R&D, Industry Dynamics and Public Policy –Revised proposal

1. Relevance

Our project covers most of the issues listed in the program, although it is organized somewhat differently than "Economics and Business Perspectives". The first part of the project covers the dynamics of industry, R&D and the decisions of firms to innovate (first part of first bullet point) and sectoral differences (second bullet point).

The second part of the project covers optimal R&D policy, including immaterial capital and public policy (last part of first bullet point), and includes policy design in an endogenous growth context (third bullet point). Moreover, the second part of the project also covers topics under "An Innovation Theoretic Perspective", for example, spillovers and spread of knowledge (first bullet point), as well as the efficiency of different types of R&D instruments (second bullet point).

2. Aspects relating to the research project

2.1 Background and status of knowledge

R&D and industry dynamics. Industry dynamics, including creation and growth of new, more efficient firms, and reallocation of resources (particularly labor) from old, inefficient firms to new firms with better technology are often considered to be the engine of capitalism, the dynamo in the economy that ensures growth and prosperity. Research and development is in many cases key in this process of creative destruction (Schumpeter 1942). This process does not always run smoothly, however. A key property of a flexible dynamic economy is that technological progress is achieved and implemented without too many resources being lost along the way, implying that the process of creative destruction is more creative than destructive.

Industry dynamics. There exists a large literature on R&D and industry dynamics. A survey of the empirical literature is given in Bartelsman and Doms (2000). Most of the empirical studies utilize the Longitudinal Research Database. This database includes information on R&D spending and company characteristics, mainly sales and the number of employees. Theories of industry dynamics are found in, among others, Jovanovic (1982) and Klette and Kortum (2004), the latter extended in Lentz and Mortensen (2005). In these models, R&D and industry dynamics are modeled in a relatively simple and stylized way which allows for closed-form solutions. The models are used to explain various stylized facts regarding R&D and industry dynamics.

Human capital and turnover. The models of R&D and industry dynamics do not include endogenous human capital formation during employment nor search frictions in the labor market. On-the-job search and its implication for the incentive to invest in human capital is studied theoretically in Moen and Rosen (2004). A survey of the theory of on-the-job search and turnover with search frictions can be found in Kiyotaki and Lagos (2006). Moen and Rosen (2006) show theoretically that turnover rates may be related to wage contracts, and that multiple equilibrium may arise with different rates of turnover. In the empirical literature on turnover, the work by Davis, Haltiwanger and Schub (1998) is central. They study gross worker flows (measured as changes in employment in each firm). The theory of job turnover is taken to data in among others Postel-Vinay and Robin (2002) and Christiansen et al (2005).

Entrepreneurship. The origin of entrepreneurs and the importance of R&D have attracted considerable attention in the literature. Standard references in the recent literature include Gompers et al (2005), Agarwal et al (2004), and Klepper and Sleeper (2005). A problem that hampers the literature on entrepreneurship is that entrepreneurs are defined as self-employed, an assumption first introduced in Hamilton (2000). With our data set, we are able to single out entrepreneurs of firms with growth potential.

A stumbling block in the literature described above is lack of data. The data set we are constructing has two major advantages: 1) it contains high quality accounting data of all firms, coupled with R&D data, and 2) it is coupled with detailed individual information on individual

employees. This allows us to trace the interrelated event histories of workers and firms, and to study the relationship between firm creation, R&D and industry dynamics in detail – and opens up for major advances in our understanding of R&D and firm dynamics.

Optimal R&D policy. There are reasons to believe that R&D, innovation and entrepreneurship create externalities through spillovers depending on absorptive capacity, through information spillovers between workers, and through the tax system. These externalities create a gap between the private and social returns to innovations. In most countries, therefore, the government actively supports R&D.

The importance of R&D spillovers is emphasized both in the IO literature and the macroeconomic literature. Central contributions in the IO literature include Nordhaus (1969), Spencer and Brander (1983) and Spence (1984). Aspremont and Jacquemin (1988) identified the implication of R&D spillovers for economic efficiency and subsidies under different market structures. Seminal contributions in R&D-based endogenous growth theory are given in Romer (1990), Aghion and Howitt (1992) and Grossmann and Helpman (1991). More references to the literature can be found in the presentation below.

