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Abstract
This paper develops a property rights perspective on the nature of the firm. The basic idea is that learning by doing in production and coordination stem from experience in production and that user rights over productive assets are necessary in order to accumulate the experience needed to perform improvements in production. Accumulation of skills from learning by doing in production is accelerated by specialization in production. However, specialization introduces greater complexity and new kinds of tools and equipment and this creates uncertainty about the best way of coordinating specialized interdependent activities. The result may be bottlenecks in production and uneven development of components. Experimenting in coordination is necessary in order to eliminate these problems. It is argued that the Coasian notion of firms where coordination is provided by the direction of managers provides a cheap way of conducting the experiments needed to collect information on how best to coordinate interdependent activities.

Keywords
Property rights, specialization in production, firm, boundaries, learning

JEL classification
D23, L22

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Contents

I. Introduction

In this paper, I explore the issue of the existence and boundaries of the firm in the context of specialization, technological interdependencies and coordination advantages in production. The perspective chosen to illuminate these issues is the property rights perspective as developed by Coase (1960), Alchian (1965), Cheung (1983), and Barzel (1989) (and as summarized by Eggertson 1990), and particular reference is continuously made to Ronald Coase's seminal 1937 paper, "The Nature of the Firm".[1]

It is a commonplace notion that there is a trade-off between the advantages of specialization in production and the costs of coordination(e.g. Becker & Murphy, 1992). Since Coase published "The Nature of the Firm" in 1937, we have known that the costs of coordination depend on the mode of coordination. But as pointed out by Coase, the advantages of the firm mode over the market mode diminish as marginal costs of coordination increase with more tasks being coordinated within the boundaries of a firm. However, increasing marginal costs of coordination make room for competition between firms for the coordination of specialized tasks, creating a pattern of vertical specialization in the chain of production which reduces overall cost of coordination relative to both coordination within one firm and pure market coordination.

In "The Nature of the Firm" Coase takes the costs of coordinating various tasks as well as the extent of specialization in the economy as *given* and proceeds to analyze why not all transactions among specialized agents are coordinated in either firms or in open markets. My point of departure in this paper is different, since I am interested in how the boundaries of the firm may be linked to learning in coordination and a gradual realization of specialization advantages in production.[2] In particular, I am interested in what are the nature of learning opportunities in production and coordination, and how do such opportunities for learning influence the boundaries of firms.

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[1] To my knowledge, this is the first application of the property rights perspective of its kind. However, Foss (1996) covers somewhat related ground.

[2] Langlois and Robertson (1995), Yang and Ng (1993) and Camacho (1995) are recent treatments with a related aim. However, their approaches are completely different from the one pursued here.

II. Productivity Gains from Specialization

As a preliminary definition, specialization in production can be described as dividing the production of consumption goods into more narrowly defined sub-tasks. Specialization in production is, as Smith pointed out in *The Wealth of Nations,* one of the main sources of productivity improvements. Specifically, he ascribes productivity gains to three aspects of the division of labor. These are 1) improvements in a workers ability to perform a task as it is repeated more often, 2) the time that is saved from avoiding having to switch from one task to another, and 3) an improved ability of a worker to identify labor saving innovations. As indicated by Smith, the subdivision of tasks is not the only characteristic of specialization; changes in tasks as new innovations are introduced are also important characteristics. However, both improved skills or dexterity as well as innovations, depend on learning by doing in production as workers repeatedly carry out the same tasks.

The idea that learning by doing underlies productivity growth was reintroduced in economics by *Arrow* in 1962. He suggested that the growth of knowledge which underlies economic growth could partly be explained as a function of learning in production and that technical change "... can be ascribed to experience, that is,it is the very activity of production which gives rise to problems for which favorable responses are selected over time" (p.156). Moreover, Arrow argued that learning associated with repetition of tasks is subject to diminishing returns, so that continuous improvements in dexterity would depend on continuous changes in the tasks. Such changes could stem from innovations which would also be endogenous to experience in production.

That hands-on experience in production is a source of innovativeness is also an important conclusion that can be drawn from various studies of innovations and technology (Rosenberg 1976; Sahal 1981; Nelson and Winter 1982). These studies point to the fact that the nature of activities and the characteristics of the techniques in use direct attention toward certain technical problems. For example, *Rosenberg* argues that most incremental improvements in products and production processes are closely connected to their physical characteristics. He uses the term "technological imperatives" to indicate how some opportunities for technological development present themselves as more or less evident. Complex technologies, he argues, create internal compulsions and pressures (focusing devices) that focus attention on the elimination of bottlenecks in productions and incompatibilities in products.

Sahal (1981) presents a similar but more elaborated characterization of the sources of innovative opportunities. According to Sahal, technological development leads to the formation of systems where the increased complexity from the mutually dependent components sets the boundaries for further development. Sahal has shed light on different types of innovative activity which underpins this kind of technological development. For example, he explains how changes in the scale of a complex technological system are particularly likely to create problems requiring innovative responses. These problems may be divided into three kinds:

1. problems due to uneven development in the components of the technology;
2. problems which arise because of the need for new materials; and
3. problems caused by a more complex structure of technology.

Solving these problems results in innovations which change the structure of the product or production process, introduce new materials, or combine different technologies into a new system with a more simple structure allowing for further improvements.

Three conclusions emerge from the above mentioned literature. First, productivity gains often stem from a combination of improved dexterity and innovativeness. Second, improved dexterity as well as innovativeness are a function of experience in production, and, third, productivity gains from innovations in, for example, structure, materials and reductions of bottlenecks in production are based on experience, shaped by the nature of activities which are undertaken and thus specific to those activities.

