STRATEGIC ORGANIZATION OF R&D

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Preliminary Motivation and Fit within the book:

There is an important opportunity in applying Economics of Organization to issues of innovation through connecting it to the extensive literature in Innovation Management. Such a dialogue between management and economics can provide a much needed "strategy perspective" to the issue of innovation. Where innovation management typically operates at the management level of the innovation process, economics will connect this to the strategy level assessing competitive advantage and performance of decisions related to the innovation process and activities. Unfortunately, very little literature exists in this area. In this chapter we propose a framework to think about the key issues in the strategic organization of R&D and innovation.

1. INTRODUCTION

Innovation has become an important driver of the sustainable competitive advantage of firms. While a particular innovation can improve the competitive positioning of the firm, the strategic question, however, is how to select the innovation strategy of the firm and how to organize the corresponding process of innovation in order to generate the innovations that will allow the firm to maintain its competitive advantage over time. The organization of innovation commits the firm to a particular innovation strategy and to a series of subsequent innovation activities depending on specific outcomes from the innovation process as uncertainties about the technology and the market get revealed. The innovation strategy of the firm will involve decisions on which product markets to be in and how to organize R&D to serve these different markets. In addition, different innovation activities will be deployed over time depending on the innovation strategy of the firm and particular outcomes of the innovation process.

In this chapter we focus on the organization of the innovation process and, in particular, we will focus on innovation using technology as opposed to innovation in a broader sense, such as finding new markets, new customers or new ways of doing business, while using the same core technology. We will, therefore, characterize innovation as a new product, a new process, or a new service to be introduced in a particular product market. Our starting point, hence, will be the product market where these innovations are sold to users. Innovation is then the result of matching key technological opportunities for which the firm is well placed to exploit them with market opportunities that the firm has been able to spot.

The key contribution of this chapter is that we distinguish between long term, i.e. strategic, decisions about the innovation strategy and the organization of the innovation process and subsequent short term tactical decision in the innovation process. Most of the existing literature on innovation actually situates itself in this latter category of more short run decisions, but provides an interesting input into thinking about the long term decisions about the innovation strategy of the firm.

In this chapter we take the opportunity to propose a 2 stage structure to think about the strategic organization of R&D. First, long run decisions at the firm level are committed to. Second, short run decisions affect how individual projects are organized and how the outcomes of these projects are exploited.

In the long run the firm has to make three key integration decisions:

1. Horizontal integration across product markets: which product markets will the firm compete in;
2. Horizontal integration across technological fields to be active in: which technologies are considered core to the firm;
3. Vertical integration between product market and technology fields

We consider two extreme cases for the innovation strategy: the firm has dedicated R&D for one particular market, and, R&D is independent from the markets. Interestingly, in these extreme cases the choice of the innovation strategy leads to either a technology push strategy in the former case or a demand pull strategy in the latter. Hence, we argue that these strategies arise endogenously through the choice of innovation strategy and corresponding organization of the innovation process.

The short run decision arises after the important technological and market uncertainties have been revealed. Our starting point depends on whether the firm needs an additional technology to realize its innovation strategy, or, on the contrary needs to decide how to exploit a developed technology. We show that the bulk of the literature on the organization of innovation can be understood from this perspective: *what I do with a technology that I have* or *where I get a technology that I need*.

2. STRATEGIC DECISIONS

Long Run Decisions

We view innovation as the match between technological opportunities and product market opportunities. As a heuristic device we think of technological and product market opportunities as specific, countable areas. (See Fig. 1) Thus, innovation is a choice of matching technology areas with product market opportunities. The match is not necessarily one-to-one. Specific product markets may benefit from many technologies at once, or a given technology may be applicable, with adaptation, to several product markets. As mentioned, the generality of the technology, the choice about which technological or product market areas will be occupied are part of the strategic decisions of the firm. In turn, these decisions are affected by the rents that the firm expects to capture. Thus, for example, as we shall see, these choices are affected by the size and homogeneity of the product market, which are related to competition in technology or in product markets, spillovers, and other factors affecting the appropriation of returns to innovation.

FIGURE 1 ABOUT HERE

We distinguish between long-term choices on the one hand and short-term choices in which the long-term factors are given on the other hand. In this respect, our approach hinges on the fact that a key long-term decision of the firm is to establish how much the strategic choices about technology are subordinate to the product market needs. By this we mean that decisions about the technological areas to target, the specific research projects to be carried out, and their goals are chosen according to the needs of developing, improving or innovating specific products within given product market. Simply put, it is the decision of how much the R&D function responds to product market functions and goals rather than being independent of them.

In turn, this decision depends on the size, nature and structure of the product market, which we consider exogenous to the problem. (SUTTON?). To clarify, we look at two extreme cases. The first case is a large homogenous product market, while the second one is fragmented in different sub-markets or niches. We then discuss the implications of these two extreme cases on the nature and type of R&D activities conducted by the firms. Finally, we highlight the impacts of three moderating factors: transaction costs in technology trade, incentives, and uncertainty in the new product markets that may arise in the future. Figure 2 offers a visual illustration of some of the key points that we discuss in the remainder of this section.

FIGURE 2 ABOUT HERE

2.1.1 Large Homogeneous Market

In this case, firms can capture rents by making large R&D investments in fixed costs dedicated to that market. The scale of the market justifies such dedicated fixed investments. In our context, this means large investments in R&D dedicated to the specific product market under considerations, or to put it in a different way, it justifies that product market managers demand R&D managers to focus on improvements or research specific to their products. The market is large enough to make the focus on the specific product goals profitable. But this means that the choice about the type of research to conduct and its goals are set by the product market goals.

NOTE: the strategic choice of the firm determines the “type” of research.

In this context, for the firm the value of more generic research will be lower. This is because a natural feature of more generic or basic research is its applicability across fields or product markets. However, in this case the firm will benefit less from such generic research than from dedicated research for the large product market. A standard analogy is flexible vs standardized machines in manufacturing. Typically, a dedicated machine produces a high value for the application for which it is conceived, but no value for other applications. A flexible machine produces lower value per application, but it can be applied at low additional cost to many applications. Thus, the total value increases as the number of applications increase. As Milgrom and Roberts (1991?) show the machining choice has important implications for other complementary firm decisions.

With large homogeneous product markets the value of keeping the potential for many applications is low compared to the cost of a less efficient tool or knowledge base for the specific application of the market. Moreover, the larger the dedicated market is, the more substantial is the advantage of a dedicated technology because of the possibility to spread the fixed cost on a large volume of specific output. Once again this naturally leads to R&D decisions geared to a large extent by the specific product market needs and goals. In short, R&D is largely a business unit R&D activity.

2.1.2 Fragmented Product Markets

The other extreme is a fragmented product market, in which products are differentiated and product market economies of scope among the sub-markets are small. Here, a dedicated technology is less effective because of the smaller size of each sub-market to which the technology will be applied. Our point is that in this case the firm will want to reduce the subordination of the R&D choices to the needs of specific product market goals. R&D

choices about projects to pursue, or development trajectories to undertake, will be more independent of individual product market needs because the size of the market of each product, and its potential rents, will not justify a dedication of R&D activities to the needs and goals of the individual product markets.

