UNIVERSITY OF TROMSØ UIT

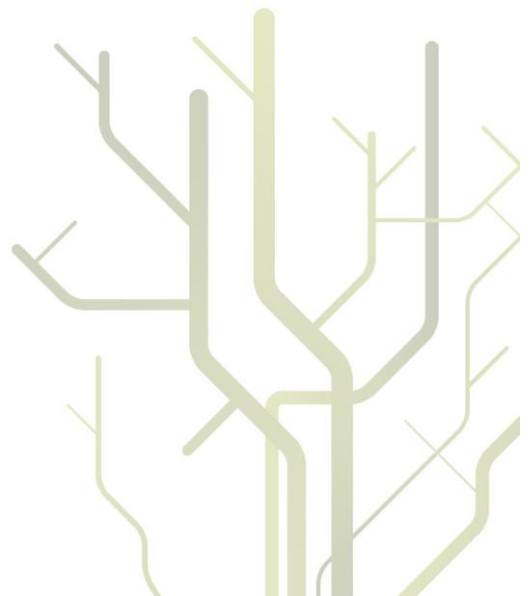# Technology transfer and R&D Policy in a knowledge-based society

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Abstract

My thesis focuses on technology transfer and innovation policy in a knowledge-based society. In particular, I analyse the firms' incentives to invest in research and development (R&D), the transfer of technological knowledge to a rival and government stimulation of R&D investment. Further, I analyse the incentives to engage in R&D cooperation in different market structures. By coordinating R&D decisions the firms can internalize the externalities of their research effort, and thereby strengthen the incentives to perform R&D.

The dissertation consists of three essays where I develop theoretical models within the subject of strategic R&D investment. As a consequence of externalities that arise when conducting R&D, the economic value to society often exceeds the economic benefits enjoyed by the innovating firms. Since the output of R&D investments is non-rival and only partially excludable, some of the knowledge also benefits their competitors and thereby reduces the incentive to engage in R&D activities. By coordinating these R&D activities the firms can internalize this externality. Knowledge created by one firm is typically not contained within that firm, and R&D spillovers occur when technological knowledge produced by one firm is transferred to other firms, both voluntarily and involuntarily.

In my first paper I study how separation of ownership and management affects firms' incentives to transfer technological knowledge voluntarily and without payment from a rival in a Cournot duopoly. The main finding is that strategic management does not necessarily increase the incentives to transfer technology, but it can change the adoption of technologies.

In my next paper I study the effectiveness of public funding aimed at stimulating business performed R&D in a vertically related market. In particular, the focus of the analysis is how to set the policy instruments upstream and downstream in order to achieve an optimal level of innovation in the whole industry. I show that it is always optimal to subsidize the R&D activity of the upstream firm. Whether a tax or a subsidy is used in the downstream market depends upon its level of concentration. If there are few firms downstream, then it is always optimal to employ an R&D subsidy in this part of the market. However, if competition is sufficiently strong, then R&D activity downstream should be taxed. The optimal R&D policy implies a differentiation of the subsidy rates between the upstream and the downstream market. Moreover, subsidizing the upstream supplier has a greater effect on welfare than the stimulation of each of the downstream buyers.

In my third paper I study strategic R&D alliances among asymmetric firms. I consider a market where some of the firms are active in research, while other firms do not conduct R&D. With non-innovative firms as technologically leading firms, the innovating firms invest in R&D to narrow the technological gap. On the other hand, with the technologically leading firms investing in R&D they expand their technological advantage. In the analysis I determine whether R&D cooperation leads to higher levels of R&D than R&D competition under different market structures. Cost asymmetries among firms seems to enlarge the interval of spillover rates where cooperative R&D secures greater R&D effort than competitive behaviour, and this depends on the number of firms that do not perform R&D or the number of firms that do not receive R&D spillover.

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List of papers

Paper I:
Clark, D. J., and Michalsen, A. 2010. Managerial Incentives for Technology Transfer.
Economics of Innovation and New Technology, 19: 649-668.

Paper II:
Michalsen, A. 2012. R&D Policy in a Vertically Related Industry. *Economics of Innovation and New Technology*, forthcoming.

Paper III:
R&D Cooperation and Market Structure.