2.3 Approaches, hypotheses and choice of method

2.3.1 Data

Our data set combines firm-level data, developed at the Norwegian School of Management, with individual-level data delivered by Statistics Norway and further developed at the Frisch Centre. In addition, it will comprise data on R&D and patents provided by Statistics Norway. The dataset will be matched by Statistics Norway provided that the required consent from NSD is obtained. During the summer, the Frisch Center will prepare the data for analysis.

The Department of Financial Economics at the Norwegian School of Management administers the Norwegian School of Management database. It is based on accounting information collected for the Norwegian Government and stored in a database in Brønnøysund (the Brønnøysund registers). It consists of the following elements:

1. Period 1995-2005. Yearly observations.
2. The identity of all firms in Norway except firms owned by the state or municipalities.
3. All accounting variables from the income statement and balance sheet.
4. Owners' identity and share of ownership.
5. Industry code, credit rating, number of employees, year of incorporation, etc.

The individual-level database consists of data from several administrative registers, the employer-employee register being the most important one. The database is organized around the individual employees, but current and past employers are identified by their organizational numbers. The individual-level database also contains significant firm-level information through the detailed description of each firm's employees at any point in time.

1. Period 1992-2003 (will be updated to 2005 when possible).
2. All persons residing in Norway covered.
3. Information on age, gender, place of residence, nationality, family ties, work experience (back to 1967), and educational attainment.
4. Information on income and wealth gathered from the yearly tax returns.
5. Ongoing as well as highest completed education.
6. Different types of social security transfers and pensions.

Importantly, from Statistics Norway we will include the R&D database (around 17,000 firms), from the Industry Database (investment data, etc.) and, finally, from the Patent Registers (all patents registered in Norway in the period 1995-2005 and identification of the patent holders).

2.3.2   R&D and industry dynamics

The database will be sufficiently rich to facilitate descriptive as well as causal analyses of R&D investments, industry dynamics and the role of worker flows, with much better data on firm characteristics and worker histories than in Longitudinal Research Database. Identification of empirical regularities in the data may give impetus to theoretical findings whose empirical relevance may in turn be rigorously tested on the basis of structural or reduced form econometric models. A key concern in our empirical analysis is that correlations do not always reflect causation. Causality can sometimes be recovered, however, by taking advantage of exogenous shocks/reforms present in the data or by imposing theoretically justified restrictions on structural models.

Industry dynamics include the evolution of firms over their life cycle, in which R&D is given a key role in many studies. Klette and Kortum (2004) construct a dynamic growth model of R&D and firm dynamics to explain a set of stylized facts regarding R&D. We plan to test some of the assumptions and implications of the Klette-Kortum model such as, for instance, that R&D is a prerequisite for growth. To the extent that we find empirical regularities that the Klette-Kortum model cannot account for, we plan to modify the model so as to incorporate these findings and analyze the implications.

In the Klette-Kortum model, the labor market is assumed to be frictionless, and no importance is attached to *worker flows*. Worker flows affect the incentives for investing in R&D, as well as the ultimate social value of such endeavors. Worker mobility is a source of spillover from R&D, as knowledge is embodied in workers' human capital. It also reduces the appropriability of new research and increases the absorptiveness of new technology among competitors. We want to study, both empirically and theoretically, how worker flows interact with R&D, innovation and entrepreneurship. We are concerned with worker flows between existing firms as well as flows from existing firms to new establishments (entrepreneurial activities). Our data set allows us to break the link between entrepreneurship and self-employment, and thus get a much better understanding of the origins of entrepreneurs. We are also concerned with flows into and out of the labor market.

On the theoretical side, we want to extend the model of Klette and Kortum by allowing for adjustment costs due to search frictions in the labor market. Search frictions influence the speed at which workers are reallocated from less to more productive firms and from unemployment to employment. An appropriate theoretical model that includes both on-the-job and off-the-job search does – in our opinion – not yet exist. A new model is being developed by Garibaldi and Moen (2007). This model combines the dynamics in Bertola and Caballero (1992) with the combination of on-the-job search and endogenous human capital formation in Moen and Rosen (2004). Our plan is to confront this model with our data.