Specialization in production influences the scope for learning by doing of individuals when their accumulation of experience in production is limited to more specialized tasks, but as tasks are repeated more often, it results in a faster learning of skills. This in turn imply that the point of sharply diminishing returns from improved dexterity may be reached faster with specialization than without, and that continuos improvements in productivity requires a faster rate of innovativeness (that is changes in the tasks). Specialization – by focusing the attention of individuals on much a more narrow set of task which – may improve the rate of

innovativness with respect to the discovery new ways of carrying out a task, of improving tools and materials used.[3]

However, as I shall explain more thoroughly in section IV, specialization in production may also create problems of *bottlenecks* and problems from uneven development of components and such problems, of course, reduce the benefits from specialization, *unless* some mechanism for coordinating the interdependent specialized tasks is devised. Before I turn to the discussion of coordination, I shall discuss the relation between specialization, allocation of property rights and learning by doing.

III. Specialization as a Reallocation of Property Rights

In the previous section, I described specialization in production as a matter of dividing tasks into sub-tasks. In this section I discuss in more detail the relation between specialization and the delineation of property rights. The purpose is to identify more precisely the relation between specialization, learning by doing, and coordination.

Property rights are the rights people hold over assets. Assets may be physical assets, such as tools, buildings and other equipment, or it may be human assets, such as the effort and work time provided by an agent. It is customary to distinguish between three different categories of property rights namely

1. *user rights*, which define the potential uses of an asset;
2. *income rights*, or the right to consume an asset, and
3. *rights to transfer* permanently to another party ownership rights over an asset – that is to alienate or sell an assets (Alchian 1965; Eggertson, 1990).

Often physical and human assets have different properties which each can be specified and be subject to negotiations between parties to a transaction. Moreover, userrights over different attributes over assets may be shared between individuals. For example a copier can be used in different time periods and for many different types of copy works. Different

[3] The ability to solve technical problems may depend on specialized technical and/or scientific knowledge. Innovations in materials, in tools and in restructuring products and production processes therefore may require coordination between individuals holding different bodies of technical and scientific knowledge.

individuals may have different rights to use the copier in different time periods and for different purposes.

Specialization in production can now be defined in the terminology of property rights theory as *a subdivision of user rights over assets, so that each individual holds rights over a more narrow set of assets or holds a more narrow set of rights over the same assets*. The latter case may imply that rights over an assets is shared between individuals. The one kind of specialization does not preclude the other.

It should be noted that the kind of assets over which one holds rights need not be the same with specialization as without specialization, since in many instances specialization is accompanied by a shift from all purpose tools to more specialized equipment. However, the introduction of more specific equipment and tools limits rights, since these have fewer different uses.

Another important distinction is between *specific* and *residual* rights (Barzel 1989; Hart 1991, 1995). This distinction is useful in connection with learning by doing in production, since this kind of learning takes place as individuals exercise rights over assets (in other words, one cannot acquire skills without having user rights). Specific rights are those rights which are specified in contracts and allocated between the transacting parties before any transaction takes place. Residual rights are those rights that are not stipulated in contracts or regulated by laws or which cannot be enforced *ex post*.[4] For example, specific user rights over a computer might be the rights to use it to run a particular program in a particular manner in a particular time period for some specific purpose, while the residual user rights are the rights to use the computer in all other not specified time periods and in all the manners possible. If the computer can be used for more than one purpose, it is a generic asset and residual rights then include the right to decide for what purpose to use the

[4] One may distinguish between private and legal enforcement of rights. The emphasis on legal enforcement as an important institution differs across the contributions within transaction cost economics. Barzel (1989), for example, emphasizes that "... legal rights, as a rule, enhance economic rights, but the former are neither necessary nor sufficient for the existence of the latter" (p.2) . The rights people hold are a function of their own efforts in acquiring those rights and in protecting them from others' capture attempts. This implies that pre-specified rights are only specific in so far as they are protected against others' capture attempts and that the legal system is just one mean of protecting rights. Hart (1995), on the other hand, views legal protection as the most important dimension in determining contractual arrangements. If pre-specified rights cannot be verified by a third party (a court), formal (and legally enforceable) ownership over assets is an important alternative to contracting.

computer. Likewise, income rights can be either specific or residual. Residual income rights (or residual claims) are the non-specified income or pleasure a person can enjoy from using or alienating an asset (including his labor). Residual user rights are often paired with residual income rights in order to create the kind of incentives which will result in efficent outcomes.[5]

The distinction between residual and specific user rights is not completely clear-cut. Sometimes only the right to decide between different kinds of uses of an asset is described as residual rights while rights to decide how to use an assets in a specific way is described as discretion (Alchian and Woodward 1988). High information costs and ignorance often imply that transacting parties voluntarily leave rights over certain properties of an asset unspecified. For example, to completely specify all rights to use a computer requires full knowledge of all possible uses and all the different ways in which the computer may be operated, as well as a detailed listing of these uses. In addition, one would need to perform a tight surveillance of the users of the computer in order to enforce one's rights. Many rights over a computer are therefore left unspecified, and these rights may be captured by the user of the computer who then is capable of exercising some discretion in his decisions on how to use or operate the computer. [6]

Finally, rights to decide between some pre-specified uses of assets may be delegated to others (Jensen and Meckling 1992, Aghion and Tirole 1997). The person who has the rights to determine the set of possible uses as well as the right to decide on delegating decision rights has the residual rights.[7] Rights to specify specific rights over physical assets, delegate and otherwise transfer rights over assets follow from formal ownership over assets, and in the case of labor from voluntary agreements to transfer these rights. In the following

[5] According to Barzel (1989), the value of an assets is maximized if those who are best able to influence its value receive the residual income stream generated by their influence.

[6] As long as there is incentive compatibility, in the sense that discretionary behavior does not favor one party at the expense of an other, rights most likely will remain unspecified.

[7] Delegation may be efficient if agents have access to information about the consequences of some actions and if that information is to costly to transfer to the principal holding the legal rights over assets. Complications may arise if the principal had preferred a different action than that preferred by the agent had he known the consequences of that action with certainty (see, e.g., Aghion and Tirole ,1995). According to Jensen and Meckling (1992) the problem of decentralization contra centralization in firms is due to such agency costs. The optimal delegation depends on a trade off between costs owing to poor information and costs owing to inconsistent objectives.

sections, I use the term "specific rights" to denote only the situation where rights are delineated in ways which do not allow for discretionary behavior. If discretionary behavior occurs, this is because some rights have been left unspecified. The difference between having discretion and holding residual rights over assets is that the latter case includes rights to unilaterally re-define and re-allocate (by delegation or otherwise) rights over assets which are not specified in contracts.

