19]

Table 6 shows the total number of licenses, engineering and plant construction contracts in natural gas & refining and in petrochemicals of our leading SEFs. The table also shows the relative scale of each activity with respect to the US firms (US=100). Both in natural gas & refining and in petrochemicals, the performance of these SEFs conform to our predictions. The top US SEFs show an absolute

competitive advantage in all three activities. However, as one moves from licensing to engineering and construction, the gap between the US SEFs and their competitors declines.

[Tables 6-8 about here]

The data in table 6 could be biased in favor of the US companies. This is because the US is the largest national markets among the countries we are considering. Hence, if the US companies have a differential advantage in their home country, their competitiveness may be affected by factors other than their actual economic efficiency. Table 7 shows the same data for OECD exports.[20] The result are consistent with our predictions in natural gas & refining. The results are somewhat mixed in petrochemicals, where the leading German licensors perform relatively better than the leading contractors as compared to US firms. The relative efficiency of Japanese licensors is similar to US licensors. The US however always maintains an absolute advantage compared with both Germany and Japan.

[Tables 9-11 about here]

The results for the non-OECD markets, shown in table 8, are consistent with our predictions about comparative advantages. The US SEFs perform relatively better in licensing than in construction. However, the US SEFs no longer show an absolute advantage in the latter. In particular, the leading Italian and Japanese contractors have an absolute advantage vis-a-vis the US SEFs in refining, and the contractors from all non-US countries have an absolute advantage vis-a-vis the US firms in

petrochemicals. In addition, if one compares tables 7 and 8 most non-US SEFs appear to have a smaller disadvantage vis-a-vis US licensors in the non-OECD than in the OECD market. As tables 9-11 show, when we look at aggregate export performance -- i.e. when we include all SEFs from the country -- the results are consistent with our theory and similar to the ones reported earlier. The US has a comparative advantage in licensing, and unless we confine ourselves to the non-OECD countries, an absolute advantage in all activities. The results are clearer in refining, and less so in petrochemicals.

Discussion of results

Clearly, an alternative explanation of the patterns displayed in tables 6-11 is of international differences in technology. Put simply, the alternative explanation would be that the US is further advanced in petrochemical and oil refining technology, whereas Western Europe and Japan are at a comparable level in terms of construction competencies. There are two points to be made in response. First, the explanations are not mutually exclusive. To the extent that the US has access to superior technology, it adds to the effects of a larger market. Second, the "differences in technology" explanation is an implication of our model. Our theory predicts that one would observe such differences in technological ability even if all countries have access to the same stock of technological knowledge.

This is not to say that countries may not have intrinsic differences in their competencies in a particular sector. As early movers in petrochemicals and oil refining, US firms did lead in the development of new petrochemical technologies. However, Germany had been the traditional leader in organic chemical technologies for coal based feedstocks such as acetylene. Clearly, a great deal of the

accumulated technology was applicable to processes using petrochemical feedstocks such as ethylene. By contrast, information about designing and constructing large continuous flow plants and refineries was something that was not a part of the accumulated expertise. Therefore, in the German case, the fixed cost of entry into licensing (the cost of acquiring TECH) may well have been relatively lower as compared with other countries, including the US. Indeed, the relatively stronger performace of Germany in petrochemicals licensing is consistent with a story of strong technological competencies in organic chemicals.

There are other institutional differences across countries that can be incorporated as extensions of the basic model. Suppose that, in addition to general construction competencies, an important component of ORG is the ability to market petrochemicals. SEFs that possess such capability can add value to clients who would prefer to pay for the plant in the form of a share of the output. Such competencies are more valuable when the internal markets for petrochemicals are poorly developed, or where chemical producers lack adequate marketing competencies, particularly in export markets. In other words, such competencies are more valuable for oil and chemical firms from developing countries, than they are for firms in developed countries. A similar case can be made for finance: SEFs that can arrange for project finance may add value to clients in developing countries.

As noted in the historical background, some non-US SEFs are affiliated with larger corporate groups. Such SEFs, especially those from Italy, France, and Japan, are more likely to be able to provide finance, and market chemical products, by drawing upon the resources of their corporate parents. For

instance, an SEF that is affiliated with a chemical producer can use the latter's marketing and distribution resources to arrange for the sale of the product. If so, this means that while such SEFs may not be as proficient at general construction management, they may be higher on a different dimension of ORG which is more highly valued outside the OECD market. In turn, SEFs from these countries will perform relatively better in developing countries as tables 8 and 11 show.