The firm's choice will then be to reduce the size of the business-unit R&D to the point that is justified by the corresponding size of the market. Yet, the firm also needs R&D independent of products to capture spillovers across product markets and technology-based economies of scope. In fact, if there are opportunities to capture such technology-based economies of scope or externalities, the firm will reallocate resources from the business-unit R&D to centralized R&D.

This also opens up an important new perspective. To the extent that the technological decisions become more independent of the specific product market needs, the need to control R&D through corporate governance within the same organization becomes less pronounced. There can be many reasons. First, the management of a subordinate relationships between two units is clearly more effectve when performed within the same organizational structure, which allows for hierarchical links between the parties. Second, the need for continuous interactions and flows of information between the units is facilitated by a common organizational background (Winter?). Third, as suggested by Aghion and Tirole (1994), there could be a moral hazard story. They show that when the value of the innovation depends mostly on the marginal value of the product market assets, there is no advantage in offering the property rights of the innovation to the research unit to enhance the researcher's or the innovator's incentives. In sum, all these arguments suggest that the business-unit R&D will always be under the control of the firm. The issue is then how big the investment in the business-unit R&D compared to the centralized R&D across products is. (Check also Dessein, Alonso, Rantakari etc on Organizational Design: allocation of decision rights coordination versus information)

If the R&D choices are more independent of the product market decisions, the need for corporate control is less stringent. To be sure, if the firm is diversified downstream, it may control upstream R&D because it can internalize the externalities that such a centralized R&D produces across product markets (Nelson, 1959; Penrose; Hounshell and Smith, 1988). But when R&D has an impact on several product markets, the boundaries on the spillovers that it can create for products controlled by the firm and other products in the market becomes blurred. Simply put, once the firm sets up an R&D department, and technologies, not targeted to specific product markets, it is hard to control for which product markets it may turn out to be useful. Thus, if the firm is large and diversified, the standard Nelsonian or Penrosian argument is that one is more likely to observe that a higher share of spillovers is internalized (see also Henderson and Cockburn?). But to the extent that one cannot fully control where the knowledge or technology can fall, the firm is bound to consider the possibility that it can enjoy rents by providing the technology to other potential users. Similarly, if other firms adopt this strategy, the firm may find opportunities to acquire the technology from others.

At the same time, there are factors that, given the independence of the R&D decisions with respect to the product decisions, encourage or discourage the independence of corporate control of R&D. As noted, a larger diversified firm is more likely to keep control, because it can internalize more externalities. Thus, for example, Rosenberg (1990) argued that larger firms are more likely to do basic research with their own money. But there are other factors as well that moderate the extent to which the independence of R&D decision with respect to product markets affect the extent of the corporate control on R&D.

2.1.3 Moderating Factors

We envisage in particular three factors that affect this decision on the locus of control of R&D.

Transaction Costs. The first one is transaction costs in technology trade, which can seriously hamper the exchange of technologies across organizations. Teece (1988) noted that R&D contracts can be seriously incomplete. More recently, (XX) showed that technology markets are still bounded by severe limitations, like asymmetric information, search costs, lack of valid enforcement of intellectual property rights (IPR) (see also …). Gans et al. (2002) for example showed that when IPR are weak, firms tend to integrate forward to embody their technologies in products. By contrast, when they are stronger, technology suppliers can appropriate value from selling their technologies. This suggests that when transaction costs are low, one may observe both large diversified firms investing in centralized R&D activities and vertical specialization processes. These processes can take many forms. On the one hand, specialized technology suppliers, such as in high-tech industries like biotech, semiconductors, and others, will find opportunities to sell their IP or to engage in alliances with partners that own the downstream assets. On the other hand, the large firms themselves may find that they can sell their technologies to users that operate in distant product markets, or even in product markets in which they do not operate. This encourages them to supply the technology because of the limited rent dissipation effect that this can produce on their own core business. It is interesting because for many years technology licensing by established companies stemmed largely from the fact that the technology was offered to companies in distant geographic markets, where the firm would not operate or where it was easier to extract rents by supplying the technology to producers better equipped to locate in that market. The similarity here is that the technology-holding firm offers the technology to firms that use it in areas in which the licensor does not operate downstream. Yet, rather than distant geographical markets we deal with distant markets in product space.

Transaction costs in technology trade have another implication for our discussion. When product markets are fragmented, but transaction costs in technology trade are high, firms will lower their investments in business-unit R&D because of the smaller scale of the individual product markets, but only the diversified firms will make sizable investments in the centralized and more basic R&D. Firms without a diversified basis of products will not have the opportunity to take advantage of the potential scope associated with their more basic investments in technology if the high transaction costs raise the barriers to selling the technology across organizations.

Thus, when product markets are large and homogenous we observe a comparatively higher share of business-unit dedicated R&D, subordinated to product market goals, vis-à-vis centralized and more basic R&D. When product markets are fragmented and transaction costs in technology trade are high, individual firms will lower their business-unit R&D investments, but only the diversified firms will raise in a sizable way their centralized R&D. Another way to see this is the following. If the fragmented product markets are occupied by different firms, and transaction costs in technology trade are high, then each firm will not invest in the centralized R&D because the benefits of this investment are only in limited part appropriated by the own products. At the same time, the difficulties in providing the technology to other product makers outside the organization dampens the opportunities to appropriate rents from those investments through the sale of technology or the set-up of alliances with such partners. Ultimately, this means that investments in R&D will be lower than in the previous case because the reduced business-unit R&D investments are not compensated by an increase in centralized R&D. (NOTE: relate to diversification decisions of firms, related to Silverman (1999)). By contrast, when product markets are fragmented and technology trade is feasible, this compensation occurs. As a result, we observe again sustained investments in R&D. However, compared to the world of large single markets there will be a higher share on more generic research vis-à-vis research driven by specific product market goals.

Interestingly, as we noted, a major limitation in the ability to gain value from technology trade is the lack of enforcement of IPR. Thus, stronger IPR may encourage vertical specialization in industries, with specialist firms selling technology to firms that operate downstream, as well as potential technology sales by established firms to companies operating in distant product markets. When product markets are fragmented, this may raise investments in centralized research, along with greater independence of the R&D decisions from the specificities of individual product markets.

Incentives. Our second moderating factor is incentives. It is well known that by making the research unit the residual claimant, its incentives to invest in research increase because they can appropriate part of the surplus that they help create. However, as Aghion and Tirole (1994) pointed out, the additional surplus that they create because of the greater effort that they exert given that they are offered profit-sharing incentives, ought to be higher than the disadvantage of the established firm when offering such incentives as opposed to fixed rewards. Simply put, the additional outcome produced by the research unit because of its additional effort has to be important because in this case there is room for both parties to gain. In this sense, incentives will reinforce the nature of the R&D process and its allocations between business-unit and centralized R&D produced by the structure of the downstream product markets.

