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How Firm Organizations Adapt to Secure a Sustained Knowledge Transfer

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abstract

New knowledge with potential commercial value is created, replicated, and transferred in a distributed manner. The highly systemic nature of knowledge production and the need for any knowledge to be individually acquired and expressed in order to produce an effect, jointly constrain the dynamics of knowledge commercialization. This paper analyzes the nature of these constraints from an individualistic perspective, focusing particularly on the often neglected entrepreneurial aspects of the knowledge transfer. It explains how the constraints are overcome by organizational adaptations inside firms so that a sustained knowledge transfer into the commercial sphere of the innovation system can be secured.

JEL code: D23, D83, J24, M13, M51, O31, O40

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I. Introduction

When new technological developments become feasible, economic institutions and organizations often have to adapt in order to secure the exploitation of the emerging opportunities. Technology and institutions thus co-evolve in an incessant sequence of innovations and adaptations. The major driving force behind this co-evolution – the growth of human knowledge (see Mokyr 1990, 2002) – also forges the systematic changes in the technology and institutional set-up of producing, transferring, and utilizing knowledge itself. To draw attention to this fact was a major motive underlying the literature on national and regional innovation systems (Lundvall 1992, Nelson 1993, Edquist 1995, Metcalfe and Miles 2000, Antonelli 2001, cf. also Nelson 1998 and Nelson and Sampat 2001). Indeed, the technology by which knowledge can be acquired, stored, processed, used, and communicated has been, and still is, subject to dramatic changes. These changes become apparent, in particular, in an individualistic perspective on the conditions of individual knowledge acquisition. The changes also feed back on, and set the stage for, the transfer of knowledge beyond the institutional boundary between publicly financed research and the commercial sphere.

It is well established now that commercial firms can profit from such a transfer by creating cost-saving processes and/or new or improved products and services, provided they are able to engage in the transfer with a sufficient “absorptive capacity” (Cohen and Levinthal 1989). In an individualistic perspective, this capacity has to be supplied by agents who are capable of performing the function of technological gate-keepers or transfer agent or, in many cases, both functions simultaneously. However, an absorptive capacity is not enough. Scientific and technological knowledge does not suggest by itself the business opportunities by which it becomes commercially valuable. There must be some agents who imagine them and take action to obtain the resources for their realization. This is an often overlooked, genuinely entrepreneurial input (Witt 1998, Shane 2000) that is essential for the knowledge transfer.

In this paper it will be argued, that the entrepreneurial input is also decisive for understanding the organizational form of the knowledge transfer and for how it is adapted to the changing knowledge technology. Depending on the kind of knowledge to be transferred there is a variety of organizational forms that can be classified along the convenient “make-or-buy” distinction in transaction cost economics. However, which one obtains is determined not only by transaction costs differences between them. The choice of the one or other organizational form also hinges on differences inherent to the prevailing knowledge technology.

To a significant extent the knowledge transfer is based on the migration of scientists and engineers from non-commercial research to the commercial sphere. The organizational form of this particular transfer results, we will claim, from a competitive sorting process of the migrating researchers. They can try to realize their own imaginings of business opportunities implied by the knowledge they carry – in which case they become entrepreneurs themselves, often as founders of technology-based start-up firms. Or migrating researchers can contribute to realizing business opportunities developed by large firms by doing R&D there – in which case they engage in an employment contract. In both cases, the peculiarities of this kind of embodied knowledge transfer imply problems for sustaining the transfer. The problems differ between (usually rather small) start-up firms and large incumbent firms with R&D departments. Yet, they call for organizational adaptations in both cases – adaptations that differ in the two cases and that can give the large firms a comparative advantage in sustaining the knowledge transfer.

The paper proceeds as follows. In Section II we elaborate on the individualistic approach to the knowledge transfer problem. Some of the conditions that technological gate-keepers and transfer agents in the commercial sphere face, and that are crucial for understanding the terms of the knowledge transfer in which they are involved, will be highlighted in the form of stylized facts derived from the prevailing knowledge technology. Section III explains what the entrepreneurial input to the knowledge transfer is and in which way a competitive entrepreneurial sorting process determines the organizational form in which embodied knowledge migrating from the non-commercial to the commercial sphere is integrated in the commercial sphere. Section IV turns to the question of how continuing scientific and technological progress affects the transfer of embodied knowledge. The focus will be on organizational adaptations by which firms try to uphold a sustained knowledge transfer. Section V concludes.