As mentioned earlier, there is a connection between learning by doing and the allocation of user rights. This connection is a consequence of the fact that learning by doing requires the exercise of user rights over assets. Moreover, I believe that the more well-specified and easily monitored user rights are, the less able are those who use assets to experiment and the more constrained will their learning be. If, for example, the manner in which a computer operator runs a program is pre-specified in a contract and easily monitored, his learning by doing may be limited to improving the speed with which he activates the keyboard. If he has greater discretion in deciding how to operate the program, he might have a greater opportunity for learning by experimenting.[8] Such experimentation may result in labor saving innovations of the kind envisaged by Adam Smith and, perhaps, today by proponents of "the learning organization".[9]

However, discretionary behavior need not always result in productivity gains. This may, for example, be the case if there is strong technological interdependencies, so that the functional performance[10] of a technology is greatly influence by the fit between parts and/or between

[8] With higher degrees of discretion an individual also has more room for shirking or otherwise appropriate a greater value from the use of an asset. The allocation of residual income rights from the use of an asset can be a powerful mean of reducing such rent-seeking behavior. Team problems (Alchian and Demsetz, 1972) is an example of problems which arise because individuals have discretion. If, for example, specialization in production is taken beyond the point where the outcome of each task is measurable in terms of the quantity and quality of output produced, and if rights over labor time is not perfectly specified and enforceable individuals may exercise discretion and shirk. A similar problem exists in the production of complex products with may parts where is only possible to test the quality of the product if all components are in place and working (David, 1987). Each supplier of parts may then have incentives to exercise discretion and shirk on the quality of their output. In these cases a more complete realization of the advantages of specialization in production may require specialization in monitoring.

[9] Improvements in dexterity and innovativeness do not come about unless individuals also have the incentives to bring about these improvements. How these incentives are provided is beyond the scope of this paper.

[10] I use the term "functional performance of a technology" accordingly with Sahal (1981) as the objectively measured performance of a technology. As examples Sahal mentions the thermal efficiency of an electric powerplant defined as the ration of the electrical to the total thermal output of the fuel or the horse-power - hour per gallon of fuel or the horse-power-to-weight ratio of a tractor.

activities. In such a case, discretionary behavior may result in bottlenecks or in uneven development of components. Basically these problems arise when those who deliver parts or carry out activities are not aware of the need for mutual adjustment between parts and activities. From a property rights perspective, these problems can be ascribed to imperfectly specified rights over assets.

High information and enforcement costs is one reason way not all rights are well specified but ignorance is an other equally good reason why rights are left unspecified. In this connection it is important to note that that ignorance may be linked to increased specialization in production and that such ignorance may be reflected in bottlenecks and uneven development of components. For example, it may take time to discover how best to sequence or conduct various activities when subdivision of rights over assets leads to increased complexity and interdependence between tasks. Moreover, specialization and growth of markets may give way for the introduction of new kinds of specialized tools and large scale equipment which in turn may introduce new problems of how to utilize capacity effectively. Finally, when ignorance a characteristic of the process of redefining tasks and implementing new equipment it is likely that some individuals will come to enjoy to large degrees of discretion in their exercise of user rights. This in turn may result in innovations which lead uneven development of tools, equipment and components.

Problems of bottlenecks and uneven development of components thus, arise because it is difficult to specify all valued dimensions of assets *prior to* specialization, since many of the valuable dimensions of assets only become apparent from *experimenting* with the use of the assets. Even if important dimensions can be specified it may be difficult to allocate these rights in ways which ensure the best use of assets. This may, for example, be the case with the time and place dimension of assets where non optimal allocations results in excess stocks of intermediate products or in idle assets.

Solving problems that arise from technological interdependencies is an important source of innovative improvements (as pointed out by Rosenberg 1976 and Sahal 1981). However, such innovations do not emerge because of increased specialization, but because of learning in coordination. From the literature on innovation studies it seems that much of this

learning depend on experience in coordinating various tasks[11]. In other words, in order for this kind of learning to take place it is necessary to experiment whit different ways of laying out production tasks. The question then arises: what institutional set-up best provides for experimentation and accumulation of experience in coordinating?

In the following section I argue that the solution to coordination problems of bottlenecks and uneven development of components is the Coasian notion of firms in which managers direct the use of resources. I also argue that the importance of the Coasian firm in a specialized economy can be ascribed to a combination of high measurement costs, resulting in imperfectly specified rights, and high costs of recontracting making it desirable to rely on explicitly open-ended contracts rather than seemingly complete contracts. Furthermore, with boundedly rational agents and technological uncertainty, there may be economic gains from experimenting in coordination and such experimentation may require the flexibility afforded by an open-ended contract for the provision of labour services and possibley combined with legal ownership of physical assets.

IV. Coordination in Production

A. Social Coordination

The need for social coordination arises as a consequence of interdependencies in consumption, between consumption and production and between production activities. These interdependencies follow from conflicting preferences over scarce resources or from technological interdependencies. The opposite of interdependence in production is self-sufficiency – a situation of self-management (Demsetz, 1995) where each person having exclusive rights over a stock of resources select for himself the uses which maximize his utility. Traditional price theory deals with the situation where pure self-sufficiency is substituted by exchange of goods between agents in an economy and examine the working of the price system as a means of coordinating conflicting *preferences* over resources. In production theory, specialization between consumption and production is introduced,

[11] To confuse matters a bit the elimination of bottlenecks may imply the implementation of a technique in which many previously separate tasks are integrated into one production step. However, one may say that knowledge based on learning in coordination is embodied into the technology.

creating a need for the price system to bridge firms' production and consumers' consumption plans.