When the product market is large and homogenous, the contribution of R&D is incremental and product-specific. Its subordination to the product goals suggests that incentives based on the possibility of claiming the residual surplus are less significant. In particular, because R&D is geared to the solution of specific problems, it is easier to monitor and to establish the extent of its contribution. Thus, researchers need not be motivated to a great extent via special contractual provisions that reveal their efforts. Moreover, they key source of rents in his case is the large downstream market, and therefore the incremental contribution of research may not be enhanced dramatically by offering special incentive provisions. Simply put, decentralized high-powered incentives may not raise surplus significantly in any case, and hence it may not be worth incurring the costs of a lower control that may arise when such incentives are put in place. All this is consistent with subordinate R&D to product market needs rather than autonomy and independence in R&D decision-making.

By contrast, more generic research requires such incentives. First and foremost, monitoring for more basic research is harder because it is more difficult to establish whether the activities carried out by the researchers are really geared towards useful outcomes for the firm or not. Second, with fragmented product markets the importance of centralized research increases. This is because the value of the downstream markets, which are now smaller, is lower. Economies are now mostly economies of scope in technology – or possibly in downstream assets – but definitely economies of scale at the level of the individual markets are less important. As a result, advances in the development of generic technologies can produce rewards and externalities in several markets, and they are now the main source of rents. In other words, benefits now arise because of the ability of the firm to gain returns by exploiting the breadth rather than the depth of the product market. If so, research becomes important, and following Aghion and Tirole (1994), the additional results produced by the research units when they are offered high-powered incentives can produce significant additional surplus to offset the loss of control.

To summarize, in our context we expect to see that incentives to the research units will be higher when product markets are fragmented and they are directed towards the generic research units. They will take the form of greater decentralization and performance-based rewards of the centralized research units in diversified corporations. In other words, researchers in these units will be rewarded on the basis of their final contributions, and these contributions may not be measured in terms of specific impacts on product market returns. For example, they may be based to a greater extent on the classical rewards of scientific or technological research. Thus, for example, patenting or publishing in scientific journals may be taken as a signal of performance. In turn, these represent natural incentives for the researchers that look less like established salaries irrespective of outputs. In short, not only are there incentive-based rewards, but the basis for such rewards will be factors that are relatively independent of product market results. These patterns will be even more apparent when the centralized research units will be independent firms in vertically specialized contexts. These companies are most often the outcome of entrepreneurial efforts where the researchers are the entrepreneurs themselves, and hence are by definition rewarded by the surplus that they create. Once again, the incentive system works consistently with the distinction between R&D decision-making that is independent vis-à-vis subordinate to product market goals. Note also the interplay with transaction costs above. Product market fragmentation is the key driver of whether high-powered incentives will be relevant or not in this context. Then, transaction costs in technology trade will shift between decentralized incentives within the large diversified firms or also through vertically specialized technology markets.

Uncertainty. Finally, the third moderating factor is uncertainty. There are two levels of uncertainties involved in the process that we are discussing here. The first level is about the technology. This can simply be characterized in terms of whether the technology will work or fail. The second level of uncertainty is about the future product markets, and particularly whether certain product markets will develop or not, or which is the same whether they will be large or small. In fact, in our discussion the first level of uncertainty is rather straightforward, and it is really the standard uncertainty about R&D or whether technological projects will be successful or not. Thus, we think that it is safe to leave it in the background of our analysis. By contrast, we see the second type of uncertainty more central for our discussion. In a nutshell, it is the fundamental uncertainty in R&D vs product-making, that is, whether R&D leads to the opening up of new interesting product markets or not.

The way we characterize the problem is the following. Ex-ante, the firm faces different potential product markets wherein the R&D projects that the firm is working upon can fall. The uncertainty is about which product market will eventually be the interesting one. Another way to see this is to think of a situation in which product markets are emerging, and the firm does not know whether they will succeed in the future or which one to bet upon, assuming that each of these markets may require some product-specific investments (e.g. in downstream assets) that creates some trade-off about whether to invest heavily in this market early enough or not.

One way to think about this problem is on the basis of the following trade-off highlighted for instance by Giarratana (2008). When facing different potential markets firms may decide either to enter early or late. The advantage of entering early is that if the market is eventually successful the firm enjoys first mover advantages, and it can move down the learning curve, thus gaining systematic advantages upon competitors who entered later. The disadvantage of entering early is that the firm runs the risk of making upfront investments that will eventually be lost if the market does not develop. The trade-off for late entrants is that they will not enjoy early learning advantages. However, they can eventually invest in the market that has actually developed, and thus limit the risk of early sunk costs. Giarratana (2008) then suggests that firms with good assets that enable them to recover learning advantages even if they move late, will of course enter late, because in this case they enjoy the advantages of a late move and can limit the disadvantages of this strategy. By contrast, firms without such capabilities will enter relatively early, as their main opportunities is to capture early rents. As suggested by Giarratana, this may reflect the different strategies of larger and smaller firms. The former typically own valid downstream assets in a market that enable them to attain leading positions even if they enter late. By contrast, smaller high-tech firms enjoy most of the advantages by entering early. Compared to a larger firm they have lower sunk costs and hence lower costs of failing. Moreover, they do not have the same ability as the larger firms to recoup positions if they enter late. Thus, to the extent that they see a chance of entering, they will be more likely to enter early. (See also Christensen).

To be sure the situation just described can be seen as one in which the product market is fragmented, but while in the previous situation the fragmentation was characterized by a set of existing markets, now the fragmentation is about a set of potential markets, of which only one or few may eventually grow. Similar mechanisms however apply. When firms face such an uncertainty about the potential markets that will develop they will move to a centralized R&D perspective, as this allows for keeping opportunities open in several potential markets. The independence between R&D and product markets will again work consistently towards decentralized incentives and targets that are defined more in terms of research intermediate outputs than specific economic returns associated with particular product performance or features. At the same time, transaction costs in technology trade affect the extent to which centralized R&D activities are performed only within diversified firms or also through vertically specialized technology suppliers. As noted, this also affects the volume of R&D investments as the lack of opportunities for the independent suppliers will cut an important source of research investments to compensate the relatively lower business-unit R&D activities.

However, one most interesting feature about the role of uncertainty in our context is the dynamic implication about the growth of some future market. Once one or more of the emerging markets proves to be successful, it grows and this will put the firms that invested in that market in the same position as the firms that in our earlier discussion were facing a large and well defined product market. These firms will now turn their R&D from centralized to product specific, as the larger market now justifies such a come-back towards business-unit R&D.

