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Location of engineering and designer services in the information economy

by

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Hildegunn Kyvik Nordås*

Abstract

This paper presents a case study of a naval architecture firm in Western Norway, which trades its services electronically. The paper goes on to analyze the market entry and location decision of such entrepreneurs by means of a theoretical model that builds on insights from Williamson's theory of market structure and relation-specific investment. I introduce a governance cost function that depends on the distance between the two contractual parties and find that there exists a wage level above which no potential entrepreneur would set up a designer firm, and a critical distance between the designer firm and the customer, beyond which no designer firm would be established. Investment in ICT extends this distance, but it is unlikely to eliminate it. The critical distance and the critical wage level depend on the cost of fabricating the designed e.g. vessel.

JEL codes: R12, L84

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1 Introduction

This paper discusses a case study of a Norwegian firm, Vik-Sandvik, producing naval architectural services for shipping companies and shipyards all over the world. Its head-quarters are located in a coastal village with less than 3000 inhabitants in western Norway, and the company has affiliates and daughter companies in 6 countries. Its core business is computer-assisted design (CAD), which is largely traded over the Internet. During the early days of the Internet, there was a widespread belief that the Internet would eliminate the relevance of distance for firms' location decisions and for people's decisions on where to live. The idea was that telecommuting would become commonplace and that information could be accessed and information-intensive services could be produced anywhere. Although there is yet no conclusive research findings on this, it appears that distance still matters, particularly in complex, high-technology services such as design and engineering (O'Connor, 1996; Gaspar and Glaeser, 1998; Leamer and Storper, 2001). These services tend to agglomerate in cities, while more industry-specific detailed engineering tend to locate in industrial areas.

The relocation of fabrication to lower-cost emerging markets has worried industrial communities in rich countries. The Internet-optimists would argue that when fabrication activities are closed down, industrial regions in rich countries could specialize in services that embody their industrial technology and experience. Such services cold be transmitted to customers all over the world over the Internet. In this way accumulated human capital could form the basis for comparative advantage in the information economy. The Vik-Sandvik case study is an example of this. The firm managed to stay in business and extend the reach of its services when the shipbuilding industry moved to, or was out-competed by shipyards in emerging markets. In the light of the most recent literature on the Internet and location of high-technology service firms, however, Vik-Sandvik appears to be the exception rather than the rule.

In order to shed more light on the location of high-technology services in the information economy, I explore the relevance of distance and the market for highly skilled labor (engineers and designers) within the framework of a formal model. This is a model where the downstream firm, say a shipyard, decides whether to design and engineer vessels in-house or buy the design from an outside specialized supplier. Potential entrepreneurs with skills in design and engineering establish designer firms and employ engineers and designers if the profits from doing so exceed the wage rate they would earn as employees. The model incorporates physical distance between the upstream and downstream firms as a determinant of outsourcing. I find that there exists a wage level above which no potential entrepreneur would set up a designer firm, and a critical distance between the designer firm and the customer, beyond which no designer firm would be established. This distance is referred to as the reach of the designer firm, and I analyze how various market conditions, such as the cost of other inputs and investment in ICT affects the reach of the designer firm.

2 The case study: Vik-Sandvik Group

Vik-Sandvik was established in 1975 and claims to be the largest *independent* source of ship designs and naval architectural services in Europe.[1] The headquarters of the group and the subsidiary Vik-Sandvik Offshore are located in Fitjar, a Western Norwegian village with just below 3000 inhabitants situated some 50 km driving distance plus a 50 minutes ferry crossing south of Bergen. The Group's niche market is naval architecture, design and engineering for fishing vessels, offshore vessels and a wide range of special-purpose vessels. Most of the vessels are specially designed, one-off projects. The Vik-Sandvik Group is independent in the sense that it is not affiliated to any equipment producing firm, shipyard or shipping firm. A shipping company's purchase of design and engineering from Vik-Sandvik therefore has no bearing on its subsequent choice of building wharf. Indeed, Vik-Sandvik typically designs the vessel in close cooperation with the shipping firm. The resulting design is then put up for tender among shipyards. Vik-Sandvik is quite often also contracted to do the detailed engineering and project management during the building of the vessel, and this has no bearing on the shipyard's choice of suppliers. The group thinks that the flexibility that follows from such independence is one of its competitive advantages that define its niche in the market.

Fitjar is part of a region with a long tradition of coastal and ocean fishing and fish-farming. Furthermore the island where Fitjar is located hosts one of northern Europe's largest offshore yards, Aker Stord. Finally, the supply bases for some of the major offshore oilfields in Norway are found not very far from Bergen. The local market for ship design and engineering is therefore substantial and local fishing and shipping companies indeed constituted the customer base of the company in the early days and still are the most important customers.

[1] Source of information: Interview with Ketil Fykse (head of data processing), 22.02.01 and Svein Sandvik (executive director) and Ketil Fykse 29.04.02, and www.vik-sandvik.com.

However, as the fishing and offshore customers have become more international and also to an increasing extent build their vessels abroad, the Vik-Sandvik company followed the customers and got a foothold in foreign markets through the relation to foreign shipyards with an international customer basis.