From traditional micro economics, we know that under certain restrictive assumption, including the assumption of perfectly defined rights and zero transaction costs, prices provide sufficient information to choose between different uses of resources in a manner that at the same time optimize the utility of individuals and ensure social coordination - leaving no valuable resources idle. For an equilibrium to be stable, all means and ends must be *given*. This imply that specialization between firms in production is given by, for example, the *ex ante* specified number of goods in the economy. With the assumption of given technologies and no increasing returns to production, this is equivalent to assuming that specialization has reached the limit set by the extent of the market for each specialized service.

Firms in this model-world are defined as specialized units of production that produce for outsiders (Demsetz, 1995, p. 8). Their "coordination tasks" consists of selecting the profit-maximizing quantities of inputs and outputs for the specialized production tasks they each carry out. Self-management characterize these firms, since with prices providing all the information that is needed to achieve coordination, self-management of resources would result in the same choices as management by others[12]. Moreover, in this model world, there is no need for firms to consider the question of make or buy, since with perfect price information there are no gains from organizing one more or one less specialized task within a firm. [13]

It is, however, a commonplace notion that there is a trade-off between the advantages from specialization and the costs of coordinating increasingly specialized tasks. Put a bit

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[12] This is because in equilibrium prices express the true opportunity costs of different uses of resources.

[13] In this world the only kind of learning that possible could take place would be an upgrading of very basic skills in performing the pre-specified tasks. This kind of learning could create a complementary between human and physical resources that could lead to a sort of path dependence in ownership structures. Furthermore, if there is costs of determining the advantage from learning by doing the initial allocation of rights may not perfectly reflect the ability of each agent to accumulate skills. Therefore depending on transaction costs the initial allocation of rights can have great implications for the pattern of specialization in uses of assets. However, any misallocations due to costs of determining the ability of individuals to accumulate skills cannot be reduced by substituting market coordination by managerial coordination. It is of course possible that long term contracts and intense monitoring of talents by an agent specialized in such an activity may reduce costs of discovering the learning abilities of individuals.

differently, at some point the marginal costs of coordinating one more specialized tasks through arm-lengths transactions across markets outweighs the marginal benefits from specialization and *this point may be reached long before the limit to specialization set by the extent of the market*. In fact, in a pure market the point at which costs of coordination out weight the benefit of specialization may be just when further specialization result in technological interdependencies This could be so because, faced with a situation of technological interdependencies and high costs of transacting it is difficult to avoid major costs from bottlenecks and uneven development of components.

Problems of bottlenecks and uneven development of components exists even with self-sufficiency, since individuals producing for their own needs may be unaware of how best to carry out an activity or how to develop the technologies they use. Specialization in production, however, is likely to magnify the problems because mutual adjustments now require awareness of what other individuals are doing.[14] If, in addition the functionality of a technology is strongly dependent on the external conditions for carrying out the tasks, there may be a permanent need for mutual adjustments.

With specialization in production it is necessary to obtain the consent of many more parties, each holding a sub-set of the user rights needed to operate the technology, in order to reallocation or re-delineate rights in a way which improves the functional performance of technologies. Therefore, if specialization is taken beyond the point of technological independence in production, reacting in a coordinated manner to contingencies requires the development of a complementary institution to arm-length markets transactions in order to solve the problems of mutual adjustment between individuals carrying out interdependent tasks. In my opinion, the Coasian firm provides such an institution

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[14] The benchmark for improving coordination by re-arranging rights over human and physical assets could be the functional performance of a technology without specialization in production However, a comparison of the functional performance of technologies in situation of specialization and no specialization is complicated by the fact that it is most likely not the same technologies which are used in both situation. For example, specialization may make it possible to increase the capacity of a technology by up scaling of the equipment or by taking advantages of much more specialized equipment. A comparison between the coordination which could have been achieved in a perfect (Walrasian) market characterized by a given degree of specialization and given technologies is another possible solution. To derive the optimal coordination by comparing an unrealistic Walrasian market model with a real situation is to commit an error which may result in too great investments in improving coordination. All one can say then is that an optimal amount of coordination requires that the opportunity costs of the resources invested in bringing

B. A Property Rights Perspective on "The Nature of the Firm"

Since the publication of "The Nature of the Firm", increasing attention has indeed been focused on how costs of coordination vary with the mode of coordination, with firms being an alternative coordination mechanism to the price mechanism.

I the following section I interpret Coase´s analysis of the nature of the firm in terms of property rights. I argue that Coase's notion of firms can viewed as a solution to problems of coordination in situations where user rights over assets cannot be perfectly specified and allocated in manners which ensures the functionality of technologies. Such situations may occur because individuals face uncertainty and because they have only limited computational capacity making it to difficult for them to specify user rights in ways that solve problems of interdependencies ex-ante to specialization. Based on Coase (1937, 1991) I argue that one of the reasons why managed coordination may be advantageous to price coordination is because the former reduce costs of learning in the coordination of technological interdependent tasks. To keep the record straight, I would like to mention that I do not believe that problems that arise from technological interdependencies are the sole reason for the existence of Coasian firms.

Coase (1937) uses coordination costs to explain why in an economy of specialized production markets and firms co-exists as alternative modes of coordination. The reason for the existence of firms he suggested is that there are costs of using the price mechanism and that "[t]he most obvious cost of "organizing" production through the price mechanism is that of ***discovering*** what the ***relevant prices*** are" (Coase, 1937, p.21; my emph.). With high market cost (later termed transaction costs), the market mode of coordination is substituted by a firm mode of co-ordination based on managerial decisions.

While Coase (1937) does not explicitly suggest that uncertainty is a reason why it may be costly to discover the relevant prices and why managed direction may be less costly than open market transactions, uncertainty seem to play an important role in his explanation of the need of open-ended contracts such as employment contracts. According to Coase an

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about a marginal improvement in coordination do not exceed the bygone Paretian rents from not improving coordination.

employment contract is preferred "..owing to the difficulty of forecasting, the longer the period of the contract is for the supply of the commodity or service, the less possible, and indeed, the less desirable it is for the person purchasing to specify what the other contracting party is expected to do" (Coase, 1937 p. 21).