Contents

Papers:

Managerial Incentives for Technology Transfer, *Economics of Innovation and New Technology*

1   Introduction
2   Delegation by the superior firm
3   Technology transfer and adoption
4   Welfare-maximizing technology combinations
5   The welfare-maximizing incentive scheme
6   Technology transfer under bilateral delegation
7 Conclusion
References
Appendix

R&D Policy in a Vertically Related Industry, *Economics of Innovation and New Technology*

1   Introduction
2   The R&D model
      2.1 Market equilibrium
3   R&D Policy
      3.1 Uniform subsidies
4   Conclusion
References
Appendix

R&D Cooperation and Market Structure

1   Introduction
2   The basic model
      2.1 Market equilibrium
3   R&D active and non-active firms
      3.1 Spillover between the innovating firms
      3.2 Spillover to some of the non-innovating firms
4   Product differentiation
5   Conclusion
References
Appendix

1   Introduction

This thesis focuses on key aspects of technology transfer, R&D cooperation and public policy in a knowledge-based society. I present three essays concerning firms' incentives to invest in R&D and to transfer knowledge to rivals. Further, I determine the optimal policy for stimulating firms' R&D activities in a vertically related market.

Knowledge is a key determinant of technological change, and economic growth is often linked to successful international transfer of technology. A central role is played by industrial innovation, a key driver of growth in knowledge-based economies. The relationship between market structure and innovation has generated considerable attention in the Industrial Organization debates, starting with the work by Joseph Schumpeter (1934, 1943). In his first framework, Schumpeter stated that new, small firms were the key to innovation. Therefore, public policy should be directed at facilitating the emergence of new enterprises. In his next work, however, he argued that only the existence of monopolies gives the correct incentives to invest in innovative activities. According to these results the optimal public policy should be to shield large innovative firms from competition. In contrast, Arrow (1962) argued that competition in the product market would increase firms' incentives to invest in R&D. His point was that monopolies have weaker incentives to invest in R&D than competitive firms due to the "replacement effect".[1]

The effect of market structure on innovation is complex, and still no consensus has been reached (De Bondt and Vanderckhove, 2010)[2]. The theoretical debate focuses on the two opposite market structures; monopoly and competitive oligopoly. The Schumpeterian supporters argue that the incentives to innovate are stronger for monopolists compared to competitive firms because the monopolist can capture gain without being imitated by rivals. The monopolists are more capable of investing in R&D due to higher profits and the large economies of scale due to diminishing unit costs. At the other extreme, they argue that firms in competition would have stronger incentives to innovate in order to outperform their rivals. For the policy makers the relation between competition intensity and R&D activities is of importance.

The economic research into R&D investment can be grouped into two classes; the stochastic approach and the deterministic approach. The first class falls within the patent race category, where the innovating firms face an uncertainty about value of return from R&D investment. Early research, pioneered by Loury (1979), developed a model where the innovating firm faced technological and market uncertainty. He assumed a stochastic relationship between firms' R&D investment and the timing of the innovation, and further the uncertainty of rivals' success in innovation. The outcome of the R&D competition takes the form of a "winner-takes-all" game, where the losers do not receive any gain from their innovation. Miyagiwa and Ohna (1997, 2002) take into account that the losing firms often copy the rivals' innovations and hence benefit from the new technology. Lee and Wilde (1980) apply an alternative specification to Loury's model, by introducing variable costs in the R&D technology in addition to the fixed cost. It turns out that this changes some of Loury's conclusions. With a higher weight on the variable costs in the R&D technology, an increase in the number of competitors may increase (decrease in Loury's model) the equilibrium level of firm's R&D investment.

In the second approach, R&D investment is assumed to have a predictable, deterministic effect on the production process. Firms undertake R&D investment in order to gain a competitive advantage over rivals. In these non-tournament models the role of the

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[1] For a monopolist, innovation simply replaces one profitable investment with a new one.
[2] De Bondt and Vandekerckhove (2010) provide some reflections on the basic oligopolistic models considering the relationship between competition intensity and R&D investment and the sensitivity of their conclusion to the underlying assumptions.

product market structure is often analysed (see, for example, Dasgupta and Stiglitz, 1980). The focus of my research is within the class of deterministic models, where R&D investment leads to a determined reduction in production costs.