2.1 Organization and market

The group consists of a holding company, which has a majority stake in 11 companies in 6 countries. Both the holding company and the 11 group members are joint-stock companies, but they are not listed on the stock exchange. Figure 1 illustrates the structure of the group. The 11 companies in the group have partly overlapping and partly complementary competence. The headquarters possess the group's core competences and it specializes in fishing vessels, research vessels, offshore vessels, seismic vessels and conversions. Vik-Sandvik offshore, established in 1997 and also located in Fitjar, specializes in vessels for drilling and production, well operations, offshore construction vessels and modifications and rebuilds. A large part of the group's R&D is conducted at the headquarters. It should, however, be noted that the members of the group are largely independent and run their own projects.

Figure 1. The Vik-Sandvik Group

The Bergen office specializes in large vessels, and it also has a representative office in Shanghai, which represents the whole group in China. The daughter company at Omastrand, El-Design, is located close to a shipyard that builds catamarans for passenger traffic. It specializes in design and class documentation of electrical and electronic systems. Omega Technology is located at Austevoll, one of the major fish-farming communities in Norway, and produces engineering and design for fish-farming vessels and other equipment. Cad Cam Consultants in Oslo is a recent acquisition, which provides expertise in computer-assisted design.

Turning to the foreign group members, the largest group member outside the headquarters is Vik-Sandvik Poland. It is located in Gdynia, close to one of Europe's most competitive shipyards. It offers design and engineering, including complete packages of production drawings. In addition analysis, calculations and project management services are offered. Vik-Sandvik Poland represents a greenfield investment. The investment was partly motivated by the fact that many customers build their vessels in Gdynia and partly in order to get access to skilled engineers at reasonable costs. The company argues, however, that engineering costs in Poland or other Eastern European countries are not lower than in Norway, and that Norwegian engineers are relatively cheap compared to other Western European countries. The Yugoslavian and Slovakian offices also contribute with engineering competence, particularly in generic areas such as piping. Finally, the acquisition of the Icelandic firm was motivated by getting access to its superior technology on fishing vessels. The Vik-Sandvik group employs more than 200 persons.

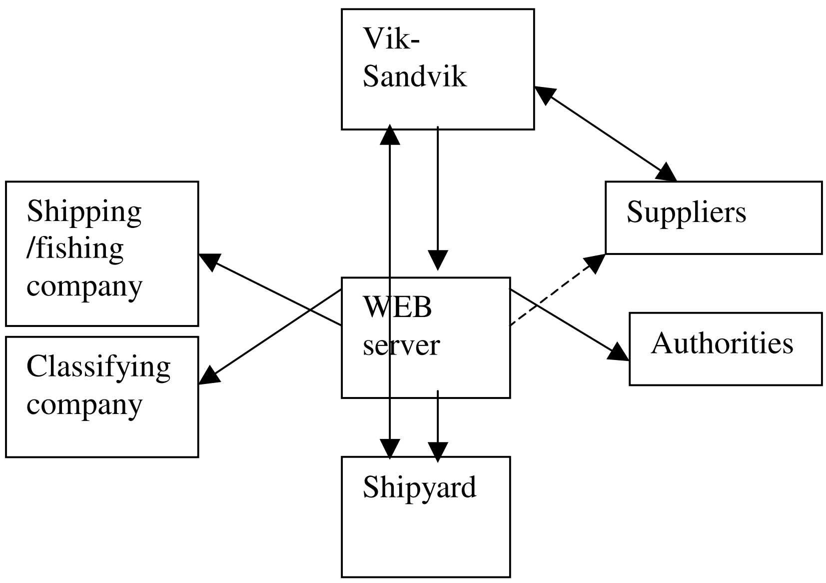
To summarize this section, Vik-Sandvik provides services during two phases of a shipbuilding project; i) developing a concept and design of a specialized vessel ii) detailed engineering and project support functions during construction. Design, concept evaluation and pre-engineering can in principle be done anywhere in the world provided that the necessary skills can be found. Local competence and long-standing traditions in marine sectors largely explain the establishment and further expansion in Fitjar. Project support functions, however, mainly have to be provided on-site and motivate establishment close to the major shipyards. Finally, detailed engineering can be done from far afield when the engineers and the building wharf are able to communicate effectively over electronic networks. It appears, however, that frequent face-to-face communication is necessary in addition to electronic communication. This largely explains the location of affiliates and daughter companies.

2.2 Technology

Vik-Sandvik has been a leading company in terms of ICT use in the industry. Electronic design was introduced in 1989/90, first on individual desktop computers. Later these were linked in internal networks. Computer-assisted design, engineering and drawings are the core activities at Vik-Sandvik. Engineering skills and advanced software thus constitute the Group's core technology. The group members are connected partly by intranet (the headquarters, Vik-Sandvik Offshore and Skipskonsulent are connected through designated lines) and partly by the Internet from which all group members can log in to the company's intranet. This allows cooperation in joint projects, information sharing in ongoing projects and sharing experience from previous projects. Individual engineers can work on different parts of a vessel and they can see the interface with adjacent parts in a virtual project room. The entire design/ package of drawings is placed on a server where each engineer/designer's contribution is fitted in by a project coordinator. The shipping firm typically also has access to the project information and can follow the progress of the project and enter into a dialogue with the designer/engineering team.