Interestingly, this has implications on incentives that again mimic our earlier discussion. As business-unit R&D becomes more important, and market size becomes the crucial source of rents, residual-right incentives will become relatively less important and leave room to more equalized systems of rewards. Similarly, if transaction costs are high, the shift towards business-unit R&D simply regards a reallocation of resources from the centralized R&D division to R&D divisions close to products. Thus, the key feature of this process will be internal restructuring of the R&D activities of the firm. If transaction costs in technology trade were low, this ought to produce in principle failures of vertically specialized technology-based firms. Another possibility is that these firms will try to tap other opportunities by levering their generic research capabilities. In other words, they can become the source of growth of other potential markets, provided that technological opportunities remain high.

There are good examples of these processes. For instance, Google made its fortune on innovation efforts highly independent of specific product markets when it started. This lead to pioneering the search engine software market and internet software more generally. Yet, recently, there is evidence that Google is moving toward more product-specific innovation activities. For example, many highly innovative engineers seem to be leaving, and the firm is refocusing towards its core skills, which is large scale computer programming (Forbes, 2007). Similarly, in several high-tech sectors start-up have thrived since the industries and related technological opportunities were high. But once product markets have settled, many of these firms failed. Only some of them however have been able to contribute to the opening up of new markets. The rising nanotechnology field provides many examples of these processes whereby the decay of previously rising trajectories have reshuffled R&D towards product-specific activities, while leaving the seeds for the rise of new opportunities.

Finally, this discussion provides us with an interesting perspective about technology-push and demand-pull factors. The perspective of the large homogenous market is typically demand-pull. In these cases, it is the market that drives R&D, and R&D is subordinate to the product market goals. By contrast, in the fragmented product market world, the detachment of R&D from the product markets, which includes independence of incentives, goals, and means of assessing returns and researcher's rewards, implies that there will be production of redundant knowledge and outcomes that is redundant with respect to the existing products. But such a redundant knowledge may (or may not) produce new opportunities via a classical technology-push route. In this respect, our view of the strategic organization of R&D may enable us to overcome the classical dichotomy of demand-pull versus technology-push and cast the discussion in a perspective where they are both part of a common underlying structure. In our view, the structure of the downstream market is then the primitive factor that can initiate such different processes.

3. TACTICAL DECISIONS IN ORGANIZING INNOVATION

As we specified up front, we consider innovations that need technology as an input. In the short run we are interested in how the firm can organize access to the required inputs to realize its innovation strategy. The vertical distinction between technology as an input to innovation enables us not to force the technology to be produced by the firm that actually commercializes the innovation. Depending on the outcome of the innovation process, the technology can be made or bought, or the firm can produce technology and sell it to firms that commercialize the innovation. Thus, we observe several cases of how innovation is realized in the short run: 1) firm fully integrates production of technology and commercializes the innovation; 2) firm produces some technology components, buy others, and commercializes the innovation; 3) firm produces one or more technology components and sells it or the whole technology to firms commercializing the innovation; 4) firm commercializes the innovation and buys all the technology. The long run choice of the firm on the strategic organization of its R&D will determine the likelihood of observing one of these outcomes. In addition, this choice determines if this is outcome is deliberate or the result of failure in the innovation process. A technology specialist on the one hand will sell its technology as part of its strategy of appropriating returns to its innovations. On the other hand, a firms dedicated to a particular market will sell technologies that have been generated but cannot be usefully applied to this dominant market. Similarly, it would be less likely to observe a technology specialist buying technology on the market, while buying technology might form part of the innovation strategy of a firm with a dedicated market.

The short run decision will then be influenced by the following factors: 1) macro-environment: this is macro factors that affects whether the opportunity that the firm is facing will be growing or not after the short-run decision was taken (e.g. growth of markets); 2) competitive environment: again factors affecting the opportunity above, and yet here the firm has to understand whether it will be able to compete and the dynamics of this competition; 3) resources of the firm: this is the outcome of the long-run decision which is fixed in the short run, and clearly affects the short-run benefits and costs of the firm in doing the actions above (including both ability to take advantage of macro-opportunities, or to face competitive environment) include here the importance of complementarities; 4) management: the ability of the management of the company to anticipate the likelyhood of different opportunities, which then affects the benefits of the actions (again both including macro opportunities and competition).

3.1 Firm has the technology: what to do with it

To understand the strategic decision of the firms that hold a technology whether they want to offer it to other parties – via licenses, spinoffs, alliances or else – a natural question to start with is the classical one raised by Teece (1986) – viz. how do firms profit from innovation? Here one has to distinguish between exclusive and non-exclusive licensing. Exclusive licensing implies a complete loss of control by the licensor, whereas non-exclusive licensing may not have the same implication. Moreover, with non-exclusive licensing, the nature of the product market competition, between different licensees, and between licensees and the licensor also becomes salient.

Teece's classical approach is that a firm holding a technology or an innovation can profit from it two ways: i) by embedding the technology in a final product; or ii) by selling it. Teece (1986) then argues that two factors affect the decision of firms between i) and ii): the appropriability regime and the control of the downstream assets

The first factor was discussed in the previous section. A well functioning system of IPR reduces the transaction costs because the property rights are well defined. As noted by Gans et al. (2002) it also encourages the firms to trade their technologies as opposed to integrating forward. Weak IPR imply that the main alternative by which the firms can secure some returns from the innovation is to embody it in products. By contrast, well defined IPR imply that they can profit from the innovation by selling the technology or the idea.

The other dimension – viz. the control of downstream assets – is a key factor in the decision to supply the technology externally. Firms with downstream assets need to feed them in order to utilize the capacity, which is a primary reason for embodying the technology in the downstream operations of the company. For this very reason, Teece also argues that the technology and the downstream assets are made to fit one another. Simply put, the firm will produce a technology that best fits its use with the type of downstream assets that the firm owns and vice versa. In short, the upstream and downstream assets of the firm are *co-specialized*. Thus, a firm with downstream assets will use the technology internally both because in this way it feeds the use of its downstream resources and capabilities, and because the technology is deliberately developed to best fit these resources and capabilities. NOTE: the Teece argument also works for the BUY side, complement your downstream assets.

Arora and Fosfuri (2003) highlight another important dimension related to Teece's argument which is salient for *non-exclusive licensing*. They emphasize that once the technology is offered to external parties it creates competitors. Thus, firms with downstream assets have to compare the *revenue from supplying the technology* with the *rent-dissipation effect* created by the fact that this produces additional competitors to the firm in its downstream market, or it makes a competitor more efficient.

A key element of their discussion is then whether the rent dissipation from creating competitors is high. In this respect, they conclude that two factors are important. First, whether the downstream operations of the firm are large (sales, assets) – this is because a firm with, say, larger sales, has more to lose, other things being equal, from the entry or the higher efficiency of a competitor. Second, whether the firm has some resource advantage that makes its profits high and that can be eroded considerably when the technology is offered externally. Simply put, a firm with large profits has more to loose than a firm with few profits once a close competitor is created.

Gambardella and Giarratana (2008) build on Arora and Fosfuri (2003) and emphasize another dimension of the downstream markets, viz. their fragmentation compared to the generality of the technology. In Arora and Fosfuri's model the technology can only be offered to partners who can use it to produce the same product. Essentially, the technology supplier offers it to a competitor that employs it in the same sub-market.