Stated in the terminology of property rights there is high costs of specifying the valued attributes of assets in all future states, and this result in rights over valued attributes of assets being left unspecified. When the coordination between factors is subject to changes in external factors (contingencies) which cannot be specified ex-ante, continuos redirection of resources and re-planning taking advantage of the dimensions of time and place of assets will be necessary in order to avoid bottleneck. [15] [16] Managed direction of resources may thus substitute for price direction of resources when parties to transactions realize that contingencies of different sorts may interrupt the timing and sequencing of interdependent activities (for a recent treatment, see Wernerfelt 1997).

An arbitrageur holding stocks of assets also makes his money from superior knowledge about the value of the unspecified attributes of time and place. The employment contract could be interpreted as providing a stock of labor services which within limits could be allocated to different uses by the direction of a manager in response to unforeseen contingencies. Managers then play the role of arbitrageurs holding stocks of labor services in

[15] Contingent contracting covering all future states is a feasible solution to coordination problems if states can be observed by all parties involved and if parties have the same interpretation of the state they observe. If these two conditions are violated it may be more efficient to set up a communication system based on a central agent who have low costs and /or superior ability to interpret the state of the world and communicate the observation to others. This communication could take the form of orders to exercising pre-specified plans or tasks. Allocation of resources based on pre-specified plans contingent on the central agents observations need not rely on managerial decisions. If all possible states are known in advance and if bargaining is relatively costless prices needed to coordinate activities and to set plans in motion may be worked out for each possible state. However, bargaining as a way of determining the prices may be very costly if each contingent plan involve many interdependent tasks that requires close contacts between those who carry out the activities. As explained by Rosen (1991) in the case of team effects (joint production), such a pricing scheme will be extremely complex to work out. Moreover "..to calculate and implement this solution requires full knowledge of the underlying technology and productivity of team members in the first place" (p.81) And since errors in prices can be more costly than errors in the allocation of activities and time it may be advantageous to rely on a manager to perform the allocation of time and workers to tasks and then let the manager monitor the activities. The importance of managerial direction of course diminish once the technology becomes fully known.

[16] In a system of production the timing of a particular sequence of activities is a way of reducing costs of idle labor or machinery and costs due to the building up of stocks of intermediate products. The advantage to tighter integration of different steps in the process is the costs saved on stocks and idle resources. These advantage has to be measured against the cost of failure or irregularities in strongly interdependent systems. Firms therefore may hold stocks of input in order to reduce these latter costs.

order to take advantages of superior knowledge of the time and place property of labor services.

Now, arbitrageurs only needs to bear the cost of stocks if they can not appropriate the benefits of their knowledge of time and place by selling this information. Two factors may explain why it is not always feasible to sell information about time and place dimensions of assets. First, there is the well known problem of information as a public good which, if revealed before the transaction, cannot be protected from capture (Arrow,1962). Secondly, negotiations may take longer time than direction by orders and because of this opportunity for profitable action may be bygone[17].

To Coase high costs of discovering the relevant prices is a necessary but not a sufficient factor in explaining why firms exist. Firms exist only if there is also "... costs of negotiating and concluding a separate contract for each exchange transaction which takes place on a market (ibid, p.21). These costs are reduced "..if the factor, for a certain remuneration (which may be fixed or fluctuating), agrees to obey the direction of an entrepreneur *within certain limits* (ibid, p.21, emph. in original)

In "The Nature of the Firm", Coase uses the employer-employee relationship as the archetype of the firm where managers rights to direct resources within certain limits fills in the holes in the open-ended employment contract. Later on Coase (1991) has remarked that already at the time when he wrote "The Nature of the Firm", he was aware that the analogy between the employment contract and the firm could give an incomplete picture of the nature of the firm. For one thing "... a firm may imply control over another person's property as well as over their labour" (p.64), an amendment which figured in a footnote of the original paper indicating that firms may also posses user rights over rented assets. Coase (1991), however, also points to a second amendment to the original article when he draws attention to a lecture note from 1934 in which he states that "..a full firm relationship will not come about unless several such contracts are made with people and for things which cooperate with one another" (Coase, 1991, p.64).

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[17] In some productions, time is not just valuable but in fact critical to the quality of products. In pea production for example, the timing of harvest is very important in order to fulfill the goals of high capacity utilizing of the pea processing equipment and avoid quality losses from perishability of peas. Pea processing firms therefore may acquire from the farmers of peas the user rights over peas and fields in order to plan and decide on all matters concerning the harvest of peas.

These amendments can be interpreted to mean that managerial decisions fill the holes of open-ended contracts in cases where coordination of large number of factors which cooperate with each other is required. This is exactly the situation when specialization in production results in technological interdependencies between many tasks.

The inability to specify future states of the world, combined with a quest for the rearranging of rights over many assets and between many individual need not be the only explanation of why managed coordination is preferred to price coordination. The importance of managed directions of interdependent assets can in my opinion be motivated by the technological uncertainty which arise when specialization alters tasks, so that self-management of technological interdependencies is no longer possible. Managed coordination thus is important even if there are no unforseenable contingencies which require adjustment in tasks. This is because the complexity of technologies may make it difficult to know in advance the particular requirements for an efficient coordination. In fact, with a great deal of interdependence in a complex systems, the best time and place to use a resource depend on the specification for the uses of all *other* resources which are needed in the production. *Firms thus arise as parallel institutions to markets in order to capture the value of the unspecified attributes of assets*.[18]

To sum up, firms exists only if there is both high costs of discovering the relevant prices *and* if these costs cannot be reduced by contracting for this information. The latter may be the case where interdependencies between many resource owner make it costly to carry out the needed rearrangement tasks to take advantage of new information on states of the world.