A major part of the strategic R&D literature has focused on R&D cooperation between symmetric firms in a horizontally related industry. The standard models consider a two-stage game, where in the first stage firms invest in cost-reducing R&D either noncooperatively or in a cooperative setting. This stage is followed by noncooperative behavior in the product market. In these models the presence of spillovers is represented by involuntary leakage of private R&D. In my first paper I analyse the effects of voluntary transfer of technological knowledge to a rival with the intention to strengthen the competition in the output market. In the second paper I incorporate the whole value chain into the R&D model, analyzing a vertical structure with research in each market. I consider policies for stimulating R&D in this setting . In the final R&D model I consider cost-asymmetries among firms where only some firms are involved in R&D activities, while others do not perform R&D.

In the following I present my contribution to the R&D literature in a wider perspective, where I first discuss the role and implication of R&D policy. In the next section I will give an overview of the literature that my research is based on.

1.1   Research Policy

R&D investments are one of the main factors behind economic growth, and successful international technology transfer plays an essential role. It is fairly well documented that private R&D investments are essential for economic growth, productivity, employment, competitiveness and social welfare in general. In the OECD countries governments aim to increase total R&D spending to 3 percent of gross domestic product (GDP), with two-thirds of the total R&D investment done by the private sector. An intermediate evaluation revealed that this goal still lies far ahead; the average spending on R&D in the EU was 2.01 percent of EU25 GDP in 2009. [3]

The Norwegian government followed the EU in this matter and set forth the goal of increasing R&D spending to 3 percent of GDP by 2010. In Norway the R&D intensity is low compared to OECD standards, with a total R&D spending of 1.8 percent of GDP in 2009 where 0.8 percent was financed by the private sector. In the OECD Economic Surveys (2007) this was presented as the "Norwegian puzzle", since productivity growth has been high in Norway despite the low R&D intensity. One possible explanation is the industrial structure, characterised by a relatively large share of small firms in the low tech industry. The majority of the research and technology development that is beneficial to Norway takes place abroad. Norwegian firms often adopt existing technology from abroad rather than developing their own, which is both costly and risky.

To stimulate business funded R&D, the Research Council of Norway introduced the tax credit scheme "Skattefunn" in 2002. This scheme provides a tax credit of 18-20% of firms' R&D expenditures. The effects of the R&D tax incentives are evaluated in a discussion paper by Cappelen et al. (2008). Their main findings are that tax credits increase the rate of innovation by firms and that collaborating firms are more likely to have success in their R&D activities. Further, Clausen (2009) analyzed whether the Norwegian subsidies program has positive impacts on firms' R&D investments. His empirical results show that research subsidies stimulate private R&D spending, and that subsidies also have positive impacts upon the quality of R&D performed by the firms.

The social returns of private R&D investments are often higher than the private returns. Knowledge transfer from one firm to other firms creates positive externalities. Due to these

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[3] In the Lisbon strategy the target was to raise the total R&D spending to 3 percent of GDP within 2010. Although they are now below their goal, the Lisbon strategy is still essential to the EU 2020 strategy.

externalities that arise as a result of the R&D investments, firms often underinvest in R&D compared to the optimal welfare solution. To cover the gap between the expected private return and the social return all the OECD countries have government programs aimed at stimulating R&D in the industrial sector (Klette el al., 2000). The effectiveness of R&D tax credits to stimulate private R&D is surveyed in Hall and van Reenen (2000). They argue that the market will fail to provide sufficient quantities of R&D. Externalities due to R&D investments may result in inefficient market solutions, and therefore there is room for governmental intervention. Hall and Reenen focus on evidence of the effectiveness of fiscal incentives on R&D, and its effect on firms' R&D investments. They review methods used in OECD countries to evaluate the question of whether the tax-credit scheme is a more cost effective way to achieve a given level of R&D. It seems that countries are finding tax treatment of R&D increasingly convenient compared to direct grants, and are turning away from the latter.