Although Fitjar is remote relative to the world markets, a major fiber-optic cable between Bergen and Stavanger runs across the island. The cable is twined around an electricity transmission line between the two cities. This cable gave Vik-Sandvik broadband access at a similar cost as companies located in Bergen or Stavanger. Access to broadband has improved the effectiveness of interaction with customers and other participants in a project. Figure 2 illustrates the organization of recent projects around electronic networks.

Figure 2. Project organization, design and engineering



The arrows show the direction of information flows. They illustrate that while all parties can draw information from the web server, only Vik-Sandvik can place data and information there. In addition to communication via the web server, Vik-Sandvik also communicates directly with the shipyard and suppliers during the project. In particular, Vik-Sanvik staff provides on-site project management services to the shipyards. The designers/engineers place continuously updated drawings and project documentation on the Web server, which is located at the headquarters. The shipyard retrieves the drawings and documentation, and the drawings can be fed directly into the computer-assisted manufacturing system. Suppliers of materials for the ship have limited access to the web server in order to secure timely delivery while protecting Vik-Sandvik's intellectual property as far as possible. The shipping or fishing company that ordered the ship also has access to the server and can follow the engineering and building process. Finally, the authorities and the classification company who authorizes the ship for its intended use have access to the server. The relevant parties are notified by e-mail when new or revised material is put on the server.

The software used for design is a standard CAD (Computer Assisted Drawing) package. It can be bought off-the-shelf, but it needs to be filled with content adapted to the purpose of the firm. The firm has some capacity in adopting the software, but special competence from outside is needed for the programming part. In order for the system to operate smoothly, weekly visits from the software supplier are necessary. Vik-Sandvik bears the cost of these visits.

Until recently drawings were mainly two-dimensional. However, the interface between the parts is much more easily seen in three-dimensional drawings, and as cost-effective technology for three-dimensional drawings has arrived, most group members now use 3-D software. This software has been adapted in cooperation with a Dutch-Finnish software company. Again face-to-face communication and frequent visits from the software supplier have been necessary. ICT accounts for 15-20 percent of the Group's total costs.

Vik-Sandvik has entered a market niche for specialized vessels. Design, engineering and documentation are therefore done for each vessel or short series of similar vessels. There is a continuous development towards making the vessels faster and more flexible while at the same time maximizing the loading capacity. Striking a balance between different and sometimes incompatible demands is a challenge and requires experience and research and development (R&D) to gain further experience. R&D accounts for another 10-15 percent of total costs. R&D is done partly in cooperation with SINTEF, a research institution related to the University of Trondheim. In particular, models are built and tested at the SINTEF laboratories. A challenge for the Group is to institutionalize its experience and know-how. The headquarters have hitherto been small with a sufficiently stable workforce to accumulate experience through personal interaction, but is now in the process of outgrowing that stage.

The ability to reap the benefits of synergies between the geographically widespread Group has improved over time due to continuous upgrading and new investments in information and communication technology.

Vik-Sandvik uses the Internet for other purposes than transferring its product to customers. The company participates in an online procurement network where the e-commerce company negotiates prices and other terms on behalf of all the members of the network. It also notifies the members if they think they can get a better deal by changing suppliers of services such as telecommunication, electricity etc. ICT is not much used for marketing or recruitment. The Group has a sales office, which works towards the customer base. This combined with word of mouth among shipping firms and shipyards have been sufficient to ensure full capacity utilization.

3 A model of outsourcing and distance

In this section I develop a formal model that explores the spatial dimension of outsourcing of design and engineering services. The model entails three agents, a customer for the final product, a producer of the final product and a designer. Let us assume that the final customer is a shipping firm that contracts a new vessel, although the model can be applied to any built-to-order product. The producer is a shipyard that builds the ship according to agreed specifications. The required properties of the vessel can be obtained in several ways that may differ in terms of cost effectiveness, given the shipyard's human and physical capital stock. Therefore, design and pre- and detailed engineering are necessary and important inputs in the production process. These services can be produced inside the shipyard or it can be purchased from an external, specialized designer firm. The designer firm is established by a skilled designer/engineer who sets up her own firm, but only if the profits she earns from doing so are at least as high as the income she would earn if she joined the professional labor force.[2]

The shipping firm specifies attributes and properties related to quality and performance criteria for the vessel, and invites shipyards to tender for the contract. The shipping firm leaves it to the contractor how to design the ship in order to satisfy the performance criteria. It is assumed that the attributes and properties can be verified ex post, for example by an

[2] See also Fonseca et. al. (2001) for a model where entrepreneurship is seen as a choice between setting up a firm or joining the pool of workers.

independent classification company, as is common in the shipping and offshore industries. By making this assumption I abstract from the problems related to incomplete contracts.