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[18] Rights over previous unspecified attributes of assets can be established by the legal system as a system of property rights. A system of property rights is "a method of assigning to particular individuals the "authority" to select, for specific goods, any use from an unprohibited class of uses" Alchian (1965). Having a low costs method of specifying and allocating rights is advantageous when there is economic gains from avoiding problems of common property. Once rights are established, formal legal ownership of assets provide the owner of assets with all residual rights over their assets including rights over all attributes which may be discovered in the process of using or experimenting with the assets. However, if some uses of assets creates externalities it may be efficient to prohibit these uses. The Coase theorem then states that if there are high costs of transaction some regulation by, for example, government may be efficient. In some respects the role of managers in firms resembles that of the legislatures of government. To avoid some of the costs of externalities which arise with interdependent activities and team production managers may "regulate" the use of assets within firms by for example, defining strict limits of authority of decision takers or by simply forbidding certain uses of assets. Finally it should be mentioned that managers reduce externalities from discretionary behavior (shirking) in team production by monitoring the performance of employees and directing rewards to those how exercise most effort.

Firms then save transaction costs by substituting *many* independently determined contingent contracts for managed directions. To this I add the cost of transactions which may be saved when technological uncertainty and complexity require sequential delineation and reallocation of rights over assets as a way of gradually improving the functional performance of technologies.

For managed direction of resources to be efficient, it is required that managers are at least as qualified in discovering the relevant prices (that is, find the highest valued uses of assets) as independent contractors would be. Otherwise, costs of transacting may be saved at the expense of efficiency in the use of resources. If managers are better able to determine the valuable uses of resources compared to other agents, managers have a natural ownership advantage over resources. Such an advantage explains the single person firm, but not necessarily why managers hire employees who are prepared to take orders within certain limits in order to take advantage of this knowledge. "Managers" could as well rent the labor time of an agents in return for the exercise of a certain well specified task.[19]

In my opinion, managers stand a good chance of acquiring superior information about the relevant shadow prices of rights over assets which make up a complex technology. From the literature on incremental innovations it is apparent that the solution to problems of bottleneck and uneven development in components are based on experience in production and development. I now argue that this experience probably more easily is accumulated

[19] Coase (1937) mentions "..increasing opportunity costs due to the failure of entrepreneurs to make the best use of the factor of production" (p.23) as one of the reasons why there is a limit to the efficient size of a firm. He also assumes that "..the costs of losses through mistakes will increase with an increase in the spatial distribution of the transactions organized, in the dissimilarity of the transactions, and in the probability of changes in the relevant prices. As more transactions are organized by an entrepreneur, it would appear that the transactions would tend to be either different in kind or in different places" (p.25). Managers, in other words, have limited capacity to "discover the relevant prices" and this increases mistakes as more and more dissimilar transactions are organized in a firm. Now, some of the problems of limited capacity of managers may be solved by delegation and selective intervention. However, as explained by Williamson (1985) there are unavoidable side effects of moving transactions into a hierarchy. These are primarily due to costs of extra monitoring which are introduced because integration often require a switch from high powered to low powered incentives in order to avoid value dissipation from excessive use of equipment. These costs may not be off set by gains from reduced transaction costs unless some degree of assets specificity is involved. In my opinion gains from integration stem from the ability to perform selective intervention. Selective interventions may only be required when there is interdependence between activities. Interdependencies may not be a sufficient condition for integration since manager from the acquiring firm must also be capable of making interventions in a way which enhance efficiency in production and this may require an experience which they do not posses. Finally, it should be noted that rent dissipation from overuse of physical asserts may be restricted by restricting user rights to these assets. Again the provision of efficient restriction may require intimate knowledge of how the equipment can be used and how it best used and this knowledge may not be available or transferable to the acquiring firms at a reasonable cost.

within the boundaries of firms. Some of the reasons why one might expect this learning to be less costly within the boundaries of firms may be that managers who hold residual rights over assets including rights to re-define and reallocate specific rights are able to conduct experiments without continuously having to re-negotiate contracts- this saves time and ink-costs. Moreover, due to the uncertainty surrounding the transaction the valuation by the transaction parties will be subjective and possible differ greatly. This is likely to complicate the bargaining process[20]. Managers then are be able to create a "controlled" experiment in which they only change some aspects of the tasks in order to trace the effects of some specific re-arrangements of rights. Setting up a controlled experiment may be more difficult across boundaries of firms and in particular if there are high costs of specifying all the interdependent activities which may not be changed during the experiment. Finally, coordinating interdependent tasks within the boundaries of a firm may provide managers with a more complete picture of the nature of interdependencies -an information which is not only important in relation to eliminating bottlenecks, but also in relation to avoiding problems of uneven development of components by setting up interface standards and other more permanent solutions.

C. Other factors influencing the "Costs of Discovering the Relevant Prices"

In the previous section I mention uncertainty and complexity as synonymous whit high costs of discovering the relevant prices. There may be many other reasons why there are high costs of discovering the relevant prices (or the true opportunity costs of rights) and some of these reasons may become more predominant with increased specialization in production. Different contractual theories of firms put emphasis on various cost of transacting –ranging from measurement costs, contract costs and costs of enforcing rights over assets– in explaining the emergence and boundaries of firms. This section provides a brief overview of some of the various arguments presented in the literature.

First, I should like to point out that, transaction costs need not require firms to solve coordination problems. For example, high measurement costs may make it costly to

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[20] In this connection wage contracts may be an efficient way of sharing risks from experimenting.

determining the valued characteristics of assets and this may cause problems of excess sorting, and of shirking on quality. Managed direction of assets is probably not the most effective mean of solving these kind of problem. Other arrangements such as product guarantees, quality classes and investment in brand name capital seem to be better suited.

However, specialization in production may create other kinds of problems related to high measurements costs. One of the advantages of specialization between production and consumption is the ability to take advantage of economies of scale in equipment. In order to realize such advantages, many individuals may have to cooperate in order to operate the equipment. If tasks are not perfectly specified in terms of each individual's rights to use different attributes of the equipment or if such rights cannot be enforced, it is possible that each individual will exercise discretion and try to gain at the expense of others.