Other differences in institutional structures, while important, may not fit as neatly into our model. Based on transaction cost considerations, oil and chemical producers are more likely to use SEFs from their own country. This implies that the performance of SEFs may depend on the investments made by chemical and oil producers from their country. In view of the more developed and thicker markets in the US, it is also likely that such ties are more marked for the non-US countries (with the possible exceptions of Germany and Britain). In other words, the performance of US SEFs is less sensitive to investments by US firms. Finally, such ties are likely to be more important in construction, rather than in licensing, where transaction costs are less culture and country dependent. Thus, we would expect the performance of contractors to depend more closely on investments by oil and chemical producers from their country.[21]

The role of national governments is also potentially important. The engineering sectors in Western Europe and Japan have been supported for many years by national industrial policies. Governments have often promoted the internationalization of the national companies in this industry towards less developed regions by means of broader political and collaborative agreements with the host countries.

For instance, Japan has a stronghold in the South East Asian market. Western European engineering companies have benefitted from similar opportunities in Eastern Europe, as well as in Asia (e.g. through government-sponsored bilateral agreements). For instance, in developing countries or in Eastern Europe, contracts assigned to Western European or Japanese SEFs are often part of broader agreements involving financial transfers, credit arrangements and the like (Barna *et al.* [1980]). Our purpose here is not to discuss in great detail the nature and the characteristics of these politically-related factors. We simply wish to note that they affected overall competitiveness, and may even have affected comparative advantage in TECH versus ORG based activities.

CONCLUSIONS

The interplay of the distribution of competencies and market size can be seen in Rosenberg's account of the development of the nineteenth century machine tools sector in the US. Prior to the development of the transport infrastructure, producers of machine tools produced a wide variety of tools, and typically produced for a limited geographic radius. As the US market became more integrated, a large number of firms emerged, each focussing a very narrow range of tools (Rosenberg [1963]).

The interplay with market size is also evident in a far more modern sector - software. The software industry is divided between packaged products and services embodying more customized solutions. While the former typically require product-specific competencies (e.g. in electronic data-bases, spreadsheets, sector-specific information systems), customized solutions require that the software firm possess a generic set of competencies that allow it to move across different types of products. The

evidence implies that the US has a comparative advantage in the packaged software, as compared with Japan where software vendors tend towards customized solutions (Cusumano, [1991]).

Traditionally large domestic markets are seen as helpful in enabling domestic firms to grow larger, and benefit from economies of scale. In our view, larger markets are important even if economies of scale are absent.[22] As long as firms differ in their competencies, and firm competencies are difficult to change quickly, the leading firms will be more efficient in larger markets. Stepping outside the confines of our formal model, one can think of this effect as saying that larger markets select more efficient leaders. The selection argument is also related to the advantages of variety, with larger markets making for greater variety.

Second, not all competencies are similar. Some are more product specific, while others are more generic. Market size matters less for generic competencies, than it does for product specific competencies. An important, but under-appreciated, consequence of the large size of the US market is the impact it has had on the accumulation of certain competencies in industries taken as a whole. The beneficial impact of a larger market has been more pronounced for competencies that are geared to the production of a relatively narrow range of products, and less marked in activities based on competencies that are applicable across a wide range of products.

Endnotes

1. Our characterization is then very close to the one advanced by the "resource-based" theory of the firm. See for instance Amit and Schoemaker (1993) or Rumelt (1984).

2. This is not deny that exports can be a powerful source of growth. Our focus here is on the formative influences of the domestic market on the development of the industry itself, and the types of activities in which domestic firms would be successful in the international marketplace.

3. In an extremely insightful article, Nathan Rosenberg [1963] makes a very similar distinction. In discussing the development of the machine tools sector in the United States in the nineteenth century, Rosenberg notes that a very large market was needed for firms to specialize in the production of a narrow range of machine tools.

4. See Arora and Gambardella, [1996], for evidence on the chemical industry, and Gambardella and Torrisi [1996] for computers and telecommunications.