II. Knowledge Technology and Knowledge Transfer – Some Stylized Facts

To better grasp the conditions under which knowledge is transferred today, a brief characterization of the now prevailing knowledge technology is helpful. Since the introduction of the printing press as a “hardware” innovation that revolutionized the encoding and storing of knowledge, encoded knowledge can be diffused and accessed massively in parallel. Moreover, encoded knowledge can be stored on a large-scale basis outside human memory and, thus, independent of its limited life time. Access to, and acquisition of, encoded knowledge is no longer bound to the limitations of face-to-face communication and personally given advice provided, of course, the user commands sufficient interpretative knowledge and skills.

At the “software” level, the path-breaking innovations have been the epistemic structuring of the knowledge under the influence of the Enlightenment (Mokyr 2002, Chap. 2) and the emergence of systematic sciences and their institutionalization as “open science” (David 1998). Since they were put in place, knowledge production and organization has been systematized at large. Powerful epistemic methods are now available for categorizing, ordering, and connecting in a systematic way the vast amount of newly generated single pieces of encoded information in taxonomies and theories. Since the introduction of the computer technology and the internet the administering of storage and retrieval of encoded knowledge can be automatized (outside the human brain) by means of symbolic manipulations. As a result, the access to, and diffusion of, encoded knowledge has now advanced to a level where it is virtually omnipresent (Weinberger 2007).

It is no overstatement when it is claimed that the rise of this powerful knowledge technology is a major reason for the strong acceleration that has occurred over the last few centuries in the growth of human knowledge (de Solla Price 1963, Chap. 1, Birdzell and Rosenberg 1986, Ziman 2000). In an individualistic perspective it is important to note, however, what did *not* change, viz. the necessity of acquiring, processing, interpreting, and expressing stored knowledge by the human mind and the limitations that follow from this fact. To become productive – and economically relevant – encoded knowledge has to be given an expression in some action. Stored knowledge as such does not produce any effect. Where technical ways have been found to program knowledge into tools, machinery, and automata, it can be deployed with less participation of a human mind (expressing only some user knowledge) or no participation at all. However, deployment and re-use cannot express anything else but what has been programmed by a knowledgeable mind before. This constrains the deployment and re-use of knowledge through tools and automata to standardized, routine tasks.

For tackling the non-standardized tasks in science and technology, the expression of stored knowledge by the medium of the individual human mind is still indispensable. It requires that the corresponding knowledge is acquired anew by each generation in the first place. Given the limited cognitive capacity of the mind and the nature of the learning process, this is a comparatively costly procedure in terms of effort and time. As a consequence – this is a variant of the well known bounded rationality hypothesis (see Conlisk 1996) – the amount of knowledge that can both be acquired and expressed by single agents per unit of time is, relatively speaking, narrowly bounded. By training and supporting information technology the individual bounds can be expanded, but they cannot be removed.

With an accelerating growth of the body of human knowledge this means that the knowledge processing capacity even of the most capable agents falls short of keeping track of all newly emerging knowledge. Technical progress in hardware and software of storing knowledge notwithstanding, all agents are forced to confine themselves to acquiring, holding, and using only limited parts of the growing body of knowledge. A natural tendency then is to take advantage of the benefits of specialization and to specialize, where possible, in the individual knowledge acquired, held, and used. The specialization patterns follow criteria inherent in the epistemic context of the particular objects of knowledge. In science and technology the epistemic context is usually a disciplinary one. Someone specializing, for instance, in molecular biology can ignore developments in astrophysics or mechanics, say. A reasonable knowledge base in chemistry and the practical use of laboratory instruments is, however, indispensable. Similarly, someone specializing in accounting can ignore the tenets of new growth theory, but hardly the latest developments in auditing practices, say, or in book keeping software.

In all fields of specialization there is a trade-off between the amount of disciplinary knowledge one can acquire and the time needed for this. Even though the history of science and technology is marked by an increasing subdivision of disciplinary specialization, the overall growth of the body of scientific and technological knowledge has led to an increase in the time requirements for education and training that are necessary to acquire the working knowledge relevant for a disciplinary domain.¹ There is little, if any, doubt that the body of scientific and technological knowledge will continue to grow. What the growth of knowledge has meant, and is likely to also imply in the future, for the terms of the knowledge transfer from the non-commercial sphere to the commercial sphere can be described as follows.

Stylized fact (i):

Scientists and trained engineers engaged in technological gate-keeping and transferring knowledge from non-commercial research to commercial users are growing in numbers and are on average ever more specialized in the individual knowledge they have acquired (Pavitt 1998).