If, for example, it is difficult to determine how much the operation of each individual contributes to the wear and tear of the equipment there is a problem of common property and this imply that there is likely to be insufficient incentives for investments in maintenance[21]. Therefore according to Barzel (1989), "[a]ttributes susceptible to serious common-property problems, such as equipment lubrication, will tend to be owned by organizations created to control these problems" (p.58).

One way of controlling such problems, which involves an organization, is to use a fixed wage contract in which workers are remunerated for their time rather than their output. But workers receiving specific income for a specific amount of time have no incentives to devise ways of exercising user rights over assets which would generate utility. Therefore, if fixed wage contracts are used monitoring of effort will be needed to induce effort. Moreover, with fixed wages workers are not likely to have incentives to identify the tasks needed for an effective operation of equipment. Managers therefore also need to specify the tasks to be performed (Barzel, 1989).

Specialization in production create a similar problem if there is high costs of determining the level of effort in the labor services provided by individuals. In particular, where co-operation is needed between different individuals in order to realize rents on their labor

[21] As explained by Barzel (1989) the common property problem disappear if the equipment is scaled down to fit a single operator producing an identifiable output. Some mean of coordinating individual operators is still needed but with each producing an identifiable output contracting in market may provide the coordination.

services from producing a given output, problems of common property may occur. This is because each individual is able to exercise discretion in providing his labor services but only bears part of the costs.

The solution to such team problems is to set up an organization which will economize on metering costs so as to better allocate rewards in accord with the effort delivered (Alchian and Demsetz, 1972)[22]. A monitor specializing[23] in metering effort and holding rights to residual income, to alter membership of the team and to sell all their rights may provide such a solution.

A second type of explanation of why firms exist, emphasizes how high information costs or uncertainty makes it difficult to enforce one's rights over assets (e.g. Williamson (1975, 1985), Klein, Crawford, and Alchian (1978) and Hart (1991,1995)). According to this literature, there is a strong correlation between asset specificity and contracting failure, and this results in inefficiencies because valuable transactions involving investments in transaction specific assets is not completed. In particular it is assumed that high costs of planning for all various contingencies, of describing future states and of communicating these plans to a third party makes it impossible to write complete contracts so that one can safeguard one's investments in specific assets with the aid of a third party (a court typically).

Specialization in production may make investments in specialized equipment and in specialized knowledge which have no alternative value outside a particular relation attractive. According to the incomplete contract theories, undertaking such investments require vertical integration, so that firms can take on the role of enforcer of contracts. Willliamson, for example, describes firms as their own ultimate court of appeal. To Hart, firms are defined by the physical assets over which an legitimate owner has formal residual

[22] According to Alchian and Demsetz (1972) team production is production in which " 1) several types of resources are used and 2) the product is not a sum of separable outputs of each cooperating resource. An additional factor creates a team organization problem- not all resources used in team production belong to one person" (p.779) . The separate ownership over resource is motivated by such factors as risk aversion, the prohibition of slavery and sunk costs investments which make short term ownership to costly. However, the separation of ownership could also have been motivated by the possibility of realizing advantages of specialization in accumulating different complementary skills of production.

[23] Monitoring denotes "..measure output performance, apportioning rewards, observing the input behavior of inputs as means of detecting or estimating their marginal productivity and giving assignments or instruction in what to do and how to do it" (Alchian and Demsetz, 1972,p. 782). However, the reason for the latter kind of activity is left unexplained.

user rights. Having residual user rights over assets provides the firm with a mean of enforcing contracts which would not be possible if transactions took place between owners of assets. [24]

These different explanations of firms have in common the idea that the best uses of resources *is* already known. The problem is "simply" how to provide the right incentives for efficient exploitation of or investment in the assets in question. Monitoring and more advanced incentive schemes than those that can be devised for re-contracting between independent individuals (with definite time horizons) help overcome such problems, but direction by order is not a central element in the solution and the possibilities of learning in coordination is limited to improving ones skills as a monitor. [25]

Each of the above explanations of firms provide important insights into factors that influence the boundaries of firms but they do not give any account of why the boundaries may changes over time. In the next section, I argue that opportunities for specialization advantages together with continuos learning in coordination within the boundaries of firms provides opportunities for continuos changes in the boundary of firms.

V. Make or Buy Decisions:

Taking Advantage of Specialization

Coase (1937) emphasized the comparison of the costs of organizing transactions within a firm. This approach explains why firms come into existence and why market and firms co-exists in a specialized economy.

[24] To Coase, the relation between asset specificity and vertical integration is not quiet as clear cut as presented in the incomplete contract theory. As Coase (1991) explains ""Even so, the conclusion they draw from this assumption,[that with increasing assets specificity and costs of contracting increase more than cost of vertical integration] if not in error, is I believe, misleading. What decides whether vertical integration or a long-term contract represents the more efficient solution depends on the absolute relation of the costs of these alternative arrangements. Even though the costs of contracting increases more than the costs of vertical integration as assets become more specific and quasi rents increase. Vertical integration will not displace the long-term contracts unless the costs of contracting become greater than the costs of vertical integration- and this might never happen for any value of quasi rents actually found". (p.70).

[25] Agency theory, a body of literature to which Alchian and Demsetz (1978) belong, ascribes all contracting costs to the costs of observing variables. Even though important aspects of the rights over which one is contracting cannot be observed this may not create high costs of writing a contract.

After having established a reason for the existence of firms, Coase goes on to apply transaction costs analysis to determine the boundaries of firms. Coase argues that there are increasing costs to organizing more transaction within a firm and that this explains why not all transactions are carried out in one big firm. [26] When increasing marginal costs of management leave room for other firms to come into existence, different subsets of production tasks will be organized in different firms. [27] Coase (1937) did not investigate the factors that would make the costs of organizing a particular subset of tasks lower for some firms than for others. However, such and analysis is important to make or buy decisions since these kinds of decisions are seldom a question of either firm or open market transactions, but of organizing a subset of production tasks within one firm rather than another firm. In fact, Coase (1991) argues that "..if one is to explain the institutional structure of production in the system as a whole it is necessary to uncover the reasons why the costs of organizing particular activities differs among firms" (p.73). and these costs according to Coase "may depend on the other activities that the firms are undertaking (p.67).