The novelty introduced by Gambardella and Giarratana (2008) is two-fold. First, the technology can be general in the sense that it can be used for different applications from the point of view of its final uses in the product markets. Second, the product market is fragmented, in the sense that it is composed of different product market niches or sub-markets. This means that if a firm holds a general technology, and the market is fragmented in relatively separate segments, the firm can sell its technology to producers who can use it in other sub-markets. Thus, even if the technology-holding firm is operating in a given sub-market, the fact that the technology can be employed in other sub-markets reduces the rent-dissipation effect because of the limited impact of competition in relatively distant domain, which is the perspective argued earlier in this chapter.

However, because of the different impacts of the technology supply strategies according to the involvement of the firm in the downstream markets, it is useful to distinguish between firms that also operate in the downstream markets and firms that do not. In the former case any strategy of diffusing the firm's technology – e.g., licensing, spinoffs – has to be assessed against its impact on the profits of the firms in the downstream markets. Moreover, since on many occasions the downstream operations of the firms are more important in terms of sales, assets, or profits, than their upstream operations (e.g., think of a manufacturing firm), the impacts of technology supply on the downstream activities of the technology-holding firm can be quite substantial, and hence they require a good deal of attention.

Technology specialists. We start with the technology specialists firms. They have no or limited activities in the downstream markets. There are many examples of these types of firms in high-tech industries since the 1980s – e.g., biotech R&D-specialist firms, fabless or chipless firms in semiconductors, software specialist firms.

Key to discussing the behavior of the technology specialist firms is our distinction between dedicated and general technologies. This distinction explains some relevant aspects of the technology strategies of the technology specialist firms. Suppose that a technology is dedicated to a particular market or application, or even to the particular product of a final manufacturer. In this case, the rents of the technology supplier cannot be higher than the value added created by the combination of the supplier's technology with the assets of the downstream firms. As a result, the rents accruing to the supplier depend on his bargaining power. The higher the price of the technology, the lower the share of value added of the integrated chain accruing to the buyer, and vice versa.

Since most technology specialist firms are small, and most downstream buyers are relatively large manufacturing firms (e.g. in licensing or in technology alliances), the bargaining power of the latter is likely to be significant, and the rents of the technology suppliers can be squeezed severely. Even if the technology specialist has a unique technology, the buyer is likely to ask for an exclusive license or relationship. This is because the technology is dedicated, and therefore if offered to other firms it can only be supplied to direct competitors of the buyer in the final market. Once the buyer obtains exclusivity, the supplier can only hope to gain as many rents as his bargaining power in this particular trade enables him to make. The supplier could still put more potential buyers in competition before offering the exclusive deal. But typically, the size and market power of the buyer firms make it hard for him to turn a significant portion of the bargaining power in his favor.

By contrast, suppose that the technology specialist owns a generic technology that can be employed in different sub-markets. What is crucial for our purposes is that it can be used in markets in which the final producers are affected very mildly, and possibly not at all, by the fact that it is also offered to firms in other sub-markets. Figure 3 summarizes our discussion on this point.

FIGURE 3 ABOUT HERE

With a generic technology the rents of the technology supplier depend largely on his ability to find new uses and new buyers for the technology. His bargaining power with the individual buyers is relatively less important because as long as the supplier finds new buyers, rents accumulate through the breadth of the market rather than its depth (i.e., its value chain).

In this respect, generic technologies free the supplier from the constraint that his rents depend on his bargaining power, which he can control modestly as it depends on the structure of the industry and the strengths of the buyer firms. Generic technologies allow him to link his rents to his ability to find new uses and buyers of his technology, which depends much more on his efforts, strategies and resources. To summarize, technology specialists with no downstream operations can raise their profits by investing in:

a) making their technology more general in order to cover more applications;

b) searching for new uses, through alliances or other deals with downstream firms in different final markets to test and possibly co-develop applications.

Moreover, in this case, the buyers are less likely to push for exclusive deals, as they realize that the technology will be offered to users in distant markets. If anything, they may ask for exclusivity in an industry or sub-market, but not in others, pretty much like firms ask for exclusivity in a geographic region of their interest, but not worldwide.

[We can provide specific examples of all this]

Established firms. The technology supply strategies of the established firms have to be assessed against their impact on the downstream operations. First, supplying their technology to the market can favor competitors in the product business. Second, technology supply may not be aimed just at obtaining revenues. Established firms have complex goals and operations. They may license to create standards, or cross-license, or they have other goals (e.g., Lichtenthaler, 2007).

Thus, some natural consequences of the fact that the established firms have downstream operations are that:

a) they are less likely to supply their technology compared to the technology specialists;

b) if there are technological opportunities, especially in nearby sectors that can be served with their downstream assets, they are likely to invest in developing the technology internally rather than offering it to others.

The evidence provided in Gambardella et al. (2007) is consistent with these statements. While 18% of the patents in the PatVal-EU sample are offered for licensing, only 11% are actually licensed. In addition:

i) the large firms (more than 250 employees) are willing to license 16% of their patents, and only license 9%;

ii) the small firms (fewer than 100 employees) are willing to license 37% of their patents, and only license 16%

This suggests that the large firms are willing to license fewer patents, and they license a smaller shares of the patents that they are willing to license. The former point is consistent with the fact that they have the resources to develop the patents internally. The latter point suggests that the technologies that they offer for licensing are selected among those that they are not interested in developing internally. Cassiman and Ueda (2006) show that this effect might also be driving spinoff behavior of firms.

Gambardella et al. (2007) also find that the patents that are not licensed, in spite of the willingness of the owner to license them, are not different, according to several characteristics, to the patents that are actually licensed. This suggests that transaction costs, rather than low value and limited demand, is the main factor responsible for the lack of licensing.

However, this result was obtained after controlling for the firm type, and particularly for whether the patent holder was a large or small firm. In this respect, the large-firm's failure to license may well be brought about by the relatively lower value of the patents that these firms offer for licensing. Yet, once the different propensity to licensing of small and large firms is controlled for, the patents for which there is willingness to license but that are not licensed are not less valuable than those that are licensed. In other words, transaction costs are responsible for the failure of licensing after controlling for whether the patent applicant is a large or small firm.

Also, the absolute number of patents offered for licensing by the large firms is not trivial. Seventy-one percent of the patents in the PatVal-EU dataset are assigned to a large firm (more than 250 employees) vis-à-vis 14% to small firms (fewer than 100 employees). Thus, 9% of a large number of patents (those of the large firms) is a sizable number, and so is the 16% of patents that the large firms are willing to license. In short, the patents licensed by the large firms, or that the large firms are willing to license, are far more than those licensed by the small firms. Thus, in absolute terms, the large firms are a significant reservoir of patents that are available for licensing or that the large firms are willing to license, in spite of their lower propensity to license.

