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**Research Report**

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# CASE Network Studies & Analyses

## Demand-driven innovation policies in the European Union

Camilla Jensen  
Itzhak Goldberg

No. 468/2014

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## Contents

Abstract.....	6
1. Introduction: Background, approach and methodology .....	7
2. State of the art: The small entrepreneurial firm is here to stay .....	8
2.1. From the level of the scientist to the economy .....	11
2.2. Gazelles and the international and global scene .....	12
2.3. Summing up the main policy lessons on Gazelles.....	13
3. Factor markets I – Access to finance .....	15
3.1. Venture capitalism – any alternatives? .....	16
4. Factor markets II – Access to knowledge and skills .....	19
4.1. Ontology of knowledge – internal and external forms of knowledge .....	19
4.2. What can policy-makers do to crowd-in investment in knowledge? .....	21
4.3. Supply of skills from the education system.....	24
5. R&D subsidies.....	26
6. Summary and Conclusion.....	28
References.....	32
Appendix .....	37

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## **Abstract**

The objective of the PICK-ME (Policy Incentives for Creation of Knowledge – Methods and Evidence) research project is to provide theoretical and empirical perspectives on innovation which give a greater role to the demand-side aspect of innovation. The main question is how can policy make enterprises more willing to innovate? This task is fulfilled by identifying what we consider the central or most salient aspect of a demand-side innovation-driven economy, which is the small and entrepreneurial yet fast growing and innovative firm. We use the term “Gazelle” to signify this type of firm throughout the paper. The main concern of policy-makers should therefore be how to support Gazelle type of firms through various policies. The effectiveness of different policy instruments are considered. For example, venture capitalism is in the paper identified as an important modern institution that renders exactly the type of coordination necessary to bring about an innovation system more orientated towards the demand side. This is because experienced entrepreneurs with superior skills in terms of judging the marketability of new innovations step in as financiers. Other factor market bottlenecks on the skills side must be targeted through education policies that fosters centers of excellence. R&D incentives are also considered as a separate instrument but more a question for future research since there is no evidence available on R&D incentives as a Gazelle type of policy. Spatial policies to foster more innovation have been popular in the past. But we conclude that whereas the literature often finds that new knowledge is developed in communities of physically proximate firms, there is no overshadowing evidence showing that spatial policies in particular had any impact on generating more of the Gazelle type of firms.

## 1. Introduction: Background, approach and methodology

The objective of this review of the studies on demand-driven innovation policies in the European Union produced for the European Commission-financed project entitled PICK-ME (Policy Incentives for Creation of Knowledge – Methods and Evidence) under Work Package number 4 is to distill implications and draw policy recommendations for stimulating demand for innovation among countries, firms and entrepreneurs. To achieve such an objective, we draw on parallels in recent literature on innovation and especially in those areas where we think that the Work Package has given cause to important policy implications. The main theme of this policy analysis will therefore be: Why are some countries, firms and/or entrepreneurs more innovative than others? How can policy stimulate the demand-side of innovations in particular?

We tried to write the policy paper from Work Package 4 using an objective approach to the scientific contributions. First, we classified the contributions into subjects or topics (see Appendix). Then an overview of the contributions was established by a linear (chronological) reading through all of the papers with the help of research assistants. This led to an identification of the papers with strong policy implications. These papers were studied further in depth; in areas where we were able to identify a critical mass of evidence and ideas to support strong policy implications, we started to look for evidence in external sources that supported or contradicted them. At the same time, it is not the intention of this paper to provide an exhaustive literature review as that is the task of other work packages. Foundational contributions are typically given less space in the policy paper. We tried to incorporate all the contributions with sporadic policy implications under the major areas and where we could find a fit with the line of thought or critical mass of supporting, related and complementary ideas.

The policy paper follows a very simple structure. Starting with the outset in the Schumpeterian theories, we choose as focal point the Gazelle firms and trace, from the nucleus of the economy (the entrepreneur) to the whole (the international economy), why policy-making should aim to support this type of catalytic firm. This is followed by two sections that focus on bottlenecks in factor markets for capital and human capital or skills, respectively. The last section discusses R&D subsidies as an incentive to Gazelle firms.

## **2. State of the art: The small entrepreneurial firm is here to stay**

The role of the firm in relation to generating new knowledge or innovation is best understood through the seminal work of Schumpeter (1934). We think of either the dilemmas of Schumpeter I (emphasis on the role of the entrepreneurial firm for innovation) or Schumpeter II (emphasis on the role of the large corporation for innovation). In practice we should probably think of the economy as really in Schumpeter I-II or somewhere in between these two dilemmas where each economic system (or in short eco-system) is different.