Worker flows are clearly also affected by R&D and innovation. Organizational changes often imply that some technologies become obsolete and that some workers become redundant. Structural characteristics of the labor market – including social security systems and the design of labor market policies – may have a large impact on the extent to (and speed by) which redundant resources are productively reallocated to other firms. But firm policies may also be important for a smooth reallocation of redundant workers. To dampen employee resistance towards organizational changes, many firms "buy their workers out" in the form of, for example, generous early retirement packages. That may improve the climate for change, while at the same time preventing a socially efficient reallocation of labor resources.

The empirical analysis will examine the following four topics:

The determinants of R&D investments

- Characterize firms and sectors that invest heavily in R&D in terms of factors such as profitability, size, employee composition, market position, degree of competition and regulation.
- Investigate the relationship between R&D investments, the firms' international competition, and the degree of foreign ownership.
- Examine the presence of external effects between firms in the same sector or in the same geographic area.
- Investigate the role of public subsidies in terms of, for example, direct support, tax relief, and education.

The impact of R&D on worker flows

- Examine how R&D affects the career pattern of affected workers; in terms of direct job shifts and entrepreneurial activities on the one hand, and in terms of redundancies on the other.
- Study how R&D influences the process of *creative destruction*, by which innovative and profitable firms absorb resources from less profitable firms in the same sector.

The supply of entrepreneurs

- Examine the importance of R&D for entrepreneurial activities. For example, the characteristics of firms that foster entrepreneurs, their R&D policy as well as the characteristics of the entrepreneurs themselves (in terms of, for example age, education and labor market and research experience).
- Gender and entrepreneurship, what characterizes female entrepreneurs, their background, and the firms they start up.
- Make causal inferences regarding the driving forces behind entrepreneurship. In particular, we plan to study the possible impact of R&D investments on subsequent entrepreneurial activities.
- Examine the extent to which adverse labor market shocks (such as unemployment) trigger entrepreneurship.

The reallocation of workers

- Identify the key factors that are important for a smooth reallocation of labor made redundant by R&D in, for example, the form of individual resources, local economic environments, and firm policies.
- Examine the circumstances in which innovation and organizational changes drive labor recourses prematurely out of the labor market ("destructive creation").

2.3.3 *Optimal R&D policy*

Spillovers, or externalities, from R&D imply that if a firm invests in R&D activities, some of the benefit from those activities will accrue to other firms with interests in the same kind of R&D, that is, to the firm's rivals operating in the same industry. However, the ability to take advantage of other firms' R&D may depend on a firm's absorptive capacity, often associated with the firm's own R&D activities (Cohen and Levinthal, 1989; Kamien and Zang, 2000). From society's point of view, spillovers are a double-edged sword: Spillovers imply that a firm's R&D activities will benefit others directly. On the other hand, such spillovers reduce a firm's incentives to do R&D.

Government policy towards knowledge-based firms should be directed at correcting the distortions created by R&D spillovers between the firms. In addition, the R&D policy of the government may influence the strategic behavior of firms. Thus, the market structure may influence optimal policy. Industries vary, for example, in the extent of vertical ownership. Industries also vary with respect to the extent of competition: Some industries are more conducive to collusive

behaviour among firms than others. In some industries capacity constraints play a major role, resulting in equilibrium prices well above marginal costs. In other industries, competition is softened by product differentiation. Moreover, industries vary in the extent of spillovers from R&D activities, and in the extent of complementarities between the various firms' R&D investments. Because of these variations across industries, it may be necessary for government to have a R&D policy that incorporates flexible instruments. Whereas a standard R&D subsidy may be useful as a basis for the government's policy, it may need to be complemented in some industries with other instruments. This rationalizes why R&D activities in the real world are stimulated in various ways.

In Norway, R&D is supported in several ways, including direct support from the Research Council after an application process (*ex ante* support), tax credits for R&D expenses or matching grants, state-owned venture capital funding and, finally, funding of research and education at universities and non-commercial research institutions. A key issue in this part of the project is therefore to *identify the optimal mix of R&D instruments*.

Private information
R&D politics in practice are generally hampered by severe informational problems (see e.g. Katz and Ordover, 1990). At each point in time there will be a vast number of potential projects to support.