5. SEFs were not confined to the oil refining sector, even in the pre-World War II era. The Chemical Construction Corporation built sulphuric acid and other plants, while the Chemical Engineering Corporation targeted synthetic ammonia and methanol processes, both owned by American Cyanamid. As Haynes notes "... These engineering enterprises created a unique phase of Cyanamid's business. The building of chemical plants, chiefly sulphuric acid, synthetic ammonia, and nitric acid operations, on a "turnkey" basis, that is, delivered in running order, soon grew into a profitable, world wide enterprise." (Haynes [Vol IV: 90].)

6. Landau and Brown (1965), among others, suggested that the shift from coal based to oil and natural gas based feedstocks, and the consequent shift from batch to continuous flow processes was another important factor.

7. A great deal of knowledge for innovation depended on experience with the actual functioning of these plants, which the SEFs lacked. Further, radical innovations entailed large investments which most SEFs, being far smaller than their clients, were unable to afford. For instance, SEFs could simply not afford the set-up costs of expensive pilot plants.

8. The reasons why the US was the birthplace of the major SEFs are discussed in some detail in Landau and Rosenberg (1989).

9. Examples are Snamprogetti of Italy, which is part of the ENI group; Lurgi and Uhde, Germany, which are subsidiaries of Metallgeselschaft and Hoechst respectively; Mitsubishi Heavy Industries, and Mitsui are part of larger Japanese keiretsu. Examples of "independent" European SEFs are Zimmer (Germany), and Topsoe (Denmark). Similarly, Chiyoda and JGC, from Japan, do not belong to any keiretsu group.

10. We grouped all the operating companies in the data base that were subsidiaries of other companies under the name of their mothers.

11. Note that the fact that SEFs hold a larger number of licenses than large operating companies does not imply that they are more innovative than the latter. One obvious reason is that licenses signal the willingness of companies to sell their proprietary knowledge. While this is the business of SEFs, larger companies typically do not license their technologies as extensively. Moreover, many of these licenses do not pertain to radical process innovations, but mostly to alternative technologies for the same process.

12. One obvious distinction is between plants located in OECD and those in developing countries. In addition, rules, regulations, and the networks of local sub-subcontractors are likely to be different within the OECD countries themselves.

13. We measure diversification using the well known measure of entropy, equal to $-\Sigma_i p_i \mathrm{Log} p_i$, where p_i is the share in field (e.g. region, technology). The entropy measure is equal to zero if all activities are concentrated in one field, and increases as the activities are more equally distributed across fields.

14. In computing the cumulative distributions we considered only the firms that had at least ten activities of a given type. This is to rule out cases in which there were too few activities to measure diversification properly. For instance, the cumulative distribution for licenses was computed from the 62 SEFs in our sample of 169 that had a total number of licenses in the data base greater or equal to 10. Similarly, the distribution of the diversity index for engineering and construction were obtained using a sub-sample of 156 and 154 SEFs.

15. One can equivalently recast the model where firms differ in their quality. Thus higher efficiency firms are those with higher qualities. The formal as well as the intuitive structure of the model is unchanged.

16. For expositional simplicity we have stated both our propositions in terms of the low cost leaders in each market. But the insight applies to the leading firms more generally. In other words, it is not just the lowest cost US contractor that is more efficient than its Italian counterpart, but also the second lowest cost contractor, and so forth.

17. Thus, for each technology, we have in principle nine SEFs per country, three for each activity (licensing, engineering, and construction). In practice, many leaders in one activity are also leaders in the others.

18. John Brown, a leading British SEF acquired Davy-Mckee, another British SEF. In turn, Davy-Mckee had been formed through the merger of a British SEF, Davy, with Mckee, a US SEF.

19. In defining OECD exports, we excluded Japan for the Japanese SEFs; Western Europe for the European ones; the US and Canada for the US SEFs.

20. In looking at OECD exports one can also control for the different size of the OECD export markets, with US firms facing the smaller export markets than the Japanese. The results, however, are very similar to those shown in table 7.

21. In this paper we have not attempted to systematically sort out the effect of such national preferences. But national preferences can explain some of the finer nuances in our results. For instance, to the extent that US oil and chemical producers have focussed their overseas investments in Western Europe, it would explain why non-US SEFs do relatively better outside the OECD market.