More generally, there is evidence that the large firms are licensing more technologies (both in and out) than in the past decade. In addition, there has been a notable increase in corporate venturing. Established firms typically create spinoffs for technologies that are not in their core business or that are not of direct interest to them. They can be technologies in nearby sectors, or at a too early stage to make substantial internal investments in their development and commercialization. Yet, because they exhibit some potential, or they may be interesting after some initial developments, they do not want to loose their control on them. The promotion of spinoffs is a way to achieve these goals. Chesborough (2003) provides a detailed account of this strategy in the case of Xerox. NOTE: Klepper, Cassiman and Veugelers (2006).

Thus, to summarize, unlike the smaller technology specialists, which lack the downstream assets and may have strong incentives to sell their best technology to enjoy licensing rents, the established firms are less likely to sell their crown jewels. However, not only they license more than in the past, but they also adopt articulated strategies of external supply of their technologies. Of course, individual firms differ in the nature and the extent of these strategies. Some firms have become active in both buying and selling their technologies, while others are still more conservative. However, a general difference compared to the technology specialists is that the established firms do not license or externalize technologies that, because of their control of downstream assets, they could profitably develop internally.

To be sure, this is the classical perspective about licensing activities or more generally about the technology supply of the established firms. These firms do not give out their technologies if this jeopardizes their position in the product markets or if the firm can profitably develop and commercialize the technology by itself. Historically this has meant that licensing was primarily international licensing and that technology-holding firms used to license their technologies to geographically separated markets that they could not reach because of the lack of downstream assets to operate in them (e.g., Contractor, 1981). The chemical and pharmaceutical industries, as well as many others, have been classical examples (e.g. Arora and Rosenberg, 1998; Winders, 1995).

Today, the generality of the technologies and their pervasiveness may also partially explain why the established companies supply their technologies to distant uses that cannot be reached by the downstream assets of the established firm. Simply put, even for large firms, the scope of the technologies that they hold can be greater than the scope of their downstream capabilities, as suggested for instance by Gambardella and Torrisi (1998). At least some, and perhaps, much, of the licensing by established firms is the result of investments in research (rather than development), often taken in response to the arrival of significant technical and scientific advances. These advances lead established firms to invest internally in new technical and scientific areas, resulting in discoveries and ideas that the firm cannot internally exploit (e.g., Nelson, 1959).

Gambardella and Giarratana (2008) provide some examples. In the 1990s, Eastman Kodak re-oriented its R&D strategy. It abandoned its traditional chemical research for photographic films and papers, and invested heavily in the technological knowledge that it desperately needed to be a credible competitor in the new digital photo era. This meant catching up with the leading firms in computer hardware and software, semiconductors, and electronics, which could themselves move in the photographic business by exploiting the rising technology convergence. As part of this new strategy, Kodak developed several basic technologies in wireless technology, nanotechnology and other fields. It used some of these technologies internally for its own businesses, but it also licensed or created spinoffs for several other applications.

Thus, some firms like Kodak are actively exploiting the opportunities triggered by their search for radical technologies to obtain new sources of rents as technology suppliers. Gambardella and Giarratana (2008) show that other firms are not as active as technology suppliers. They focus on developing the technology that is important for their specific business. These firms, e.g., Shell, create spinoffs or license other technologies, but this is not pursued with the same persistence and intensity of firms like Kodak. Yet, even for these firms technology supply may play an important role. Technology markets are secondary markets for the by-product inventions that naturally arise from the search for radical innovations. As long as firms can profit or make better use of these by-products, they internalize to a greater extent the outcomes of more fundamental research meant to regain solid control of the basic technologies of the firm's business.

3.2 Firm needs the technology

On the flip side of owning a technology and facing the tactical decision of what to do with it is the short run issue of needing a technology and facing the tactical decision of how to get it. As in the previous section, the likelihood of facing this decision will depend on the strategic decision of the firm on how to organize its R&D strategy. Large established firms will act differently than technology specialists. There exists a lot less knowledge on the demand side of technology markets.

In addition to doing own research and development, firms typically tap knowledge sources external to the firm through various forms such as licensing, contracting out R&D, acquisitions of other firms and attracting qualified researchers embodying relevant knowledge

(Arora and Gambardella, 1994; Cockburn and Henderson, 1998; Granstrand et al., 1992). Furthermore, they can cooperate actively in R&D with other firms and research organizations and/or attempt to absorb existing technology without any explicit involvement or permission from the innovator. Cassiman (2008) finds that 72% of innovation active firms engage in some form of external technology acquisition.

While most of the early theoretical literature has focused on the choice between different innovation activities as substitutes, particularly the technology make or buy decision, the joint occurrence of these innovation activities at the firm level is suggestive of complementarity between these activities. By now, a growing empirical literature has documented the complementarity between technology make and buy (Cassiman & Veugelers (2006), Belderbos et al. (2004), Arora & Gambardella (1994), CHECK Parmigiani SMJ). Own internal know-how will increase the marginal return to external knowledge acquisition strategies. First, as argued by Arora and Gambardella (1994), performing internal R&D allows the firm to scan the environment and screen the different technological options better because of an improved understanding of the basic technology and knowledge. This in turn improves the innovation performance of firms combining both innovation activities as better knowledge is accessed and developed. Second, as mentioned earlier, external technology is more easily integrated into the innovation process given the absorptive capacity that internal R&D activities provide (Cohen and Levinthal, 1989). Many firms engage in this kind of "research tourism," but the ones with own R&D operations are better capable of capitalizing on the available external knowledge and spillovers. Finally, external technology increases the efficiency of the internal R&D activities because the complementary knowledge outside the boundaries of the firm already exists and transferring this knowledge is less costly than developing it from scratch. For example, several companies such as Eli Lilly, Boeing, Dupont or Procter & Gamble post technology queries on Innocentive, a web-based site with access to more than 75 000 scientists world wide. These external scientists can propose solutions to these specific queries and win an award. However, without internal R&D capabilities it would be hard for these companies to post, evaluate and screen proposed solutions, and then integrate them into their own innovation process to effectively leverage this external knowledge source.

Relatively few studies have focused on other parts of the innovation strategy. Belderbos et al. (2004) examine the substitute versus complementary relationship between various types of cooperative agreements. Arora & Gambardella (1990) examine the complementarity among four different external sourcing strategies of large chemical and pharmaceutical firms in biotechnology (agreements with other firms, with universities, investments in NTBFs and acquisitions of NTBFs). They find evidence for the joint occurrence of all types of external sourcing strategies, even after correcting for a set of firm characteristics.

In the economics literature, technology acquisition is typically of the disembodied kind, through licensing (in case of "off the shelf" technologies) or R&D contracting (in case the know-how still needs to be developed). Building further on the general literature on make or buy decisions, i.e. transaction cost economics (Williamson, 1985) and property rights theory (Grossman & Hart, 1986), the theoretical framework to explain disembodied acquisition stresses the advantage of tapping existing often more specialized knowledge if available. This leads to time gains and lower innovation costs, at least if the market for disembodied technologies is sufficiently developed. However disembodied acquisition may create considerable transaction costs, ex ante in terms of search and negotiation costs and ex post to enforce contracts. The typical uncertain nature of R&D projects exacerbates these transaction costs. Hence, disembodied acquisition is more likely to occur for generic, non-firm specific, already sufficiently standardized know-how (Mowery & Rosenberg, 1989).