A more in-depth understanding of why firms differ with respect to their costs of organizing different activities is important to the analysis of the make or buy decisions of firms. If firms are not equally good at coordinating the same types of tasks, this should influence the boundaries of firms. The arguments presented in section IV B suggests that learning by doing in production and coordination results in different abilities and thus different costs among firms with respect to organize different kinds of tasks. Make or Buy decisions of firms must reflect these endogenous changes in production and coordination costs as individuals learn in production and coordination.

From the arguments presented in section IV. C, it seem likely that the importance of learning in coordination depends on the extent and complexity of technological interdependencies in production activities. If specialization creates strong technological interdependencies, there

[26] Coase (1937) mentions tree factors which may effect marginal costs of organizing more transactions within a firm.. These are; decreasing return to the entrepreneur function as more tasks are organized within a firm; increasing opportunity cost due to the failure of entrepreneurs to make the best use of the factor of production and finally, a rise in the price of one or more of the factor of production because " other advantages of a small firm are greater than those of a large firm" (p23.).

[27] According to Coase (1937) a vertical specialization between two firms persists as long as costs of transacting between firms do not exceeds the costs of bringing the entire set of tasks organized by the suppliers within the purview of a firm thus eliminating all market exchange.

may be advantages from learning in coordination which favor organization within the boundaries of firms, at least until sufficient experimentation have resulted in the delineation of specific rights in manners which deals with these interdependencies.[28]

The costs of organizing the interdependent tasks of course also needs to be considered when deciding on make or buy. These costs consists in increasing marginal management costs and bygone opportunities for taking advantage of further specialization until coordination costs with the already obtained degrees of specialization have been reduced. Since accumulation of experience in coordination is often local and not transferable (except maybe at high cots) firms tend to persistently differ in their capabilities and this may explain a certain path dependency in the kind of activities firms undertake. In other words, it may be difficult for firms to buy the services they produce in house cheaper from suppliers.

Accumulation of experience in coordination may explain some of the cost differences between firms but this may not be the entire explanation. A different reason may be found in the fact that there are also advantages of specializing in knowledge. Managers in firms then may posses different scientific and technological knowledge and therefore have different abilities to perform experiments in coordination .

This explanation is in line with Demsetz (1991) who also argues that firms are not be perfect substitutes in production of goods and services. According to Demsetz firms are specialized production entities each holding a different subset of the production knowledge needed to produce a consumption good. For specialization in knowledge be productive, specialists needs to be able to take advantage of other specialists' knowledge. Within firms coordination between specialists with different kinds of knowledge is achieved by giving orders and following Demsetz this is efficient because otherwise each specialist would have to learn what all other specialists already know. The boundary of firms is shaped by the relative costs and advantages of putting specialized knowledge to use by means of orders or

[28] Socially developed norms, rules and routines also reduce costs of coordination. Norms and routines make the behavior of others more predictable thus reducing the need for information required to coordinate actions (Heiner 1983). In the terminology of property rights, norms and routines can be said to act as self-enforcing constraints on user rights. Such norms and routines certainly also play a great role in determining the costs of coordination in different firms and the decision to make rather than to buy may often be grounded on superior, non-imitable and non transferable routines which aids coordination in production. Norms and routines are not confined to firms, they may as well evolve as means of coordinating actions between independent individuals or individuals in different firms. In that case they also reduce costs of market transactions.

by means of selling goods accompanied by instruction on uses. The latter is advantageous when the best use of an asset does not strongly depend on it being used at a particular time and place.

Giving orders and producing goods embodying specialized knowledge is thus two different way of economizing with the costs of transferring knowledge. This explanation indicates that a decision to make or buy must also depend on the trade-off between taking advantage of low costs experimentation within the boundaries of a firm and taking advantage of specialized knowledge located in other firms.

VI. Conclusion

I have argued that learning in coordination within firms must be centered on ways of discovering the relevant opportunity costs of assets where prices would either fail to provide the proper information or where bargaining is particular costly to complete.

There are many reasons why price information either fails to indicate the true opportunity cost of assets or why bargaining is costly, but I have focused on one in particular – the increasing interdependence among various tasks which follows from increased specialization in tasks. I have argued that a high degree of interdependence may make it impossible for managers *ex ante* to specify rights over assets and labor in such a way that that each sub-task fits optimally to all other tasks carried out.

For example, the problem of defining an optimal sequence of task in a complex systems of production may require more calculation capacity than is available in a supercomputer (Galloway, 1996)[29]. In such cases improvements in allocation of rights require experimentation in the sequencing of tasks which in turn require sequential re-delineation and reallocation of specific user rights among those carrying out the various tasks. Managed coordination is likely to be less costly relative to arm-length bargaining partly because order-taking saves bargaining costs, partly because some specialized technological

[29] In describing the problem of scheduling batches in a 5 stage production process, Galloway (1996) writes "[t]he best schedule is the one which minimizes this idle time. Unfortunately, the only way to find the best schedule is by trail and error, and whit 20 batches there are $1.8x10^{18}$ possible schedules. This problem is too large even for modern computers, so a simplifying assumption is frequently used (p.64).

knowledge may be required in order to discover the opportunity costs (or shadow prices) of various subdivisions of tasks and the respective allocation of rights.

Specialization in production influence the boundaries of firms by creating opportunities for economic gains for learning in coordination of technological interdependencies. However, since there are increasing marginal costs of coordinating more specialized tasks within the boundaries of a firm it may sometime be advantageous to out-source interdependent tasks in order to take advantage of further specialization in other tasks. Finally, the knowledge acquired in experimenting with coordination together with advantages of specialization in scientific and technical knowledge may explain the relative advantages of firms in organizing some particular tasks and these advantages must also be taken into account in the make and buy decision.

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Danish **R**esearch **U**nit for **I**ndustrial **D**ynamics

The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the ressource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human ressources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

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