The model analysis starts when the shipyard has won the contract and the contract price is fixed at R. The shipyard will then minimize cost of delivering the vessel with the agreed properties and attributes. Two major categories of activities are carried out during the production of the vessel: design, denoted z, and fabrication, denoted y, according the production function:

$$\bar{S} = \left(\tilde{A}z\right)^{\alpha} y^{1-\alpha} \text{ or } \bar{S} = Az^{\alpha} y^{1-\alpha} \text{ where } A = \tilde{A}^{\alpha} \qquad (1)$$

While materials and operations during fabrication are assumed to be standardized, design can be customized to each vessel. Customization requires investment in a virtual prototype, and the establishment of a particular encrypted web site or a virtual project room for the purpose of the project. These investments cannot be fully recovered in the market outside the project, and results in a tailor-made concept, denoted A. $\bar{S}$ represents the vessel with the agreed quality. Fabrication involves the working of materials into parts and assemblage of the parts by means of workers, machinery and materials. The two activities (z and y) are substitutable in the sense that more careful design contributes to economizing on materials and reducing the number of operations necessary during fabrication. The shipyard minimizes costs, which yields the unit cost $c = \breve{\alpha} p_z^{\alpha} p_y^{1-\alpha}$ where $\breve{\alpha} = \alpha^{-\alpha}\alpha^{-(1-\alpha)}$. The cost of fabrication, p_y entails the wage rate of shop-floor workers as well as the cost of materials and machinery rental. The cost of design, p_z entails the wage rate of professional workers and the cost of other inputs, e.g. computer software. The wage rate in the two activities may differ. By Hotelling's lemma we get the shipyard's demand for inputs as follows:

$$\frac{z}{y} = \frac{\alpha}{1-\alpha}\frac{p_y}{p_z};$$

or using the production function we get demand for design as a function of relative input prices and the level of specificity:

$$z = \frac{1}{A}\left(\frac{\alpha}{1-\alpha}\frac{p_y}{p_z}\right)^{1-\alpha}; \quad \frac{\delta z}{\delta(p_y / p_z)} > 0; \frac{\delta z}{\delta A} < 0 \qquad (2)$$

Thus, when for example wage rates in the fabrication activity increase or the cost of software declines, the shipyard would demand more designer services. We also notice that the demanded quantity of designer services declines with the specificity of design. This can be seen as a trade-off between quantity and quality. The shipyard can choose to produce the design in-house or it can enter into a contract with an outside designer firm.

The shipyard's total costs consist of production costs and governance costs. Production costs are the costs of the direct inputs adjusted for the specificity of design, denoted c/A. Governance costs relate to managing and coordinating the designer activity to make sure that the design fits exactly the specifications of the vessels in such a way that it can be fabricated cost-effectively, e.g., that the design is tailor-made for the shipyard's machinery and competence. The more specific the design or prototype is to the requirement of the shipping firm/the shipyard, and the less relevant the design/prototype is to the outside market, the more asset- specific the investment (i.e. the larger is A in equation (1)). The governance cost differs between internal production and external purchase of the service. Governance of internal production entails a fixed cost in terms of additional management resources employed in the shipyard denoted β, and a term, εA, that varies with the specificity of the design. Governance of a contract with an external supplier only entails a term that increases with the specificity of the input, σA. We follow standard models (e.g. Riordan and Williams, 1985) and assume that the marginal cost of governance is lower within the firm than governing a contract with an external firm, implying that $\varepsilon < \sigma$.

One important factor explaining why the governance cost of external suppliers is different from governing an in-house project team is the distance between the shipyard and the designer. Distance can be interpreted literally as the physical distance between the two parties. Then the cost of traveling or communicating between the two parties will normally increase with distance. Distance may also represent differences in culture that affect the ability of the parties to communicate effectively. Finally, some of the knowledge embedded in fabrication workers' experience cannot or has not been codified and transferred to engineers and designers. It is for example often claimed that civil engineers working on design and pre-engineering are not well enough aware of problems with manufacturability of their designs. This problem is probably smaller when designers are in the same organization and observe the fabrication process more directly than when designers are located far away. Governance is conducted through direct observation/communication, electronic monitoring and combinations of these. When the design is complex, frequent direct communication between design and fabrication is needed in order to ensure that the design can be fabricated reasonable ease.

The so-called gravity equation of international trade, where the trade volume is a declining function of the distance between the trading partners adjusted for the relative size of the economies has strong empirical support. Furthermore, distance appears to negatively affect the volume of equity flows, foreign direct investment and technology flows as well.[3] The empirical literature on the gravity model finds that the impact of distance on transaction volumes is a concave function of distance. To capture this and analyze the impact of it, we introduce the following linkage between the governance cost of in-house production and outsourcing of design:

$$\sigma = \varepsilon d^{\eta} \qquad (3)$$

where d represents distance, $0 \leq \eta \leq 1$ and we choose units such that $d > 1$ in order to maintain our assumption that $\varepsilon < \sigma$. With this specification the governance cost of outsourcing over and above the variable governance cost of in-house production depends on the distance between the two parties. I follow standard models of outsourcing and assume that the two parties will share equally the surplus that accrues from the contract (i.e. a Nash bargaining solution).