22. Since our model has a fixed entry cost, potentially economies of scale are present. The primary role of entry costs in our model is however to ensure a finite number of firms.

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Appendix

■ Notation

Let the total number of plants in product *i* be given by S_i. For simplicity, we assume that S_i is fixed. For notational simplicity, we will omit the product subscript when the context is sufficiently clear. Let the value of the service be U. The unit cost of SEF *k* is c_k. We assume that c_k is a random variable with probability distribution function, H(*x*). Before entry, c_k are unobserved. After SEFs enter, all uncertainty is resolved. For later reference, let G(*x*) = 1 - H(*x*).

■ Nature of competition

SEFs are assumed to be Bertrand competitors i.e. they compete in prices. Below we also analyze models with Cournot competition, and price taking behavior. Assume that each client builds one and only one plant. The fixed cost for acquiring TECH competencies to enter the market *i* as a licensor is F_{Ti}, while it is F_O for ORG competencies for construction. This formalisation captures the idea that the competencies required for construction are not product specific.

■ Number of firms in the market

Let $\pi(n)$ be the expected profit per plant, and where *n* is the number of SEFs in the market. The expected payoff from entry are given by LHS of equation (A1a) and (A1b) for licensing and contracting respectively. The equations themselves define the "no entry" or zero profit condition which determines the number of firms in each market.

{EMBED Equation.2}
{seq Equation * Arabic}
{EMBED Equation.2}
{seq Equation * Arabic}

Let c^r_n refer to the *rth* smallest value of the random variables $\{c_k\}$, k=1,2,...*n*. With perfect information, the price that the SEF that wins the contract gets is $P = c^2_n$. Therefore, the expected payoff for the winner (SEF that gets to provide the service) is $_(c^2_n - c^1_n)$, where _ is the expectation operator. Since SEFs are ex-ante identical, each has a 1/*n* probability of being the low cost leader, and hence, $\pi(n) = 1/n \; _(c^2_n - c^1_n)$. The following result is standard in the theory of order statistics (e.g. David [1981].)

{EMBED Equation.2}
{seq Equation * Arabic}

Proposition 1′: $\partial(_c^1_n)/\partial Q < 0$.

Proof: Using the zero profit condition (A1) above, it follows that if $\pi(n)$ is decreasing in *n*, then *n* is increasing in Q. Further, noting that $(_c^1_n) = \int_0^\infty G^n(x)\, dx$, we see that $\partial(_c^1_n)/\partial n < 0$. Finally, we note from (A3) that $\pi(n)$ is decreasing in *n*. The result follows directly.■

We next show that the difference between the cost of the market leaders in two regions becomes smaller as we increase the scale of both markets in question. To economize on notation let C(n) be the expected costs of the market leader with *n* firms i.e. $C(n) = _c^1_n$. Let the size of the market in region 0 be $Q_0 = \alpha S_0$, where

α is a scale factor. Therefore, $C(n_0)$ is the expected cost of the leader in region 0. Let $C(n_1)$ be defined similarly, with $S_1 > S_0$. Therefore, as we increase α, it is equivalent to increasing the size of the market in both regions, while keeping the relative market size fixed. In terms of the discussion in the text, this is what we need to establish that the difference between the costs of the market leaders in construction is lower than the corresponding difference in licensing.

Proposition 2: There are diminishing efficiency gains from market size.
Proof:

{seq Equation * Arabic} {EMBED Equation.2}

Example: Suppose that costs are distributed exponentially with parameter λ. $C(n) = 1/\lambda n$, and $\pi(n) = 1/\lambda n(n-1)$. The applicability of the two propositions is immediate.

Extensions beyond Bertrand competition
The two propositions are not necessarily limited to the case of Bertrand competition. From the "zero profit" condition, it is evident that as long as $\pi(n)$ is decreasing in n, the first proposition is true. In other words, as long as the average profitability per unit market size declines in the number of firms in the market, it must be the case that increasing the size of the market must result in lower expected costs for the market leader. In other words, proposition 1 is very general.