A second stylized fact – also resulting from the outlined changes in knowledge technology and the accelerating growth of knowledge – relates to some peculiarities of individual knowledge acquisition regarding tacit and overt knowledge. Tacitness is a technological feature

¹ See Jones (2005). With the formalization of education and training that accompanied the disciplinary specialization, a sufficient expertise of the disciplinary state-of-the-art is now supposed to be given when student graduate as scientists or engineers after roughly two decades of education and training in schools and universities – a time span coming close to the average life expectancy of our early ancestors.

of knowledge that is related to its encodability. Tacit knowledge is ill-defined, cannot completely be articulated, and, for this reason, cannot be codified, at least not at with the prevailing knowledge technology.

As a consequence, tacit knowledge has to be acquired through own trial-and-error learning by each agent anew. It has to be in individual memory and is therefore largely inaccessible to others agents. (Advice by, and/or the observation of, others using their tacit knowledge may, of course, ease the learning process.) In contrast, knowledge that is codified qualifies as overt knowledge provided access is not restricted by technical or legal means. To the extent to which it is accessible, codified knowledge can be commanded by all agents with a sufficient capacity to interpret its meaning.²

For the transfer of knowledge, the distinction between overt and tacit knowledge is particularly significant where it correlates with the difference between two kinds of knowledge that are generated and used in scientific and technological research. This is propositional on the one hand and procedural knowledge on the other. Propositional knowledge deals with theoretical and empirical findings and technical construction principles. Its production is typically pursued with the intention to publish the results, i.e. to encode the generated knowledge and make it publicly available. Accordingly, to the extent to which it has already been encoded, this kind of scientific and technological knowledge is overt. It can be acquired by anyone without any personal interaction with those who originally created and disclosed it.

With procedural knowledge this is different. It typically deals with the

- socially shared, inarticulate standards, research strategies, and problem-framing assumptions specific to the epistemic culture of the disciplinary field (Knorr-Cetina 1999);
- contextual know how of conceptualizing and solving problems analytically by reducing complexity (Brusoni, Marsili and Salter 2005);
- practical operation of the physical infrastructure of the research process (e.g. the handling experimental set-ups, lab-specific equipment, and instrumentation, see Zellner 2003);
- topic-tailored software programming, simulation designs, etc.; procedural knowledge like this is expressed in the analytical and practical skills of mastering the “technicalities”.

Since it is difficult, if not impossible, to (completely) encode procedural knowledge, it is largely tacit. It is acquired by doing research in communities of practice usually in non-commercial research activities (Kurz-Milke, Nersessian, and Newstetter 2004), where the interaction with other researchers and the opportunity of observational learning ease its absorption. The daily scientific work involves the different kinds of knowledge in varying proportions. For example, an agent who needs to work with a new laboratory equipment can extract a large part of knowledge on how to use the equipment from the manual, i.e. a codified knowledge part. Additional, often more specific, knowledge about the equipment can be obtained by asking others who have already collected experiences with it. (This additional user knowledge could, in principle, be encoded, if there were incentives to do so.) Finally, by working with the equipment on the job, the agents may acquire an own user know how, e.g., with respect to handling the equipment. It allows the agent to run down a learning curve in operating the

² Because of differences in accessibility and the extent of codification, the degree of overtness may vary and approach tacitness as a limiting case. For a detailed discussion of the various forms of knowledge see Witt, Broedel and Brenner (2007). The present interpretation of tacit knowledge accords with Polanyi (1966, Chap.1). For slightly different interpretations cp. Cowan and Foray (1997), Saviotti (1998), Cowan, David and Foray (2000).

equipment. The latter kind of know how cannot be articulated and, hence, is tacit, non-codifiable knowledge.

With regard to the terms of the knowledge transfer the following can be stated.

Stylized fact (ii):

For most of the experimental sciences like, e.g. molecular biology, chemistry, material sciences, a significant share of the state-of-the-art scientific and technological knowledge is procedural knowledge of analytical and domain-specific skills. It can only be acquired while doing research in communities of practice usually in non-commercial research activities (Martin and Irvine 1981, Salter and Martin 2001, Zellner 2003).

For firms whose technology relies on a knowledge transfer from these disciplines, a sufficient command of that procedural knowledge is therefore a substantial precondition for their absorptive capacity. However, there are peculiarities here that need to be accounted for in some way to by appropriate organizational measures. It is expressed by

Stylized fact (iii):

Procedural knowledge that is individually acquired and continuously up-dated by agents while actively involved in non-commercial research activities sooner or later suffers a debasement effect when these agents migrate to commercial firms and lose their personal grip on the developments at the research frontier (Rothman and Perrucci 1970, Machlup 1984, Chap. 19).