The cost function of the shipyard when design is produced in-house can be denoted:

$$C_i = \frac{c}{A_i} + \gamma A_i + \beta + \varepsilon A_i \qquad (4a)$$

The first term follows directly from the production function and cost minimization. The second term represents the investment cost in specificity, while the last two terms represent

[3] For a recent discussion and overview see Crafts and Venables (2001)

the fixed and variable governance costs. When the shipyard outsource design, its cost function reads:

$$C_o = \frac{c}{A_o} + \sigma A_o + \frac{R - c/A_o - \sigma A_o}{2} = \frac{1}{2}\left(R + \frac{c}{A_o} + \sigma A_o\right) \tag{4b}$$

Here the first term corresponds to the first term in equation (4a). The second term represents governance cost of outsourcing. The shipyard obviously does not invest in specificity in this case and the third term represents the price it pays the independent designer for her investment in specificity. This amounts to half the gains in the shipyard's profits from such investment. Subscript *i* represents internal production of design, while subscript *o* represents external purchase of design. We have set $\bar{S}$ equal to unity. The level of specificity that minimizes the total cost of the project when design is produced in-house is given by:

$$A_i = \left(\frac{c}{\gamma + \varepsilon}\right)^{1/2} \tag{5a}$$

Turning to the designer, she has specialized skills in ship design and can choose whether to take up employment at the going wage or set up her own designer firm where she would employ the staff needed to produce the design and engineering for the vessel. She will only set up the firm if the profits from doing so are at least as high as the wage income, *w,* she can earn from joining the professional workforce. The designers and engineers employed in the designer firm will earn the market wage rate, and it is assumed that p_z equals the marginal cost of z, which is produced according to a constant returns to scale technology. The designer's profit is then her share of the shipyard's surplus less the investment cost. It is assumed that the designer's cost of investing in specificity is the same as the shipyard's. The designer will maximize profits, taking into account the impact of her investment in specificity on the payment she gets from the shipyard:

$\max_A \left[\frac{R - (c/A + \sigma A)}{2} - \gamma A\right]$ which yields the optimal investment in A for the designer firm:

$$A_o = \left(\frac{c}{\sigma + 2\gamma}\right)^{1/2} = \left(\frac{c}{\varepsilon d^{\eta} + 2\gamma}\right)^{1/2} \tag{5b}$$

The investment level is clearly less when undertaken by the designer than when undertaken internally at the shipyard. We also notice that the optimal level of investment in asset specificity declines with the distance. Thus, the farther away from the shipyard, the less tailor-made design. We now derive the conditions under which i) the shipyard would outsource design ii) the entrepreneur would establish a designer firm. The shipyard will outsource whenever $C_i > C_o$ which is satisfied for:

$$\frac{4c^{1/2}(\varepsilon+\gamma)^{1/2}+2\beta-R}{2c^{1/2}} > \frac{\sigma+\gamma}{(\sigma+2\gamma)^{1/2}} \tag{6}$$

The designer's participation constraint is:

$$\frac{R-(c/A_o+\sigma A_o)}{2}-\gamma A_o > w$$

Inserting (5b) and reorganizing yields:

$$R-2w > 2c^{1/2}(\sigma+2\gamma)^{1/2} \tag{7}$$

I will now analyze under which conditions outsourcing will take place and focus on how distance, the wage rate, the contract price and the fabrication cost affect the outsourcing condition. Suppose that variable governance cost and investment costs are incurred in terms of professional workers. Without loss of generality it is assumed that it takes one unit of labor to govern one unit of A when produced in-house while it takes $\varphi > 1$ units of labor to produce A.[4] Inserting this in expressions (6) and (7) yields:

$$\frac{4(cw)^{1/2}(\varphi+1)^{1/2}+2\beta-R}{2(cw)^{1/2}} > \frac{d^{\eta}+\varphi}{(d^{\eta}+2\varphi)^{1/2}} \tag{8}$$

[4] It could be assumed that γ represents efficiency units of designer inputs and φ the cost per efficiency unit. It would in that case be possible to have more efficient and better paid designers in the designer firm while maintaining the assumption that the cost of design is the same in the shipyard and the designer firm.

$$\frac{R-2w}{2(cw)^{1/2}} > \left(d^{\eta}+2\varphi\right)^{1/2} \tag{9}$$

Both the outsourcing constraint (8) and the participation constraint (9) imply that there exists a maximum distance between the parties beyond which outsourcing will not take place. Obviously this distance is larger the larger are the left-hand sides of expressions (8) and (9). Inspecting the two constraints it is also immediately clear that the shipyard will be more willing to outsource to far-away designer firms the lower is the contractual price. Given that competition will put a downward pressure on the contractual price, (8) indicates that the downstream producer will be more willing to outsource the more competitive the market. Evidence from the Japanese car industry and the Norwegian and British offshore petroleum industry indicates that lower profit margins in the downstream firm indeed squeeze the profit margins of the upstream suppliers.