To examine the validity of the second proposition, note from (A3) that $\{C(n_0) - C(n_1)\}$ will decline with the size of the market as long as the responsiveness of n to a scaling up of market size does not increase as the market becomes larger. Formally, one can rewrite (A3) as

{EMBED Equation.2} {seq Equation * Arabic}

The notion that the number of firms should not increase at an increasing rate as the market is scaled up is intuitively plausible, and indeed, has been shown to be true in the case of Bertrand competition. Although we do not have a general proof of the proposition for the case of Cournot competition, we illustrate its validity with a simple Cournot model, with exponential costs.

Cournot competition

Suppose SEFs compete in quantities. As before, each firm's marginal cost is given by c_k. Suppose that costs are distributed with the exponential distribution, with parameter λ. If the demand curve is given by P ={EMBED Equation.2}{seq Equation * Arabic \h}, then SEF *k* sets quantity according to the equation,

$(P - c_k) = q_k$ (A7)

Summing (A7) over all *k* and dividing by *n*, and re-arranging we get

{EMBED Equation.2}{seq Equation * Arabic}

One can easily show that when c has the exponential distribution, the expected cost of the lowest cost firm, C(n), is equal to $1/\lambda n$.

{EMBED Equation.2}{seq Equation * Arabic}

More generally, as long as the elasticity of C(n) with respect to *n* is of the order of $1/n$, it follows that scaling up the market by a given factor will decrease the difference between the cost of the leaders in the two regions.

{PRIVATE } Location of plants	No. of plants engineered by the buyer (staff)	% of total eng. known	No. of plants engineered by SEFs in our sample	% of total eng. known	No. of plants engineered by other companies	% of total eng. known	Total enginee known
USA	463	6.94	5206	78.00	1005	15.06	6
Canada	43	3.52	896	73.32	283	23.16	1
Central & Latin America	59	3.62	1188	72.97	381	23.40	1
Western Europe	311	6.86	3511	77.44	712	15.70	4
Eastern Europe	5	0.50	811	80.30	194	19.21	1
Africa	10	1.27	640	81.32	137	17.41	
Mid-east	22	1.67	1138	86.21	160	12.12	1
Far-east	71	2.57	2052	74.21	642	23.22	2
Japan	122	9.24	1029	77.90	170	12.87	1
Australia	20	3.37	461	77.61	113	19.02	
Total	1126	5.15	16932	77.47	3797	17.37	21

{PRIVATE } Location of plants	No. of plants constructed by the buyer (staff)	% of total contr. known	No. of plants constructed by SEFs in our sample	% of total contr. known	No. of plants constructed by other companies	% of total contr. known	Total contr. known
USA	448	7.73	4255	73.41	1093	18.86	5796
Canada	33	3.09	767	71.82	268	25.09	1068
Central & Latin America	237	17.95	790	59.85	293	22.20	1320
Western Europe	451	11.61	2890	74.37	545	14.02	3886
Eastern Europe	25	2.70	685	73.97	216	23.33	926
Africa	32	4.53	503	71.25	171	24.22	706
Mid-east	51	4.31	951	80.46	180	15.23	1182
Far-east	135	5.99	1560	69.27	557	24.73	2252
Japan	75	6.21	1014	84.01	118	9.78	1207
Australia	36	6.68	384	71.24	119	22.08	539
Totals	1523	8.07	13799	73.08	3560	18.85	18882

{PRIVATE } Location of plants	No. of plants licensed by SEFs in our sample	% of total lic. known	No. of plants licensed by top 100 pchem Cos.	% of total lic. known	Total licensor known	
USA	1684	50.13	1024	30.49	3359	
Canada	268	53.17	149	29.56	504	
Central & Latin America	743	53.22	455	32.59	1396	
Western Europe	1634	47.36	1032	29.91	3450	
Eastern Europe	373	40.15	227	24.43	929	
Africa	341	55.09	95	15.35	619	
Mid-east	546	57.66	328	34.64	947	
Far-east	1212	48.83	470	18.94	2482	
Japan	518	39.63	442	33.82	1307	
Australia	257	55.87	124	26.96	460	
Totals	7576	49.03	4346	28.12	15453	