In the individualistic perspective taken here, the firms' absorptive capacity that allows them to tap and commercially use scientific and technological knowledge is based on the service of people who have acquired and can express the corresponding knowledge in the first place. However, as will be discussed in the next section, the identification of commercial potential of that kind of knowledge is not an act of science or engineering, but a genuinely entrepreneurial act. It is based on an entrepreneurial input that is equally important for understanding the specific conditions of the transfer of embodied knowledge and the organizational arrangements taken to secure the transfer.

III. Entrepreneurial Conceptions and the Organizational Form the Knowledge Transfer

While the body of human knowledge continuously expands, human information processing capacity remains limited. The rapidly growing body of knowledge therefore needs to be acquired and expressed by each new generation on the basis of an increasing individual specialization and an increasing number of specialists (stylized fact (i)). This fact implies an increasing inter-personal division of knowledge and skills whose flip side is a contextual and personal fragmentation of scientific and technological knowledge. It is this implication that creates a new, and genuinely entrepreneurial, challenge: specialized individual knowledge resources need to be made available where their specializations are demanded, e.g., for productive purposes. This

³ The effect is the more rapidly occurring the more rapidly the disciplinary technicalities of cutting edge research advance. Propositional knowledge can be subject to a similar debasement effect. Yet, the open access makes its up-dating independent of an active involvement in research, so that the effect can be compensated where necessary by keeping up with the current publications.

allocation problem is solved by market transactions, but to carry out such transactions requires the involved parties first to develop some conception of what they want to accomplish. Thus, contracting knowledge resources presupposes a conception of what to do with them. The potentially commercially valuable applications of the contracted expertise must at least vaguely be envisioned.

Scientific and technological knowledge does not by itself suggest the new business opportunities. There must be some agents who imagine them, e.g. in the form of improved production method and/or new products that (better) serve customer needs (Witt 1998, Shane 2000). Furthermore, the imaginings of new business opportunities need to be translated into concrete, commercially viable activities by which the resources required for the venture are identified, contracted, coordinated, and motivated to perform. All these prerequisites for allocating knowledge resources are genuinely entrepreneurial accomplishments, i.e. activities by which production and trade are restructured and, ultimately, new products and services are made available.⁴ Without the envisioning of business conceptions by entrepreneurial agents, and without the organizational manifestations of these conceptions in the form of business ventures and firm organizations, no commercial exploitation of new technological knowledge would occur. The agents who provide the entrepreneurial inputs may be specialists in the relevant knowledge domains, e.g. when engineers or scientists become entrepreneurs. However, this is not a general prerequisite for an entrepreneurial exploitation of scientific and technological knowledge. It suffices that those who pursue a technology-based business conception know enough to decide what technological expertise is needed and where to contract it. (In fact, this is a common situation in large corporations when managers in entrepreneurial positions are no longer experts in the respective knowledge domain.)

If some particular scientific or technological knowledge is envisioned or conjectured to offer opportunities for new or improved processes, goods, or services, this knowledge needs to be made available in detail. From an organizational perspective, an existing firm can secure the availability by internal sourcing (“make”) or by external sourcing (“buy”). Which of the two strategies, or what mix of them, is chosen is, of course, part of the entrepreneurial business conception. In the first case, engineers and/or other scientifically trained staff need to be contracted who have previously acquired and are capable of expressing their specialized knowledge on the job in tackling little or non-standardized tasks (Song, Almeida and Wu 2003). Typically, the contractual arrangement by which the availability of these internal resources is secured are employment contracts. In the external sourcing case, in contrast, the corresponding knowledge resources can be made available through contract research or contracted consulting services, research alliances, licensing, franchise takings, or even the acquisition of entire companies commanding the desired know how.⁵

⁴ The question of how this is achieved is at the core of the recent debate on knowledge-based entrepreneurship cf. Witt and Zellner (2007). Like in the classical definition of Penrose (1959, p. 32), entrepreneurial inputs (services) will be interpreted here as being distinct from “...managerial services which relate to the execution of entrepreneurial ideas and proposals and to the supervision of existing operations.” However, both entrepreneurial and managerial services may be provided by one and the same person, be it the entrepreneur(s) and/or paid manager(s).