The main policy instruments used to improve private R&D are according to Lööf and Heshmati (2005) direct government funding of business performed R&D, tax incentives and publicly performed research. In an early version of paper 2 I started with an analysis of the effectiveness of two policy instruments; direct public support of R&D performed by firms and public support based on firms' R&D expenditures (tax incentives) in a vertically related structure, consisting of an upstream supplier and a downstream buyer. The main findings were that differentiation of the subsidy rate is the optimal, welfare maximizing solution, where the optimal subsidy rate is higher for the downstream firm than for the upstream supplier. Moreover, with differentiation of the subsidy rates the optimal subsidized R&D efforts are equal for the two policy instruments. Comparing the effectiveness of the two policies the conclusion is that public support of R&D expenditure is, from the tax payer's point of view, more efficient in stimulating incentives for R&D than providing a direct subsidy based on R&D performed by the firms. The support of R&D expenditure involves lower costs for the government. In the current version of this paper, I extend this analysis by including competition in the downstream market, which improves the previous analysis. To make the new analysis tractable I assume no R&D spillovers between firms (as in the cited paper by Banerjee and Lin, 2003). In this revised setting with no spillovers, it is very clear that the two policy instruments that I considered previously will have qualitatively similar effects on R&D activity; hence I no longer compare the two instruments, but concentrate on one of them (subsidy/tax on R&D per unit as is common in the literature). When examining the optimal R&D policy my research shows the importance of including the whole value chain in the model. By considering the whole industry, the optimal solutions are changed. Instead of a R&D subsidy to the competing firms in the output market (from the model with the single horizontal market), it is optimal for the government to subsidize the upstream supplier and tax the downstream firms whenever the competition is sufficiently strong. As far as I know, existing literature has not included the whole value chain in the evaluation of the optimal R&D policy.

Within the strategic policy literature Spencer and Brander (1983) developed a model to analyze how R&D subsidies affect the strategic interplay between a domestic and a foreign firm. In their framework R&D subsidies are considered as a policy instrument for increasing competitive advantage in the export market. The focus in my model is that R&D subsidies are given in order to achieve the welfare optimal level of R&D investments in the upstream and the downstream market.

One branch of the R&D literature emphasizes the uncertainty related to knowledge production, and the fact that underinvestment can be a consequence of risk aversion among firms. One explanation for this is the possible financial constraints that firms are facing. Another factor is the selection process, and the allocation process in the subsidy program. A

7

paper by Kleer (2010) develops a signaling model for screening the projects with high social returns. Although this is of importance, I do not focus on the probability of success of the R&D activities and the selection of projects.

For policy evaluation it is interesting whether R&D subsidies stimulate or substitute private R&D spending (see David et al., 2000 and Aerts and Czarnitzki, 2006). The question is whether public funding are used to finance projects that could be carried out without government subsidies, which implies that private R&D expenses would be at the same level with and without subsidies. Empirical studies have found a positive effect of public R&D support on private R&D investment (Gonzàlez and Pazò, 2008, Ali-Yrkkö, 2004). Guellec and van Pottelsberghe (2003) examine the effect of government funding on business R&D in 17 OECD countries for the period 1981-1996. Their main result is that both fiscal incentives and direct funding stimulate business R&D expenditure, whereas research performed by governments tends to have a crowding out effect. Despite the lack of consistency in the empirical evaluation, at present most studies agree that public subsidies of R&D performed by firms have a positive effect on business financed innovations.

1.2   Technology transfer and cooperative R&D

The research into the effects and benefits of firms' R&D activities has exploded since the 1980's. A rich literature has been developed to study issues related to horizontal cooperative R&D, where the collaborating firms are competitors in the same market. Much of this research is based on the seminal paper by d'Aspremont and Jacquemin (1988) and later the paper by Kamien et al. (1992). In these works it is often assumed that R&D activity has a deterministic effect on firms' competitiveness in the product market, and that actors will cooperate with their competitors if this is beneficial. The models examine the incentives and welfare effects of R&D cooperation among competing firms, focusing on the role of R&D investments and R&D spillovers.

Firms' R&D efforts are broadly classified into two types; process and product innovations. Process innovation is characterized by R&D which is designed to reduce the production costs, whilst product innovation is the implementation/commercialisation of a new or improved product. The type of R&D that is considered in my papers is the one that is designed to reduce the marginal costs of production.