In Malerba and Orsenigo (1997), this is explained as the combined process of widening and deepening the knowledge base, which is often seen as one of the fundamental ideas or starting points of enquiry for a large number of the papers in Work Package 4.

The dilemmas for the creative destruction process in Schumpeter I-II are securing: (1) enough entry of new firms, (2) sufficient rivalry and selection among new firms, (3) that the best firms are given the right conditions to continue to innovate and (4) the inevitable necessity of destruction. (For a more detailed discussion and test of some of the propositions using growth data see also Aghion et al, 2013).

Work Package 4 contributions that focus on the agency of firms cover most of these dilemmas directly or indirectly as discussed here, even though 4 (the inevitable necessity of destruction) is less emphasized in the academic research on innovation.

Antonelli and Gehringer 9/2012 articulate a demand-pull innovation framework in which knowledge creation downstream in the value chain is driven by sales growth upstream in the value chain. This is what they call a 'qualified' demand. It is where the total factor productivity growth upstream rather than demand or sales growth as such is the driver of total factor productivity growth or innovation downstream. Endogenous growth theory shares some analogy with these assumptions; see for example Barro and Sala-i-Martin (2004) Chapters 6 and 7. But it is the allocation of labor (or scientists) that is decisive in most of these models which means that they in fact focus on the secondary problems of factor market bottlenecks.

The paper by Colombelli, Kraft and Quatraro 6/2011 analyzes the contribution of high-growth firms (Gazelles) to innovation. Colombelli et al 6/2011 seek to understand the dynamic problem of how to get from Mark I to Mark II and what the knowledge characteristics of the successful firms in this transition and growth process are.

Gazelles are defined by Colombelli et al 6/2011 as firms that showed an average growth rate of 20% or more over the period analyzed: 1988-2005. The phenomenon of these rapidly growing entrepreneurial firms has received increasing attention over the 1990s and 2000s in research on growth and innovation. For policy-making, the main questions here seem to be why some countries/environments foster more of the Gazelle type of firms and how policies can aid Gazelles in terms of reaping the full benefits of these firms, exploiting their potential demand-led trajectories.

We will address this question using the PICK-ME literature listed in appendix and a number of contributions by renowned authors in the field of innovation studies such as Josh Lerner and David Audretsch, as well as work done by the World Bank, the German Ministry of Economy and the European Commission in recent years.

According to Lerner et al (2012), the pivotal role of small, usually venture-funded, companies in developing those innovations has added urgency to government efforts to create a venture capital friendly eco-system. The incentive to a small firm that has developed an innovative new technology is survival and, at best, success. Facebook, one example of innovative new technology, was valued at \$104 billion when it went public. The difference in the incentive sets between established firms and startups creates the impetus that drives many engineers in large companies to leave and form their own small operations, where they can reap the rewards from their own discoveries.

Another disincentive for large companies to innovate may stem from the comfort of the status quo and the resulting blind spots when they survey market opportunities. A significant body of research addresses this phenomenon: incumbents are focused on the current market and technology and miss opportunities to address new market needs that new companies can fill. Such a dynamic is particularly acute when innovating to address the new market need would cannibalize the existing product.

Finally, small new companies have less to lose. A large company that “bets the farm” on an innovation that fails, risks its brand and respect in the market. A startup has no option but to try something new. Everything big and proven is already in the market. To established firms, innovation can be disruptive; for entrepreneurial companies, innovation is essential.

A recently published study on high growth firms on behalf of the German Federal Ministry for Economics and Technology (Dautzenberg et al, 2012) analyses the importance of Gazelles to the German economy. The report identifies 13,021 high-growth companies over the period

1999-2010 which were founded since 1995. One of the main observations of this study is that in 2000 the number of new Gazelles reduced dramatically. While, between 1995 and 1999 on average 800 new Gazelles were identified, between 2000 and 2007 on average only 492 new Gazelles could be identified. The number of created jobs thus reduced similarly: in 1997, nearly 30% of all new jobs could be attributed to Gazelles, while in 2005 only 10% of new jobs were created by Gazelles.

Concerning the sector distribution it turns out that Gazelles are prevalent in nearly all economic sectors. However they are not equally distributed. 43 out of the 50 industries with the highest share of Gazelles are in the manufacturing sector.

Audretsch and Aldridge (forthcoming as an EC/JRC/IPTS Working Paper) argue that the prevalent and traditional theories found in the entrepreneurship literature typically hold the context constant and then examine how characteristics specific to the individual impact the cognitive process inherent in the model of entrepreneurial choice. This often leads to a view that is remarkably analogous to that concerning technical change in the Solow model – given a distribution of personality characteristics, proclivities, preferences and tastes, entrepreneurship is exogenous.