Top 100 and Non-Top 100 Petrochemical Companies, 1970-1990

{PRIVATE }	No. of plants engineered by the buyer (staff)	% of total eng. known	No. of plants engineered by SEFs in our sample	% of total eng. known	No. of plants engineered by other companies	% of total eng. known	Total engineer known	% of total	TOT
OECD Countries:									
Top 100 Pchem Cos. (*)	569	7.19	6280	79.32	1068	13.49	7917	83.46	
Non-Top 100 Pchem Cos.	386	6.33	4551	74.64	1160	19.03	6097	85.51	
Non-OECD Countries:									
Top 100 Pchem Cos. (*)	131	2.75	4001	83.91	636	13.34	4768	85.56	
Non-Top 100 Pchem Cos.	40	1.30	2100	68.34	933	30.36	3073	84.28	
TOTAL	1126	5.15	16932	77.47	3797	17.37	21855	84.59	

(*) Top 100 operating companies in terms of number of plants in the HPI data base, 1970-1990.

Top 100 and Non-Top 100 Petrochemical Companies, 1970-1990

{PRIVATE }	No. of plants constructed by the buyer (staff)	% of total contr. known	No. of plants constructed by SEFs in our sample	% of total contr. known	No. of plants constructed by other companies	% of total contr. known	Total contr. known	% of total	TOT
OECD Countries:									
Top 100 Pchem Cos. (*)	567	8.40	5162	76.51	1018	15.09	6747	71.13	
Non-Top 100 Pchem Cos.	475	8.77	3864	71.30	1080	19.93	5419	76.00	
Non-OECD Countries:									
Top 100 Pchem Cos. (*)	320	7.61	3112	74.02	772	18.36	4204	75.44	
Non-Top 100 Pchem Cos.	161	6.41	1661	66.12	690	27.47	2512	68.90	
TOTAL	1523	8.07	13799	73.08	3560	18.85	18882	73.09	

(*) Top 100 operating companies in terms of number of plants in the HPI data base, 1970-1990.

{PRIVATE }Country of Top 3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	21	270	240	0.76	
Germany	104	327	207	3.74	
Italy	150	576	550	5.40	
Japan	32	744	768	1.15	
UK	156	434	361	5.61	
USA	2780	1477	1003	100.00	1

Petrochemicals

{PRIVATE }Country of Top 3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	28	166	173	4.65	
Germany	352	620	489	58.47	
Italy	200	372	299	33.22	
Japan	118	424	425	19.60	
UK	90	403	319	14.95	
USA	602	689	443	100.00	1

{PRIVATE }Country of Top3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	1	1	3	0.12	
Germany	12	95	47	1.47	
Italy	1	5	5	0.12	
Japan	0	28	27	0.00	
UK	27	271	269	3.31	
USA	816	475	318	100.00	1

Petrochemicals

{PRIVATE }Country of Top3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	0	7	1	0.00	
Germany	58	59	34	35.37	
Italy	29	40	30	17.68	
Japan	25	22	12	15.24	
UK	23	135	98	14.02	
USA	164	219	112	100.00	1

(*) OECD-export is total activity in OECD with the home region excluded.

{PRIVATE }Country of Top 3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	9	126	97	1.03	
Germany	44	79	41	5.01	
Italy	96	277	276	10.93	
Japan	19	402	361	2.16	1
UK	66	74	37	7.52	
USA	878	381	162	100.00	1

Petrochemicals

{PRIVATE }Country of Top 3 SEFs	Licenses	Engineering Services	Construction Services	Licenses (USA=100)	Engineering Services (USA=100)
France	9	104	136	2.62	
Germany	159	310	234	46.36	1
Italy	123	175	125	35.86	
Japan	68	187	169	19.83	
UK	32	143	122	9.33	
USA	343	230	73	100.00	1

{PRIVATE }TOTAL				USA=100	
	Licenses	Engineering Services	Construction Services	Licenses	Engineering Services
FRA	14	237	226	0.50	
GER	114	314	224	4.04	
ITA	132	505	487	4.68	
JPN	34	761	818	1.20	
UK	127	420	332	4.50	
USA	2823	4068	2908	100	

Petrochemicals

{PRIVATE }TOTAL				USA=100	
	Licenses	Engineering Services	Construction Service	Licenses	Engineering Services
FRA	74	194	212	8.37	
GER	502	814	713	56.79	
ITA	160	475	432	18.10	
JPN	93	785	781	10.52	
UK	77	450	355	8.71	
USA	884	1775	1376	100.00	1