Firms' incentives for R&D investment consist of both the profit and strategic motives. Hence, the effects of the firm's R&D investments on the profit function in Cournot competition can be divided into the following terms: profit motive, strategic motive and cost effect (see Qiu and Tao, 1998). First, an R&D investment increases the firm's profit by lowering the production costs, thus the profit motive is positive. The second motive is strategic, where firms' R&D investments influence their rivals' output, both through the spillover effect and through a more aggressive competition in the output market. This effect could be either positive or negative, depending on the level of the spillover parameter. With a positive effect of rivals' R&D activities on own innovation, the R&D activities are strategic complements. On the other hand, the R&D levels become strategic substitutes when rivals' R&D reduces own innovation through spillover effects. The last component, the cost effect, is always negative since R&D is costly. For further decomposition of the strategic motive, both for R&D competition and R&D cooperation, see Qiu (1997) and Hinloopen and Vandekerckhove (2010).

The concept of R&D cooperation takes various forms, ranging from simple sharing of information about technological improvements to full integration of units. In R&D cartels firms form a strategic alliance and decide the individual firms' R&D levels such that the joint profits are maximized. This implies agreements to coordinate R&D investment, but not an agreement to fully share the outcome of the R&D activities. On the other hand, research joint

ventures (RJV) are agreements where the firms fully share their R&D knowledge but do not coordinate their R&D decisions. RJV cartels refer to strategic alliances with agreement to both fully share the results of R&D and to coordinate their R&D activities (see Hinloopen, 2000). In my research I consider the type of R&D cooperation where investment decisions are made to maximize joint profits in a static game, and where the motivation for disclosure of knowledge is mainly of a strategic character.

R&D spillover is often described by economists as a positive externality of firms' research efforts, since the economic value to society exceeds the economic benefits enjoyed by the innovating firms. Research spillovers arise when technical knowledge produced by one firm is involuntarily or voluntarily transferred to other firms. The model by d'Aspremont and Jacquemin (1988) assumes that the spillover is added to the output of R&D, while Kaminen et al. (1992) assume that spillovers affect firms' inputs.[4] The input spillovers are defined as the flow of knowledge between firms within the R&D process, whereas the output spillovers refer to final R&D results transferred between firms (Hinloopen and Vandekerckhove, 2011).

An interesting question is whether voluntary spillovers could arise in an oligopoly. The usual assumption is that new knowledge is freely transferred to rivals. In some settings the knowledge could be "superior", where the technologies can be more or less efficient (this is the case in the paper by Bacchiega and Garella, 2008). The definition of superior here is that firms have knowledge about different kinds of production techniques. Technology transfer can arise from strategic considerations, as shown by Bacchiega and Garella (2008), and considered in paper 1.

Managerial delegation is a common phenomenon in an oligopoly market structure,[5] where separation of ownership and management could change the incentives for technology transfer to rivals. The argument is that managers seem to act more aggressive in the product market due to the incentive schemes, which is often a weighted sum of firms' profit and revenue. Zhang and Zhang (1997) examine the effects of strategic delegation in a setup where managers choose both the level of R&D and production level in an oligopolistic market structure. They show that managerial delegation increases the R&D activities and output whereas profit is reduced compared to an owner-managed firm whenever the spillover is small. The owner strategically directs their manager away from profit maximization towards the maximization of revenue. Zhang and Zhang extend the existing literature by including the noncooperative R&D decision. Further extension is done by Pal (2010) who analyses whether cooperative managerial delegation can ensure a collusive level of profits. The contribution of my research (paper 1) is within strategic delegation and incentives to transfer knowledge about competing production technologies to a less knowledgeable rival in a Cournot duopoly.

In a large body of the strategic investment models, incoming and outgoing spillovers are treated as symmetric and exogenous to the firm. However, the spillover parameter can be determined endogenously as part of an optimal strategy (Poyago-Theotoky, 1999, Kultti and Takalo, 1998, Katsoulacos and Ulph, 1998 and Amir et al., 2003). With endogenous spillover firms develop strategies in order to obtain external knowledge. Firms want to prevent that technological knowledge flows to their competitor, and on the other hand they try to obtain a spillover from their rivals by for example attracting R&D workers from other firms (Gersbach and Schmutzler, 1997). Some papers (as Grünfeld, 2003, Kamien and Zang, 2000) focus on the role of own R&D in order to realize spillover. They assume that firms invest in absorptive capacity to be able to benefit from other firms' R&D investments. Hence, the own R&D investment both increases a firm's innovative abilities and its ability to learn from others.