⁵ For an empirical estimate of the shares of internal and external sourcing for the Canadian Industry see Rosa, Rose and Mohnen (2006). In transferring knowledge, “make” and “buy” are not necessarily mutually exclusive options. A firm that creates an internal source of knowledge and then uses

As is well known from transaction cost theory, to avoid or reduce contractual hazard is an important motive influencing the make-or-buy decision. It is relevant in the context of knowledge transfer, for example with regard to the principal-agent problems involved in consulting contracts and contract research. The yet unknown results of the application of expert knowledge on the tasks defined by the firm as the principal do not allow to establish a clear relationship between the observable outcome and the agent's non-observable effort. Furthermore, consulting contracts, contract research, and an engagement in research alliances involves contractual hazards with intellectual property rights, particularly where patenting is not possible and newly developed applications therefore have to be protected by secrecy. Problems like these provide a standard cause for integrating the corresponding knowledge resources in the firm (sometimes by acquiring a whole company commanding the desired know how).

Conversely, a conventional cause for vertical disintegration may lie in economies of scale resulting from re-using specific, customer-tailored knowledge applications where this does not conflict with confidentiality requirements or intellectual property rights (see Langlois 1999). For example, in the consulting business the commercial application of new knowledge may result in the ready-made solution to the specific problems of a client. If the development costs are high and the knowledge-application or some part of it can be re-used for solving the same or similar problems in other places, the vertical disintegration of this service is straight forward. The re-use results in costs that are substantially lower than those of the generic problem solution which each of the clients would have to incur if they were to produce the generic solution in house. Something similar holds for research alliances, licensing arrangements, and franchise takings.

Yet, there are also reasons for acquiring relevant knowledge either from internal or external sources that follow from the characteristics of the prevailing knowledge technology and the conditions of the knowledge transfer discussed in the previous section. An example is the decision to source technological knowledge externally in a pre-packaged form, viz. by buying intermediate products or machinery, instruments, and other equipments that embody such knowledge. Knowledge can be programmed into equipments so that it is expressed in a standardized way upon their use (usually implicitly by producing a certain desired effect). Examples of such 'intelligent' equipments are computer software, micro chips, bio-engineered reactants, computer-controlled machine tools, advanced diagnostic instruments, etc. The crucial point is that the users does not have to acquire the knowledge that has been programmed into the equipments by their developers. All that is required is usually only a rather limited know how concerning the handling of the equipment. Like in the cases of consulting contracts, contract research, research alliances, licensing arrangements, and franchise takings, this is a means of economizing on intra-organizational knowledge resources. Often it may be the only way of getting along with the limited knowledge and skills of the labor force a firm can afford to pay.

Another example for how the peculiarities of the prevailing knowledge technology influence the make-or-buy decision is the relatively more costly strategy of building up an in-house knowledge source. It creates a capability for scanning, screening, and tapping the scientific and technological developments ongoing elsewhere. Unlike in the case of standardized tasks for

it to make relevant scientific and technological knowledge applicable can nonetheless buy additional knowledge via markets. There is some evidence for such a complementarity, particularly where a firm's industrial R&D heavily depends on the result of non-commercial basic research (Cassiman and Veugelers 2006).

which equipment with inbuilt knowledge can be bought, these tasks involve non-standardized problem solving and therefore require hiring staff with an extended training and education in the corresponding discipline as scientists or engineers. What is particularly important for the choice of the organizational form of the knowledge transfer in that context is the difference between propositional knowledge and procedural knowledge.

Since most of the propositional knowledge is published, it is publicly accessible by all interested parties provided they command a sufficient absorptive capacity to interpret context and meaning of the published information.⁶ Not so for procedural knowledge. It is because of this difference that the stylized facts (ii) and (iii) – the significant role played in the experimental sciences by procedural knowledge and its potential debasement – become hard constraints for the entrepreneurial organization of the knowledge transfer. As explained, procedural knowledge is individually acquired as tacit knowledge by doing non-commercial research in communities of practice in a costly and time intensive way that usually not influenced by profitability considerations. The only way of transferring it across the institutional boundary between publicly funded research and firm-based commercial R&D is to induce scientists and engineers who carry the relevant knowledge to migrate from academia to business.

The employment of scientifically trained staff may thus be claimed to be essential for commercial R&D not only to keep up a suitable “absorptive capacity” for propositional knowledge. It also represents the way by which to get a hold of tacit state-of-the-art procedural knowledge that cannot otherwise be transferred. However, stylized fact (iii) – the potential debasement effect individually acquired procedural knowledge – poses a problem, if the boundary between the academic and the commercial sphere is not equally permeable in both directions. This peculiarity of the transfer of embodied procedural knowledge calls for specific organizational adaptations to be made to secure the availability of the corresponding knowledge resources. Before discussing them in detail, it is useful first to clarify in the individualistic perspective adopted here how scientists and engineers who are about to leave publicly funded research activities can be motivated to enter the firm. As will turn out, the answer to this question provides a key for understanding how the knowledge transfer through researchers migrating from publicly funded research to the commercial sphere is organized.