From (9) we see that the entrepreneur is less likely to establish a designer firm the higher is *w*. Thus, ceteris paribus, high wages for professional workers discourage entrepreneurship. The impact of the wage rate on the shipyard's outsourcing constraint is less clear-cut and depends on the relative size of the contractual price and the fixed cost of managing an in-house designer team. Differentiating the left-hand side of expression (8) with respect to *w* (or *c*) yields a positive derivative when $R > 2\beta$, and a negative derivative otherwise. At least for industries building large and/or technologically advanced vessels it is reasonable to assume that $R > 2\beta$ and thus that the distance for which the outsourcing constraint is binding widens as the wage rate (or c) increases. Recall from (2) that if *c* increases due to an increase in fabrication costs, the shipyard will demand more, but less specific design. Intuitively this should indeed tilt the make-or-buy decision towards buy. The two conditions ((8) and (9)) are satisfied simultaneously and outsourcing will take place when:

$$\frac{2(cw)^{1/2}(\varphi+1)^{1/2}+\beta-w}{(cw)^{1/2}} \geq \frac{2d^{\eta}+3\varphi}{\left(d^{\eta}+2\varphi\right)^{1/2}} \tag{10}$$

Given that the agents are indifferent between outsourcing and in-house production; and employment and setting up a firm respectively when expression (10) holds with equality, we can derive the equation for the boundary of the distance between the two firms:

$$B = \frac{2(cw)^{1/2}(\varphi+1)^{1/2} + \beta - w}{(cw)^{1/2}} - \frac{2d^{\eta} + 3\varphi}{(d^{\eta} + 2\varphi)^{1/2}} = 0 \tag{11}$$

Implicit differentiation of expression (11) yields:

$$\frac{\mathrm{d}d}{\mathrm{d}w} = -\frac{(w+\beta)(d^{\eta}+2\varphi)^{3/2}}{\eta d^{\eta-1} w (cw)^{1/2} (2d^{\eta}+5\varphi)} < 0 \tag{12a}$$

The boundary in the *d*-*w* space (see figure 3 below) is hence downward sloping. It can also be shown that the boundary in the *d*-*w* space is convex, and more so the larger is η. We recall that the shipyard's outsourcing constraint allows for a longer distance between the parties the higher the wage rate (provided that R > 2β), while the opposite was true for the entrepreneur. The downward sloping boundary thus indicates that it is the entrepreneur's participation constraint that is binding along the boundary.

$$\frac{\mathrm{d}d}{\mathrm{d}c} = -\frac{(\beta - w)(d^{\eta}+2\varphi)^{3/2}}{\eta d^{\eta-1} c (cw)^{1/2} (2d^{\eta}+5\varphi)} < 0 \text{ when } \beta > w \tag{12b}$$

When the fixed cost of monitoring and coordinating a designer team in-house in the shipyard is higher than the unit professional labor cost (e.g., if it takes more than one unit of management labor input to monitor the designer team), the boundaries in the *d*-*c* space is also downward sloping. Again we see that it is the entrepreneur's participation constraint that is binding along the boundary. This result can shed some light on the spatial division of labor when fabrication activities in rich countries relocate to emerging markets or are closed down due to stiff competition from emerging markets. This would indeed lower *c*. Expression (12b) indicates that the de-industrialized region would be more likely to retain the designer activity the lower the fabrication costs in the new location. In other words, if a shipyard relocated from Norway to China, it would probably find ready suppliers of design and engineering in Norway, and thus outsource these services to Norway. This may not be the case if fabrication relocated to South Korea. Although the distance is about the same, fabrication costs are significantly higher than in China. Therefore, the profits to be shared could be too small for the potential Norwegian entrepreneur to enter the market, and the South Korean shipyard would produce design in-house.

$$\frac{\mathrm{d}d}{\mathrm{d}\beta} = \frac{2\left(d^{\eta} + 2\varphi\right)^{3/2}}{\eta d^{\eta-1}\left(cw\right)^{1/2}\left(2d^{\eta} + 5\varphi\right)} > 0 \qquad (12c)$$

The fixed cost of managing an in-house designer team at the shipyard, β, does not enter the entrepreneur's participation constraint, and obviously the shipyard would be more willing to outsource the higher this cost.

$$\frac{\mathrm{d}d}{\mathrm{d}\eta} = -\frac{d \ln d}{\eta} < 0 \qquad (12d)$$

Finally, the boundary as drawn in figure 3 below, becomes more convex the larger is η. Hence the reach of the service firm is shorter the higher is η for a given wage rate. This makes intuitively sense since η determines how much governance costs increases with distance. Figure 3 depicts the boundary in the d - w space.

Figure 3, the outsourcing boundary

Outsourcing will take place in the area under the curve. There will be no outsourcing outside the distance marked by the horizontal line, no matter how low the wage rate is. By the same token, at wage rates to the right of the vertical line no entrepreneur will be willing to set up a firm, not even if she can locate just outside the factory gate. As indicated in conditions (12b) - (12d) the outsourcing boundary shifts down and inwards when the cost of fabrication increases, given that $\beta > w$, and it shifts up and outwards for an increase in β, while it becomes more convex for an increase in η.