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[4] For the implications of the two ways of modelling spillover, see Amir (2000) and Stepanova and Tesoriere (2011).

[5] Starting with the papers by Vickers (1985), Fershtman and Judd (1987) and Sklivas (1987).

Empirical studies (Cohen and Levinthal, 1989 and Adams, 2000) confirm that the capacity to absorb external knowledge from rivals depends on their own R&D efforts.

In horizontally related markets the effect of R&D cooperation depends on the spillover rates. R&D cooperation increases R&D investment when the spillovers are substantial, while for relatively small spillovers R&D cooperation decreases the incentive to invest in process innovation (d'Aspremont and Jacquemin, 1988). In vertically related markets cooperation involves higher investments in process innovation independent of the spillover effect (Wang and Yang, 2002).

Atallah (2005), among others, allows for asymmetric spillover in his analysis of R&D cooperation. R&D spillover may differ between firms because of different absorptive capacities, different kinds of protection of the new knowledge, a basic or applied approach in the research and different regimes for protection of intellectual property rights. He shows that R&D cooperation increases total R&D investment when the average spillover rate is sufficiently high, and further that for a wide range of the spillover value R&D cooperation is not beneficial to at least one the firms. Contrary to the findings of Atallah (2005), in the symmetric models R&D cooperation is always profitable for the innovating firms.

Empirical research confirms that there is a wide use of cooperation among different types of R&D partners, including supplier and competitor cooperation. Some of the empirical papers investigate the impact of R&D cooperation on firms' innovation input and output (see Becker and Dietz, 2004), while other models analyse the technological effect on the cooperating firms. Lhuillery (2006) investigates what motivates firms to disclose knowledge, which industries are more apt to disclose information and if disclosure of knowledge is an efficient strategy. An analysis of four French data sets reveals that knowledge disclosure is more likely to occur in high-tech sectors where the R&D intensity is high and the firms are engaged in a partnership.

2 Summary of the papers

Paper 1: "**Managerial Incentives for Technology Transfer**", *Economics of Innovation and New Technology.*

The first paper "Managerial Incentives for Technology Transfer" (co-authored with Derek Clark) analyses how separation of ownership and management changes the incentives for technology transfer and its subsequent adoption. The technologically superior firm has two types of technologies: one with a positive marginal cost and one with a positive fixed cost. The less knowledgeable rival has only the latter type of technology, and may get the former technology from the technology leader through voluntary transfer of knowledge. In the first scenario the advanced firm is assumed to be managerial, both with respect to product market decisions and regarding the choice of whether to transfer technology. We find that a separation of ownership and management will not necessarily change the incentives to transfer knowledge about a new technology to a rival, but it affects the technology choice of the managerial firm and hence the intensity of competition in the product market.

In the most interesting case the leading firm chooses to transfer the knowledge of the variable cost technology to its rivals, who in turn adopted it while the superior firm itself chose the fixed cost technology. This technology adoption occurs for a wider range of the fixed cost level than in the model with owner-managed firms (see Bacchiega and Garella, 2008). Separation of ownership and management leads, in some cost ranges, to higher profits for the most advanced firm.

From a welfare point of view, we compare the results that are privately optimal with those that would be consistent with maximizing society's welfare. A social planner would often dictate the firms to use the same production technique, even though the firms themselves would have used different production techniques for certain parameter values. In the last section our analysis considers the case in which both firms are managerial. The outcome depends on the incentive scheme designed by the firms. When the technologically superior firm is the one that places less weight on profits, it acts more aggressively than the rival and then the results are little changed. On the other hand, different results occur when the potential recipient of the alternative technology places less weight on profit compared with the initially more sophisticated firm. The superior firm would be less aggressive and then several types of technology adoptions are possible.

Paper 2: "**R&D Policy in a Vertically Related Industry**", *Economics of Innovation and New Technology.*

In my second paper I analyze the effectiveness of public funding aimed to stimulate firms' incentives to invest in cost-reducing R&D. The optimal policy is found in a vertically related market. Innovation is associated with positive externalities and consumer surplus, and the social rates of return from R&D may be substantially higher than the private rates of return. Therefore there may be, from a social point of view, underinvestment in technological knowledge created by firms. The market failures related to R&D activities have generated a vast array of policy instruments designed to affect firms' incentives to invest in R&D. The main policies include direct funding of firms' R&D activities, tax incentives and intellectual property rights (see Scotchmer, 2004).