{PRIVATE }TOTAL				USA=100	
	Licenses	Engineering Services	Construction Service	Licenses	Engineering Services
FRA	0	7	5	0.00	
GER	10	9	5	1.26	
ITA	1	5	5	0.13	
JPN	1	32	32	0.13	
UK	23	213	175	2.89	
USA	796	782	532	100.00	1

Petrochemicals

{PRIVATE }OECD-EXP				USA=100	
	Licenses	Engineering Services	Construction Service	Licenses	Engineering Services
FRA	6	9	4	2.55	
GER	88	87	65	37.45	
ITA	16	38	22	6.81	
JPN	13	57	49	5.53	
UK	19	145	141	8.09	
USA	235	365	214	100.00	1

(*) OECD-export is total activity in OECD with the home region excluded.

{PRIVATE }TOTAL				USA=100	
	Licenses	Engineering Services	Construction Service	Licenses	Engineering Services
FRA	6	99	89	0.64	
GER	42	91	46	4.45	
ITA	78	244	244	8.27	
JPN	20	366	338	2.12	
UK	54	90	65	5.73	
USA	943	753	333	100.00	1

Petrochemicals

{PRIVATE }TOTAL				USA=100	
	Licenses	Engineering Services	Construction Service	Licenses	Engineering Services
FRA	37	119	144	9.07	
GER	258	434	383	63.24	
ITA	103	219	196	25.25	
JPN	62	381	317	15.20	
UK	28	169	105	6.86	
USA	408	450	304	100.00	1