This information problem is acknowledged in the economic analysis of intellectual property rights (IP). The patent system is known to be an imperfect instrument for stimulating innovation because of monopoly pricing, but is nevertheless accepted because of the ability to decentralize decisions to firms. (Scotchmer, 2004).

Although there is a vast literature on the implications of asymmetric information for contracting in general (see Bolton and Dewatripont, 2005), there are few examples of studies that apply this knowledge to the problem of designing optimal governmental R&D policies.
True enough, there is a literature on procurement of innovation (reviewed by Cabral et al (2006)), but this line of research is partial and considers procurement of (relatively) well-defined "common ideas" held by the government. The majority of innovations in the economy is rather based on "scarce ideas" held privately by the individual firms themselves (Scotchmer, 2004).

Our goal in this part of the project is to bring the informational problem of the policymaker explicitly into the analysis of optimal R&D policy, both regarding patents and procurement of scarce ideas. Procurement of scarce ideas raises particular difficulties. Some of the ideas will be realized without support, as they are privately profitable. Others will need support to become privately profitable. The latter group contains both projects that are socially profitable and socially unprofitable. The problem of identifying socially desirable but privately unprofitable projects is well known in the public debate but is still an unexplored area of economic research. We will analyze this issue using techniques from regulation theory (Laffont and Tirole 1993).

We will also analyze the effects of combined policy measures. A combination of subsidies (or tax reliefs) in combination with flexible patents (with endogenous patent length and /or licence) may be used to reduce the costs associated with private information.

Intellectual property rights and weak patents
There is increasing concern over the patent-granting process, which grants weak patents (Jaffe and Lerner, 2006). A patent can be weak because it turns out to infringe on existing patents, or because it is not sufficiently "non-obvious". If brought to court by litigation, weak patents could prove to be (with some probability) invalid or infringing. However, weak patents are still valuable to firms, since litigation is costly and suffers from free-riding. This may be an increasing concern for Norwegian industries in the future if Norway chooses to enter the European Patent Convention (EPC). Due to the small market in Norway there are many patents in Europe that are not registered as a Norwegian patent. Once Norway has entered EPC, all patents registered in Europe will immediately be valid in Norway. Thus, we will *investigate litigation choices of firms in the presence of weak patents under different market structure assumptions*.

R&D in a Small Open Economy

The defining models in endogenous growth theory all describe closed economies. This assumption seems plausible when addressing the technology growth common for a group of countries integrated by trade. However, when it comes to R&D *policies* and the associated trade policies, the unit of analysis must be a country. A small economy only contributes marginally to new knowledge in a large world, and innovations that have broad benefits might not yield large domestic gains. This could lead a country to focus more on alleviating technology adoption instead of stimulating to innovation (Acemoglu et al., 2006). On the other hand, access to larger markets could stimulate the more successful firms to extend trade to new markets (Melitz; 2003). Such expansion of markets could make R&D *more* profitable and increase the national gain from pursuing R&D-stimulating policies, provided that the protection of intellectual property rights is sufficiently rigorous. Interesting issues to analyze are first how the increased exposure to trade affected the level and distribution of R&D. Second, how does openness to trade influence the (national) optimal R&D policy?

2.6 Project management

The project is a joint venture between the research center CREAM (Center for Research in Economics and Management) at the Norwegian School of Management and the Ragnar Frisch Centre of Economic Research, including professors from University of Oslo with part-time positions at the Centre. The host institution will be the Norwegian School of Management. The project will finance a post-doctoral position (at the Norwegian School of Management) and a Ph.D. position (at the Frisch Centre). The rest of the budget will be divided evenly between the two institutions. Another project participant, Alessandra Luzzi, starts as post-doc at BI in August this year (sponsored by BI). Her Ph.D thises is on R&D, Innovation and Industry dynamics (supervisor: Giovanni Dosi). The Ph.D. student will be enrolled at the Ph.D. program at the University of Oslo.

Professor Espen R Moen (BI) will head the project. Senior Researcher Knut Røed (Frisch) will be responsible for the Frisch Centre part of the project. Other participants include: Dag Morten Dalen (BI), Christian Riis (BI), Alessandra Luzzi, Øyvind Norli (BI), Erling Steigum (BI), Bernt Bratsberg (Frisch), Rolf Golombek (Frisch), Steinar Strøm (Frisch), Kjetil Storesletten (UiO and Frisch), Tore Nilsen (UiO and Frisch), and Åsa Rosen (University of Stockholm).