To summarize the results so far, by introducing distance in a firm's governance cost and an opportunity cost of setting up a designer firm, I have derived the spatial reach of intermediate designer services. Perhaps surprisingly, it appears that the binding constraint at the boundary of outsourcing is on the supply side. Both increased professional wages and increased fabrication costs will incline the shipyard to outsource, but it will be less likely to find a contracting party the higher the fabrication cost and the higher the professional wage rate. These results apply when the potential entrepreneur has no means of affecting the customer's governance cost. We now turn to a situation where the entrepreneur can reduce the impact of distance by investing in ICT.

3.1 The designer can affect governance cost through investment in ICT

Although governance cost falls on the shipyard, it is nevertheless a barrier to entry for the designer. Furthermore, it is reasonable to assume that the shipyard will invest in state-of-the-art technology, including computer-aided manufacturing systems, whether or not designer services are produced in-house or outsourced. Investing in ICT, as the Vik-Sandvik case indicates, enables the designer firm to enter these manufacturing systems directly. As discussed above, monitoring the supplier and managing the contractual relationship can only partly be undertaken electronically. Therefore, investments in sophisticated communication technology will probably not eliminate the relevance of distance altogether. But it will reduce the cost of governance and thereby increase the shipyard's surplus of which the designer gets half.[5] I focus on investment in sophisticated communication equipment such as connecting to broadband Internet networks, and argue that it is this investment category that affects *governance costs*.[6] In order to keep the analysis tractable, I assume that this investment is a fixed cost, denoted I. I further make the simplifying assumption that this investment will lower the exponential on the distance variable by a fixed coefficient, θ; $0 \leq \theta \leq \eta$. We notice that when $\theta = 0$, ICT investments have no effect on governance cost, while when $\theta = \eta$, ICT investments will eliminate the relevance of distance on governance cost altogether.[7] Equation (2) is modified to:

$$\sigma = \varepsilon d^{\eta-\theta} \tag{13}$$

We see from (5b) that the introduction of ICT induces the designer to invest more in specificity. The designer's participation constraint now becomes:

$$R - 2w - 2I - 2(cw)^{1/2}\left(d^{\eta-\theta} + 2\varphi\right)^{1/2} > 0 \tag{14}$$

The entrepreneur will make the ICT investment if it improves her profits compared to the situation presented by condition (9). Comparing (14) to (9), we see that she will invest when

$$I < (cw)^{1/2}\left[\left(d^{\eta} + 2\varphi\right)^{1/2} - \left(d^{\eta-\theta} + 2\varphi\right)^{1/2}\right] \tag{15}$$

[5] The analysis applies equally to an arbitrary share of the surplus, but for convenience I stick to the 50-50 Nash bargaining assumption.

[6] Investment in CAD systems improves the productivity of design and investment in specificity, but is less relevant for governance costs.

[7] A more sophisticated, and more realistic, but technically more complex way of modeling the impact of ICT investments on governance cost is to make η a function of I and let designers maximize profits subject to investments in A and I. The simpler alternative offered here will nevertheless give a reasonable first attempt at analyzing the impact of ICT on the spatial reach of services.

We notice that the expression in square brackets increases with d such that the designer entrepreneur will gain more from investing in ICT the further from the shipyard she is located. The boundary of the outsourcing condition is now given by:

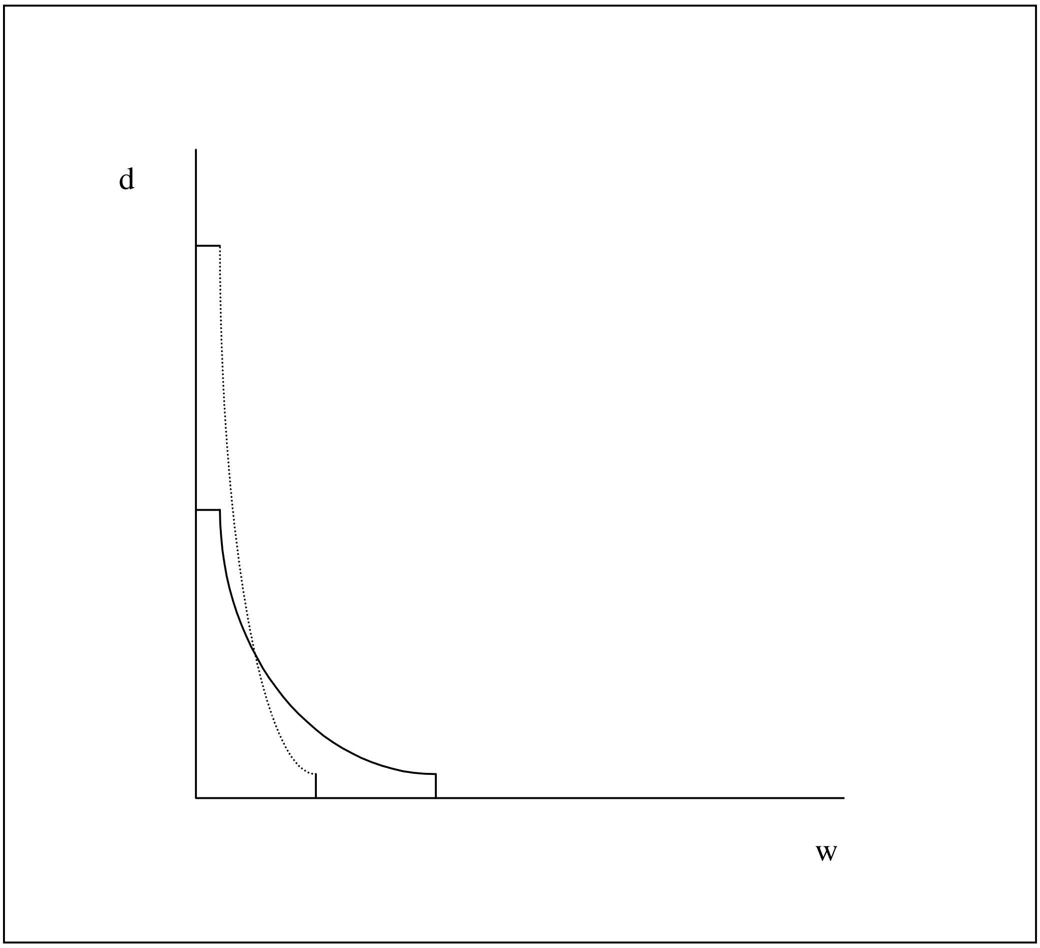
$$F_s = \frac{2(cw)^{1/2}(\varphi+1)^{1/2} + \beta - w - I}{(cw)^{1/2}} - \frac{2d^{\eta-\theta} + 3\varphi}{\left(d^{\eta-\theta} + 2\varphi\right)^{1/2}} = 0 \qquad (16)$$

Subscript s refers to the space economy where designer services are traded electronically. Comparing (16) to (11) we see d^{η} is replaced by $d^{\eta-\theta}$, which implies more investment in specificity with outsourcing. The smaller exponential yields a less convex boundary compared to figure 3. Investment in ICT appears in the nominator in the first term of (16). It can be shown that I must be smaller than β for an outsourcing solution to exist. Otherwise the fixed cost of the outside supplier would be higher than the fixed cost of managing the internal designer team, and there would be no gains from outsourcing. It can easily be shown that the boundary shifts down- and inwards for an increase in I. Equations (11) and (16) are depicted in figure 4.

The solid curve depicts equation (11) while the dotted curve depicts equation (16). We notice that the reach of the designer service firm has increased substantially following the investment in ICT, provided that θ is sufficiently large compared to I. In other words, if a potential entrepreneur located far from the fabrication activity have access to low-cost communication services such as broadband Internet services, she will be more likely to establish a designer firm. However, if the wage rate for professional workers is high, potential entrepreneurs located close to the shipyard would enter the market, but without investing in sophisticated communication technology. This is simply because higher fixed costs reduce the profits.[8] If the potential entrepreneur is located at a distance beyond the intersection of the two curves on the other hand, ICT investment would increase the reach of services and make entrepreneurship attractive for a higher range of wages.

[8] If the entrepreneur could spread these costs on many customers, a possibility we have not considered in the model, this result may not hold

Figure 4. The outsourcing boundary with and without ICT investments



4 Summary and conclusions

In this paper I have discussed a case study of a small multinational naval designer firm located far from the major markets. The firm trades its designer and engineering services through a combination of face-to-face interaction with customers and electronic transmission of drawings and documentation. Inspired by the case study, I developed a model of spatial division of labor between fabrication and design, and found that the reach of designer service firms depends on the wage rate for professional workers, the cost of fabrication and investment in ICT. I argue that the model is useful for analyzing restructuring following de-industrialization in rich countries. The interesting and hotly debated question is whether de-industrialized regions will thrive on trade in industrial design and engineering in the information economy, or stagnate and decline. The case study and the model indicates that industrial design and engineering will be retained in the region when the physical or cultural distance to the new location of fabrication is moderate and the fabrication costs in the emerging market is significantly lower than in the rich country. These two conditions are usually not satisfied at the same time, since neighboring countries tend to have similar income and cost levels. Nevertheless, relocation from Western to Eastern Europe could probably satisfy these conditions. So would relocation from Western Europe to China, but probably not from Western Europe to South Korea. Retaining designer and engineering services would also be more likely if the opportunity cost of entrepreneurship is not too high in the rich country region, and if the region has good access to low-cost and effective telecommunications. In particular, ICT investments allow for spatial separation of CAD services and CAM fabrication over large distances, but complementary direct communication is necessary and this limits the reach of designer and engineering services. Thus, there probably exists a distance beyond which outsourcing will not take place and a wage rate above which entrepreneurs will prefer to join the labor force.

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