Beyond disembodied technology acquisition, external know-how can also be accessed, without any explicit involvement from the sending party (Arrow (1962)). The channels through which such "spillovers" occur are many, ranging from informal communications networks, meetings, input suppliers and customers, patent applications, reverse engineering, and mobility of researchers. By now an extensive theoretical literature in Industrial Organization has developed around the effects of such spillovers on the incentives for investment in R&D, shedding further light on the relationship between technology Buy and Make. Whether spillovers and own R&D will act as substitutes or complements, depends on the competition regime, the need for absorptive capacity and the strength of the appropriability regime (see De Bondt (1997) for a review). Cassiman and Veugelers (2002) argue that these spillovers are not exogenous though. Firms can invest in better access, increasing the incoming spillovers (Buy), but at the same time also invest in better protection from outgoing spillovers. This increases the likelihood of the firm engaging in cooperative agreements with different players in the value chain.

The technology management literature further clarifies the drivers of the choice between technology buy and make. It emphasizes as advantages of external sourcing the option to get quick access to technological know-how, which is important when the firm lacks familiarity with, or competence in, the new market/technology. At the same time this already indicates a major roadblock to external sourcing, namely matching the existing technological capabilities of the receiving firm with the transmission capacity of the source. Chatterji (1996) pinpoints as a general problem in external sourcing strategies an insufficient "post-agreement" management and commitment to the external sourcing strategy. To overcome the extra costs of external sourcing, an organizational structure that builds in absorptive capacity and is able to overcome the classic "not invented here" syndrome, is an important asset. Allen (1977) suggests the use of technological gatekeepers to improve the external sourcing strategy, as a way of bridging the gap between internal and external environment. Furthermore, Arora (1996) shows that licensing with contracts of knowledge transfers can be constructed to give parties the correct incentives. CHECK

Beyond the choice between make & buy, the technology management literature also discusses the choice among the various external sourcing modes. When choosing the mode of external sourcing, ranging from acquisition to majority-minority holdings to networking and short-term contracting, firms have to trade off commitment and control versus flexibility (Roberts & Berry (1985)). More flexible modes are more attractive for ill-defined, embryonic technology with a high level of risk for which the company is unfamiliar, while higher control/ownership modes are more important when appropriation is weak, assets specialized and the technology is highly relevant for sustaining a competitive advantage.

In addition and as discussed before, the appropriability regime will influence the selection of the external innovation activity (Teece, 1986). When appropriability is high, firms are willing to sell their technology to other firms to appropriate the benefits from innovating. Hence, firms that decide to acquire technology externally, will find it easier to acquire this technology in disembodied form such as through licensing agreements or R&D contracts. Loose appropriation environments quickly erode a firm's technological advantage. In that case firms will develop specialized complementary assets internally to protect their technology. This is reminiscent of the "resource based" view of the firm who stresses the imperfect mobility of resources as a condition to sustain a firm's competitive advantage. Firms that decide to acquire technology externally in this environment, acquire this technology in embodied form through the acquisition of other firms or by attracting specialized personnel.

To summarize, most of the existing literature, both economics & management, discusses external sourcing motives individually or in relationship with internal sourcing. If there is a relationship suggested, it is mostly as being substitute choices to acquire knowledge. However, instead of discussing “make or buy” or buying modes as substitutes, the potential for combining sourcing modes as complementary innovation strategies should not be ignored. Although one strategy may substitute for the other at the project level, combining sourcing creates extensive scope for complementarities, particularly at the firm level, across projects. If combining different sourcing strategies increases the efficiency of each sourcing strategy, they are more likely to be observed in combination. But which conditions need to be present to realize the scope for complementarity? Arora & Gambardella (1994) identify internal knowledge capabilities which allow effectively utilizing foreign know-how, stimulating external sourcing. Internal capabilities generate ability to better screen available external projects. Once developed within the firm, this capacity will lead to a more focused search, which may reduce or stimulate various external sourcing activities. In any case, internal capabilities are needed to lead and support the external sourcing effort. Cassiman & Veugelers (2006) identify the reliance on basic R&D – as measured by the importance of universities and research centers as an information source for the innovation process – as an important contextual variable affecting complementarity between internal and external innovation activities. In a similar spirit, firms which have basic R&D capabilities developed, may be more prolific in developing several external sourcing strategies simultaneously.

Cassiman and Veugelers (2008) look explicitly at the firms’ technology buy decision and whether embodied and disembodied technology acquisition forms are complementary or substitutive. They find that both types of activities are complementary for large firms. Smaller firms, however, engage typically only in one type of technology sourcing activity. Embodied technology sourcing dominates in these cases.

Large firms can be expected to be less likely to buy on a larger scope and scale, to the extent that scale advantages in R&D can be realized in-house. To the extent that large firms have own in-house R&D with better absorptive capacities, they are better tuned to benefit from external sourcing (see Aurora & Gambardella, 1990, Gambardella, 1992 and Cockburn & Henderson, 1998 for evidence on this from the pharmaceuticals industry).

The specific problems of SMEs in establishing external linkages are tackled in Rothwell & Dodgson (1991). These authors again stress that a SME's ability to access external know-how is conditioned by its in-house employment of qualified technical specialists, scientists and engineers.

4. SPECULATIONS

Speculations: complementarity, complementary assets, absorptive capacity, open vs closed, IP policy of the firm, open innovation within our setting.

- Complementarity: matters for large established firms, not for technology specialists?
- Open innovation: relates to complementarity between buy and sell activities of the firms. This is more likely with large established firms than with technology specialists.

Note Complementarity: expected complementarity affects LR decisions. Actual complementarity affects SR decisions.