All the participants in this project actively participate in the international research community, and the project seeks to draw heavily on their research networks, see enclosed CVs for details. The project participants have extensive networks through co-authorship (at University of Stockholm, University Of Pennsylvania, University of Turin, Princeton U, U of Zurich, U of Southampton, New York University, Carnegie Mellon U and Georgetown U. and Universidad Carlos in Madrid), editorial positions in the *Scandinavian Journal of Economics* and the *Review of Economic Studies*, and as research fellows at the Centre for Economic Policy Research CEPR. In particular, we will have contact with Professor Dale Mortensen, a full-time professor at Northwestern University who hosts a part-time position at the University of Århus where he works on a related project. Professor Mortensen was in Professor Moen's Ph.D. committee, and Moen visited him for a year at Northwestern University 2004-2005.

3. Perspectives and compliance with strategic documents

Compliance with strategic documents

For the Norwegian School of Management, as a high-profiled business school, R&D and innovation are key subjects. The school is currently launching a new master program in innovation and entrepreneurship. A separate master course in innovation is currently thought at the Econ department. Our last hire, Alessandra Luzzi, has specialized in empirical studies of R&D and industry dynamics. In 2006 the school established a research center at the Economics Department, Center for Research in Economics and Management (CEPR)

(http://www.bi.no/templates/omSkolested____41466.aspx). The objective of this center is to carry out applied research and analysis in industrial economics broadly defined, of which R&D and industry dynamics is an integral part. At the Frisch centre, applied and empirical economics research in industrial organization and labor economics is the major activity. A core competence is empirical analysis using large data sets, and the project will broaden the scope of their already rich database.

A key idea of the project is to merge not only the two established datasets, but to exploit the synergies arising from the cooperation between two research environments that have each specialized on different segments of the market economy; the Economics and Financial Economics Department of the Norwegian School of Management, with their expertise in industrial economics, labor economics and firm-level accounting data, and the Ragnar Frisch Centre for Economic Research, with its experience in the empirical analysis of individual event histories and expertise in micro-econometric analysis. The merged dataset will be located at the Frisch Centre, where large investments already have been made in reliable security systems and storage capacity, and where access to supercomputing facilities is ensured.

Relevance to society

Clearly, R&D and its impact on industry dynamics and growth are relevant for society. In addition, the project will also look into the costs of creative destruction, in terms of resources being idle or underused. Although growth certainly is good for society, the costs of creative destruction may be substantial for those who are hit.

Environmental perspectives

R&D in environmental friendly technologies is decisive in order to reach environmental goals, such as meeting future emission targets on green house gases, without imposing excessive costs. Because a key topic in our study is optimal design of R&D policy, the present project will provide guidelines for efficient R&D instruments also within environmental economics.

Gender equality and gender perspectives

Two women will participate: Post doc Alessandra Luzzi (BI) and Professor Åsa Rosen at the University of Stockholm. Rosen is project manager Moen's prime coauthor.

Our data allow for studies that identify possible gender differences, for example, whether male and female entrepreneurs enter the same sectors, have the same educational background and work experience, and obtain the same return. The answers to these questions are important in designing policy instruments that may stimulate female entrepreneurship.

4. Communication with users and exploitation of results

4.1 Communication with users and dissemination plan

The ambition of this project is that the research output meets a *scientific standard* sufficient to facilitate presentation on international research conferences and publication of the results in top international journals. At the same time, it is also an ambition that the research output maintains a degree of *policy relevance* sufficient for publication in "user-oriented" journals and presentation at Norwegian policy conferences. As fellows in Centre for Economic Policy Research (CEPR), the project conferences may be organized joint with CEPR and obtain the status of CEPR-conferences. The researchers in this project will seek to maintain close contact with policy-makers and relevant non- governmental organizations in Norway and to actively participate in relevant policy debates.

We would like to emphasize that the project participants have long experience in acting as advisors for the Ministries, for governmental bodies like the Post and Telecommunications authorities and the Competition authorities, as well for as for the private sector. Furthermore, in addition to research, advisory activities are an integral part of CREAM's long-term strategy.

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