To answer the question, a thorough grasp of the entrepreneurial basis of the knowledge transfer is required. Consider again the initial imaginings of business opportunities potentially implied by new knowledge that have to precede any attempt to undertake a venture. Such imaginings can be developed by many agents, but only a small fraction of them will ever be turned into a real business venture for which the necessary resources are activated. How is it decided which of the imaginings are realized? As has been argued elsewhere (Witt and Zellner 2007), the decision is implicitly made in a competitive self-sorting process of precisely those researcher about to migrate. They either decide to pursue their own business conception and found an own knowledge-based start-up business. Or they sign an employment contract with existing firms that offer them a (non-entrepreneurial) staff position, often in R&D, as catalysts of the knowledge transfer. Such an offer is, of course, based on the expectation that the future employee is ready to subscribe to, and act on, the entrepreneurial business conception pursued

⁶ For commercial applications it is important, in addition, that the business potential of the published new knowledge can be assessed and its compatibility with the firm’s already existing capabilities can be appraised (Rosenberg 1990).

by the hiring firm. This usually means that it is not the imaginings of the migrating researcher of how to commercialize the relevant knowledge that are realized.

Obviously, the question of who sorts into what role – self-employed or employed – hinges on subjective expectations that are influenced by many factors.⁷ As an entrepreneur, a migrating scientist would have to tackle the tasks of attracting resources and coordinating their interactions in a way that is conducive to realizing the own business conception. The self-assessment with respect to the own coordination skills is therefore likely to play a role as are the expectations concerning the profitability of the own business conception. The income stream that is imagined to be retained after paying the hired resources has to be put in perspective with the income stream to be earned by accepting an employee's position in someone else's firm. The same holds for the expected workloads and the non-pecuniary features of the two alternatives.

Implicit to the self-sorting process, entrepreneurial imaginings of new business opportunities are thus subjected to a contest long before the markets evaluate those that are indeed realized. Given the complexity of the sorting decision and the initial lack of experience, the outcome of the contest, the resulting self-sorting, is not necessarily stable. On the one side, entrepreneurial business conceptions pursued in a start-up firm may turn out to be flawed. If, as a consequence, the firm goes out of business, its founder is back on the labor market. On the other side, a former scientist or engineer who has become an employee may later find out that her or his own imaginings of business opportunities are more promising than originally thought. If she or he lacks the possibility to realize them within the employing firm, she or he may leave the firm and set up a spin-off enterprise (see Klepper 1997).

IV. Organizational Adaptations to the Knowledge Transfer – Start-ups, Career Tracks and Other Tales

With respect to the organizational form in which scientific and technological knowledge is transferred to commercial use, both outcomes of the sorting process discussed in the previous section result in an internal sourcing of knowledge, i.e. an in-house making available of the corresponding

knowledge. In the start-up case, it is the founding scientist-entrepreneur herself or himself who applies the knowledge she or he has acquired to develop innovative commercial processes, products, or services. In the case of scientists and engineers hired into existing firms, the knowledge they transfer usually contributes to ongoing activities of product and process development inside the hiring firms, often in R&D departments. However, where the knowledge basis of a business firm is characterized by the stylized facts (ii) and (iii) a sustained knowledge transfer faces problems that may become critical over time and may then necessitate significant organizational adaptations. As will be explained now, the constraints differ in the case of start-up firms from those incumbent firms face, and so do the observable organizational adaptations.

In the case of a start-up firm that successfully establishes itself in the market, the problem related to sustaining a transfer of procedural knowledge is the following. The longer such a firm

⁷ See, e.g., Stuart and Ding (2006). If an option to continue academic research exists that, in the eyes of the researchers, is attractive enough, it is, of course, unlikely that they migrate at all to the commercial sector.

stays in business, the more likely progress in relevant scientific research in the publicly funded sector will generate new opportunities for improving processes and products or creating new ones. The firm could take advantage of the progress provided its absorptive capacity suffices to scan, screen, and tap the relevant developments. Indeed, making use of these new opportunities may even be necessary to keep up with competitors and defend the own market position. As long as the newly emerging knowledge is accessible in the form of propositional knowledge, the start-up founder may be able to achieve the transfer by virtue of the capabilities acquired earlier as scientist or engineer. The same hold in case of procedural knowledge that is not subject to a debasement effect. Therefore even comparatively small business ventures do not necessarily have a disadvantage in keeping up with technological developments and in exploiting new commercial opportunities, if they are run by former scientists or engineers.