5. CONCLUSIONS

TBC

References

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Figure 1
Combinations of technological fields and product markets

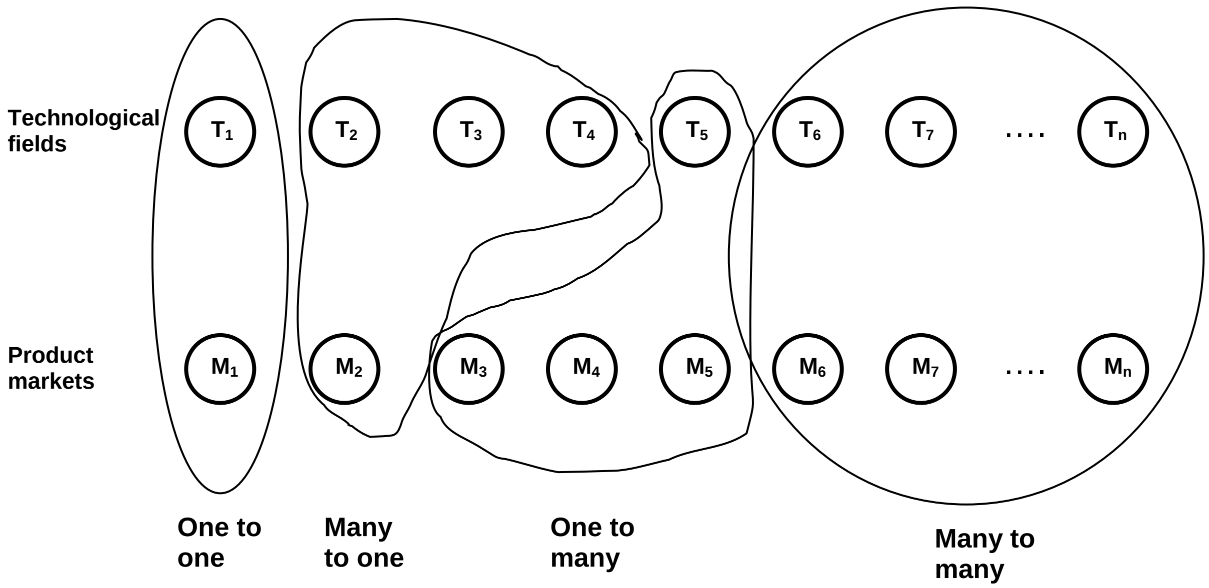


Figure 2
A model of strategic organization of R&D

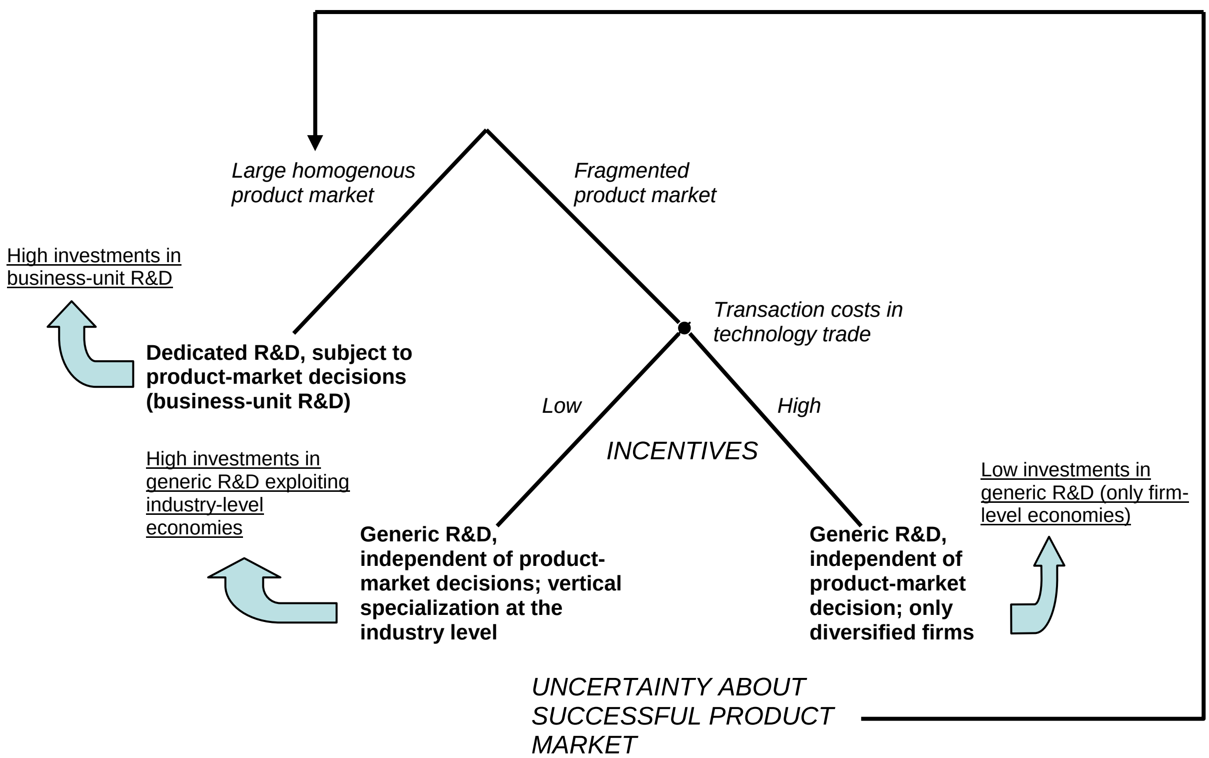
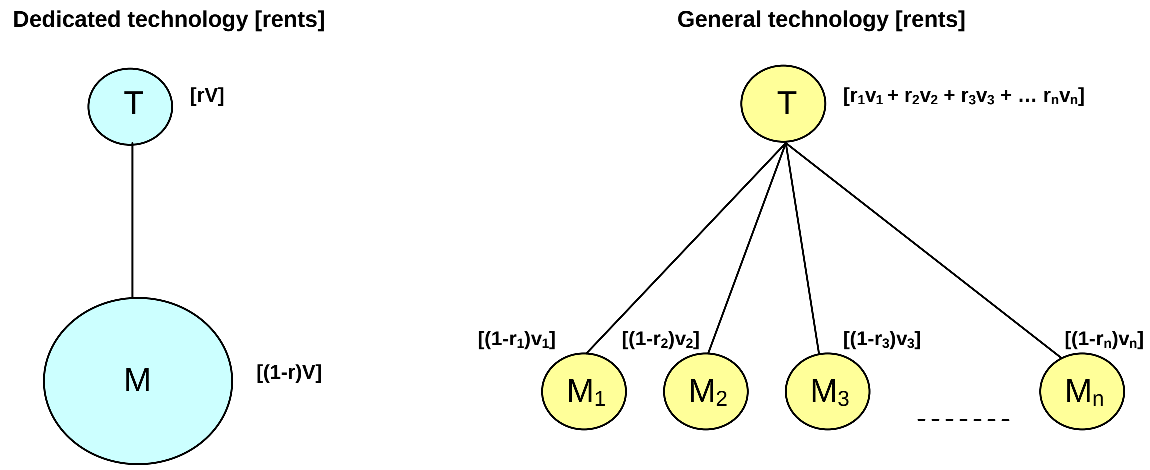


Figure 3
Dedicated vs general technologies: shares of industry rents



V = Total value in the vertical chain
r = Share accruing to the technology firm

$v_1, v_2, v_3, \ldots v_n$ = Total value in each vertical chain
$r_1, r_2, r_3, \ldots r_n$ = Share accruing to the technology firm

T = Technology firm. M, M_1, M_2, M_3, …, M_n = Manufacturers

Figure shows that with dedicated technology rents accruing to T-firms only depend on their bargaining power (r), which is not in their control. With general technologies T-rents also depend on their ability to find new uses (manufacturers), which is in their control (better technology, investments in downstream links and alliances).