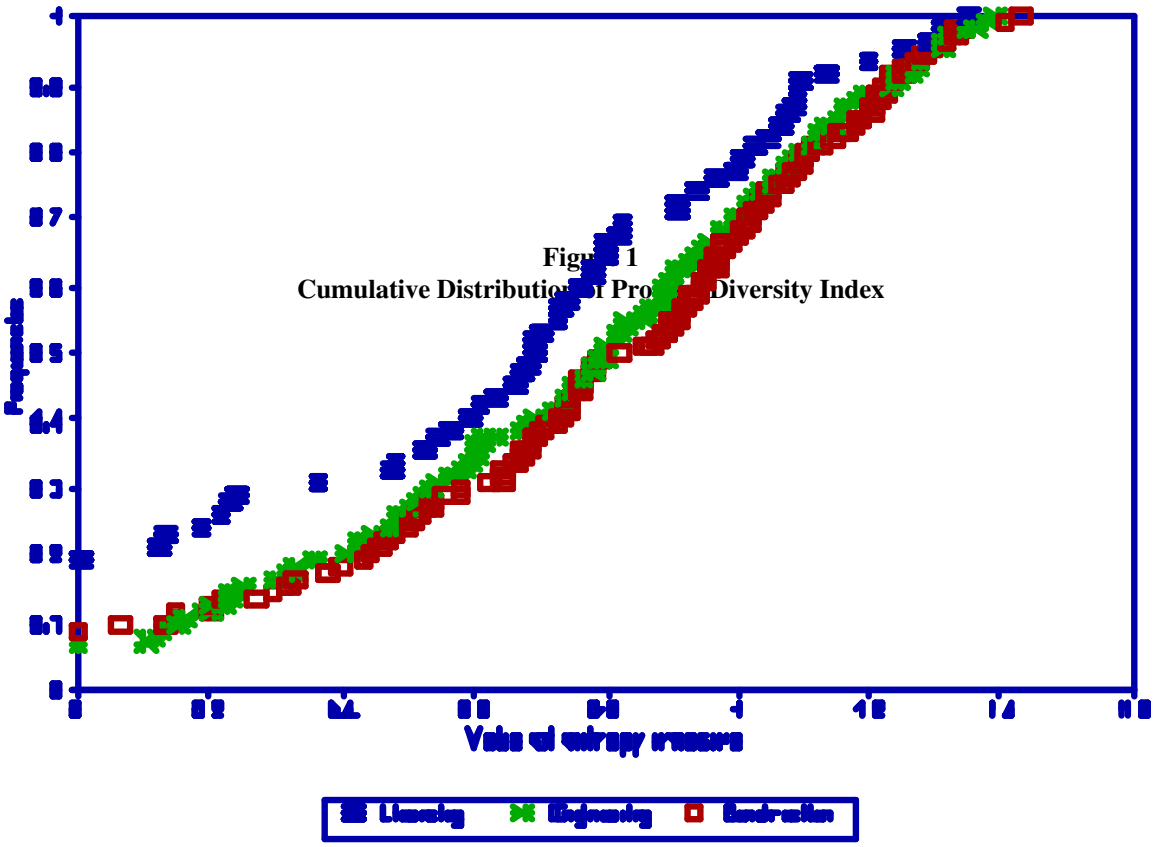

Figure 1
Cumulative Distribution of Product Diversity Index

{seq Figure * Arabic}

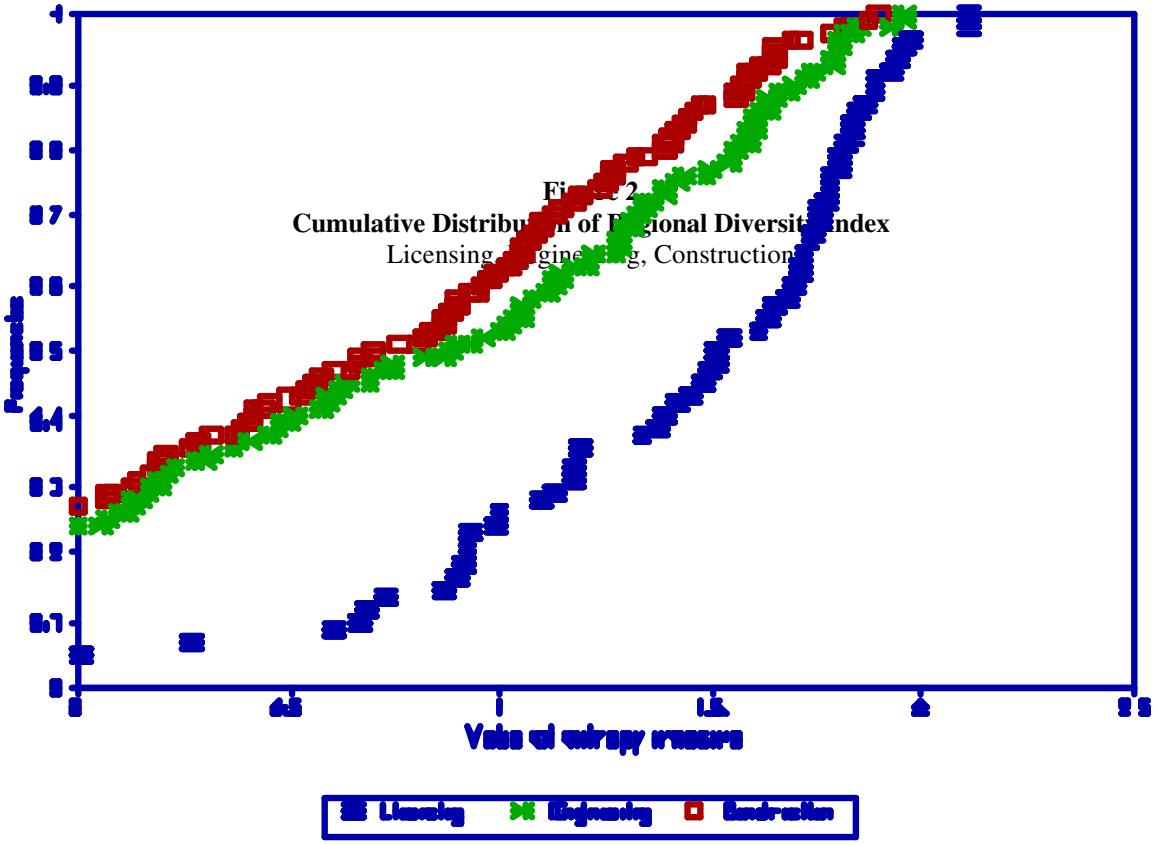

Figure 2
Cumulative Distribution of Regional Diversity Index
Licensing, Engineering, Construction

{seq Figure * Arabic}

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