This is different where stylized fact (iii) is the relevant. Former researchers who have turned into start-up entrepreneurs with what was the state-of-the-art procedural knowledge when they left non-commercial research are confronted with a potential debasement of their knowledge. Being cut off from the further development of procedural knowledge, they may be unable to up-date by themselves their products, processes, and services. In order to prevent the debasement of their own knowledge from undermining their competitiveness in innovative markets they would have to find ways of getting hold of the most recent brand of procedural knowledge, i.e. of attracting migrating scientists or engineers who embody that knowledge.⁸ However, to try to attract such knowledge resources means participating as a potential employer in the contest in which another generation of researchers migrating from academic institutions sort themselves into entrepreneurs and employees. To prevail in the competitive process, a migrating researcher must be motivated to engage in an employment contract instead of becoming an entrepreneur in her or his own venture. Moreover, this has to be accomplished by out-competing also the employment offers that large firm organizations capable of supporting an own R&D division can make (Sørensen 2004).

The particular challenge here is that in experimental sciences in which the debasement effect is significant, migrating researchers are likely to anticipate the effect. Accordingly, they can be expected to pay attention to the question of how long the own, embodied knowledge will be valued when they become either self-employed or are hired into an existing firm. Future employers may be assessed not least by the opportunities they can offer for earning an income after the debasement effect has taken place. Given this anticipation, firms of a comparatively small size, like most maturing start-ups have it, face a dilemma. They may be able to meet the financial obligations implied by hiring own R&D staff to ensure the transfer of new procedural knowledge (though these are usually relatively large overhead costs that imply considerable risks for the profitability of the whole venture). But they are usually still too small to credibly offer migrating researcher a long-term employment perspective in house when their embodied knowledge has suffered a debasement effect.

As a possible organizational adaptation to this dilemma the firm founder can offer a partnership to scientists or engineers to attract them with a long term involvement in the firm. Yet, given the uncertainty about the actual value of the procedural knowledge to be transferred by the new partner such a solution may appear extremely risky. If there is no way to attract

⁸ Start-up firms, particularly those in science-based industries, often try to maintain links with the non-commercial institutions, sometimes by contracting consulting services or by project-based collaborations. Such efforts may compensate a debasement effect to a certain extent.

migrating scientists and engineers, a technology-based start-up firm would eventually be cut off from new procedural knowledge and fall back in its competitiveness in markets that are highly innovative. To avoid such a development may be a strong motive for the founding entrepreneur to consider mergers or acquisitions as a way out. By merging with, by acquiring, or by selling off the own business to, another firm, the size of the firm may be expanded so that the handicap of smallness with respect to the competition for migrating scientists and engineers may be overcome.

In view of the role the firm size plays for making organizational adaptations to the stylized fact (iii) it can be expected that large, incumbent firms have an advantage in compensating their employees for a knowledge debasement effect. On the other hand, in order to protect their specific organizational capabilities, privileged customer relations, and brand reputations that have been accumulated, a sustained transfer of the latest brand of procedural knowledge may be even more important for large incumbent firms than for more flexible start-up firms.⁹ In the attempt to secure such a sustained transfer of procedural knowledge the large firms face specific problems, as the hiring of one cohort of scientists and engineers coming from publicly funded scientific research is only a temporary solution. Even with considerable communication effort, it is, in most cases, not possible for that cohort to keep up with the cutting edge research progress in publicly funded research.

To compensate for that debasement effect, it is necessary to replace the earlier cohort by ever new cohorts of migrating scientists and engineers carrying the most recent brand of mostly tacit, procedural knowledge. Yet, unlike instruments, machinery and other equipment in which embodied knowledge becomes obsolete and that can simply be scrapped, R&D staff whose knowledge becomes obsolete cannot simply be laid off. Potential new migrants would be deterred from engaging in an employment contract when they would have to expect being laid off later. Thus, a dilemma of a different kind emerges here that calls for organizational adaptations to secure a sustained knowledge transfer. The solution that has been found are in-house career track options offered to scientifically trained R&D staff. By systematic human resources management career paths can be shaped that promote people from research and development to managerial occupations with comparable or even higher remuneration.¹⁰

Offering career track options allows the firm a turn over in R&D staff positions that suits the knowledge transfer while, at the same time, offering the newly entering scientists and engineers a long-term employment perspective. In addition, this organizational adaptation has the advantage of creating a high quality management resource with extensive in house experience. For the employees to make the transition from R&D to management in their career means a major change in working content. From manipulating objects or processes and solving

⁹ See Sørensen and Stuart (2000) and the evidence from business history e.g. in Galambos and Sewell (1995), McKelvey (1996), Murmann (2003), Buenstorf and Murmann (2003).