In order to stimulate R&D investment in the private sector I investigate a vertically related market, consisting of an upstream monopoly and n downstream firms, all of which perform R&D. The analysis focuses on the role of i) an active R&D firm upstream and ii) competition in the downstream market. The policy instrument is a direct subsidy of firms' R&D efforts. The framework adopted in this paper builds on Banerjee and Lin (2003), where I include innovation of the upstream sector and public funding of firms' R&D investments.

I calculate the first best R&D levels and the optimal policy parameter. The optimal R&D policy implies a differentiation of the subsidy rates between the upstream and the downstream market, whereas the second best solution is a uniform subsidy rate.

The optimal solution is to offer a higher subsidy rate to the upstream supplier than to the downstream firms whenever there are more than two firms in the output market. The opposite occurs when there is a monopoly in the downstream market. Moreover, with differentiation of the subsidy rate between the upstream and the downstream market the optimal solution is a positive subsidy for the upstream firm. For the downstream firms the optimal subsidy is positive whenever the market concentration is high (less than five competitors in the output market). Increasing the number of competitors in the output market makes an R&D tax the optimal solution, although the total public spending is always positive.

The usual rationale for taxing R&D is that firms are doing too much in relation to the economically efficient level. This is indeed the case in my model when the upstream firm does not carry out R&D. However, when the upstream firm has an active innovation policy, an R&D tax on the downstream firms may be appropriate even when these firms have less innovative activity than the socially optimal level. This is a somewhat surprising result. The R&D activity of the upstream firm reduces the cost of the input for all downstream firms, and subsidizing this activity strengthens the effect. Private R&D by the downstream firms reduces only the cost of a single firm; if there are sufficiently many of them, the optimal policy

discourages downstream firms from expending resources on R&D, and at the same time stimulates innovation upstream.

Paper 3: "**R&D Cooperation and Market Structure**".

In the third paper I consider a market consisting of innovative and non-innovative firms. The main question is how asymmetries among firms affect the set of spillover rates which give a higher total R&D level under cooperation than under competition, and how this depends on the market structure. A major part of the strategic R&D literature is assuming symmetric firms and that all firms conduct cost-reducing R&D. Halmenschlager (2004) introduced cost asymmetries into the R&D models and the distinction between firms that have an active R&D policy and those that do not. I extend her model by incorporating an arbitrary number of innovative and non-innovative firms.

In the first section a basic model is examined, where all firms engage in R&D (a generalization of the model by d'Aspremont and Jacquemin, 1988). In the next section we take into consideration that some firms perform R&D and that some firms are not active in the research field. In the first setting we assume that transfer of technological knowledge occurs only within the group of innovating firms. In this model it is shown that asymmetries among firms seem to lower the spillover rate at which R&D cooperation and competition give the same level of R&D investment. The absolute number of competitors does not affect these results, only relative numbers. Further, the innovating firms earn more profits under R&D cooperation than under competition, while the non-innovative firms prefer R&D competition whenever the spillover rate is substantial. The model encompasses the analysis of Hinloopen (2000) and Halmenschlager (2004).In the second setting, we assume that some of the non-innovating firms also receive spillover from the innovative firms. A comparison of the R&D level under R&D cooperation and R&D competition is now independent of the number of firms doing R&D or not doing R&D, it depends only on the number of that do not receive technological spillover.

In the last section product differentiation is analysed under Bertrand and Cournot competition. The minimum value of the spillover parameter that gives a higher R&D level under cooperation than under noncooperative R&D is influenced by the total number of firms in the industry, the number of firms doing R&D, the type of competition and the extent of product differentiation. The degree of product differentiation reduces the minimum spillover rate in all cases. A higher degree of product differentiation lowers the intensity of competition and reduces the strength of the negative spillover effect. Hence, the innovating firms' profit increases. Further, the minimum spillover rate where the R&D under cooperation exceeds the noncooperative R&D level is higher under Bertrand than under Cournot competition.

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Paper 1

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Paper 2

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Paper 3

R&D Cooperation and Market Structure.