¹⁰ There is evidence that scientists in corporate R&D rate non-scientific managerial work very differently, and not overwhelmingly positively (Bowden 2000). However, the relatively flat hierarchies in corporate R&D rule out the possibility of “pure” R&D careers for a significant number of people employed there. To successfully pursue a career therefore usually requires making a transition into management position (Biddle and Roberts 1993, Bowden 2000). Independent of this, a career track leading from corporate R&D to managerial functions may also serve to compensate the phenomenon of individual productivity losses in doing research after a certain age, cf. Levin and Stephan (1991).

technical questions they have to move on to the coordination of other employees, to spotting of new business opportunities and the managing of their realization. To master that change a promoted employee needs to have both talent and motivation fitting the new tasks. This cannot always be expected. Employees differ in their abilities, their aspirations, their task responsiveness, their working attitudes, and, not least, their entrepreneurial talents. Since personal promotion is usually supposed to be contingent on the employee's demonstrated performance, there is time for an attempt to verify the employees' personal skills and abilities. The firm can identify and seek to deploy the entrepreneurial talent of employees who are scientifically trained and have gained a background in the technical capabilities and procedures of the firm.

Scientifically trained employees who, in moving beyond corporate R&D functions, show exceptional capabilities may eventually be given the responsibility for a subdivision of the firm organization where they get the opportunity to develop an own business conception and participate in the profits. Indeed, such an offer may be advisable to prevent entrepreneurially talented people from leaving the firm to start an own venture. It may well be that, when migrating from academia to the business sector, these people have underrated their entrepreneurial prospects and, for this reason, have become an employee of the firm. By gaining experience with their own skills, by learning about their firm's knowledge base, and by acquiring management capabilities they may arrive at a point where they are inclined to reconsider their original sorting decision. To prevent them quitting, the firm must find more highly valued position for these employees in the organization. To ensure that they can still be profitably employed, this usually are positions with some entrepreneurial responsibility higher up in the firm hierarchy— precisely what the notion of a career commonly stands for.

V. Conclusions

In the present paper an individualistic perspective on the prevailing knowledge technology has been suggested. It helps to understand the consequences of the unprecedented, continuing growth of knowledge that defines the terms of individual knowledge acquisition today. These terms, highlighted above by three stylized facts, also affect the way in which scientific and technological knowledge that is generated in publicly funded research can be transferred to the commercial sector. It has been argued that the particular features of knowledge to be transferred – overt propositional vs. tacit procedural knowledge – influence the choice of the organizational form of the sourcing of scientific and technological knowledge by business firms, internally (“make”) or externally (“buy”). The very identification of commercial potential of scientific and technological knowledge has, however, been claimed to be a genuinely entrepreneurial act that is not just an exercise on transferred scientific or technological knowledge. The entrepreneurial input and the conditions under which it is delivered are equally important for understanding the specific conditions of the transfer of embodied knowledge and the organizational arrangements taken to secure a sustained transfer.

New products, processes, or services can only emerge from scientific and technological knowledge, if there are agents who conceive of corresponding business opportunities and tries to realize them by attracting and coordinating the necessary resources. It can happen that this entrepreneurial input is provided by people who have specialized in relevant technological knowledge and are capable of giving it an expression in the form of a business conception themselves, e.g. engineers or scientists who (have) become entrepreneurs. Yet this particular

combination is the exception rather than the rule. It suffices that entrepreneurial agents who pursue a technology-based business conception know enough to decide what technological expertise is needed and where to contract it. Part of the entrepreneurial task is then to find and contract the fragmented knowledge resources necessary for realizing the development of commercial applications. Accordingly, two forms of organizing the transfer of scientific and technological knowledge have been discussed. One is represented by start-up firms founded by (former) scientists or engineers as entrepreneurs. The other is represented by large, incumbent firm organizations with specialized R&D staff.

Both forms compete for the knowledge resources needed to realize the development of commercial applications. The competition is latent and decided in a sorting process in which scientists and engineers who are about to migrate from academic research into the commercial sector sort themselves into who becomes entrepreneur and who employee. As has been explained, the transfer of new knowledge between publicly funded research and business firms is far from being trivial. Particularly in the case of procedural knowledge a debasement effect can occur that causes problems to both start-ups and large incumbent firms in securing a sustained knowledge transfer. However, the constraints start-up firms face in this respect differ from those large incumbent firms face. As a consequence very different organizational adaptations to the need of securing a sustained knowledge transfer can be observed. They can take the form of mergers and acquisitions in the case of maturing start-up firms and of the institutionalization of career track options in the case of large, incumbent firms.

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