They suggest that the scientist i.e. the individual knowledge worker and not necessarily the firm is the analytical unit of observation. This scientist has an endowment of knowledge and ideas that is, at least partially, the result of research and interaction within the scientific community. Possibilities for commercialization may arise from this research. In the view provided by the knowledge spillover theory of entrepreneurship, knowledge is viewed as being exogenous and the new firm is created endogenously in an effort by the scientist to appropriate the value of her ideas.

Audretsch et al (2006), Acs et al (2009) and Audretsch (2012a) posit a knowledge spillover theory of entrepreneurship which states that Gazelles are associated with market failures because knowledge, new ideas, and innovation play a key role in the spillover framework. Knowledge generated by failed firms is absorbed in Gazelles which learn from the market about the viability and compatibility of a new idea that was rejected, or undervalued by incumbent organizations. The new startup serves as a conduit for knowledge spillovers from the source producing that knowledge to commercialization in a new firm.

Since investment activities in Gazelles foster their productivity, support should be provided to Gazelles for accessing requisite consulting services, specialized technologies, and obtaining

information and expertise. Gazelles may benefit from assistance in accessing international markets which can help facilitate their rapid growth. Hence institution building for innovation should center on this catalytic type of firm.

The concept of Gazelles is similar to that developed by Wong et al (2005) for entrepreneurship. Wong et al (2005) distinguish between the following types of startups or entrepreneurial entities: opportunity, necessity and high growth potential. The cross-country growth regressions show that only entrepreneurship of the latter kind is robustly associated with economic growth.

## **2.1. From the level of the scientist to the economy**

The paper by Pyka and Saviotti 13/2011 describes the broader problem of the economy from the perspective that since firms both innovate in terms of variants, quality and efficiency – they conclude that in the eco-system there must be more creation than destruction. As the economy evolves it goes through a process of widening (adding new activities, industries or products – also sometimes called the extensive margin) and deepening (improving or bettering conditions for existing activities through incremental and process oriented innovations and product variants – also sometimes called the intensive margin). All else being equal, total potential economic space increases as more and more types of activities are made possible through innovation.

As capitalism matures this feature may become more important for policy-making. If resources are scarce, from a policy-maker's perspective, the natural conclusion will be to make sure that there is sufficient rivalry and selection among firms. Whereas the normal state of crisis economics is to think exactly the opposite way (e.g. the problem of policy-making is always thought to be done under a scenario of unemployed factors of production).

### **2.1.1. The importance of aiding factor markets to cater to the demand of entrepreneurs**

Under an ever widening and deepening scenario, a central problem of new entrants may be access to sufficiently qualified employees including access to credit in competition with an increasing number of incumbents over time. The process of innovation may also be improved by making the trial-error process itself of widening and deepening more efficient. This is exactly where the demand for innovation comes into the picture. If entrepreneurs and fast growing firms or Gazelles are better at anticipating what the market needs (Lerner, 2009) supporting them will lead to more innovation. The fostering of entrepreneurial skills to

decipher and understand market information related with demand for innovation is therefore extremely crucial.

This is also the finding of the German study of Gazelles (Dautzenberg, 2012); shortages of skills and financing are the two most important barriers to the emergence and growth of Gazelles. A shortage of skills, however, cannot be understood in isolation from the underlying factor markets such as the education sector and also the perceived advantages of the skilled to work in a newly established firm compared to a long established firm.

Gazelles by their very nature could be attracting employees that are more willing to take risks and prioritize other factors besides pay such as freedom and participation in decision-making in the workplace (Toner, 2011). If the returns are approximately the same, rational behavior should lead people to choose the less risky employment option (Aronsson, 2004). Therefore we conclude that securing sufficiently qualified and motivated employees is at least as difficult for new firms as it is to secure credit or capital.

## **2.2. Gazelles and the international and global scene**

One important factor that may fuel the competitive process is the international economy and the specialization and selection that it gives rise to. The importance of openness to international competition and rivalry should therefore increase over time under a scenario of more creation than destruction. Returning to the idea of the widening and deepening of the creative eco-system that most papers in Work Package 4 build upon, with international trade and production part of the economic space is so to speak 'deleted' or moved abroad so there can now be many empty spaces in the economy as these spaces are now taken care of by producers abroad. Trade and foreign direct investment can lead to displacement effects in the eco-system that could hamper or further the innovation process and fundamentally change incentives for where innovation can and will take place (Dachs and Peters, 2013).

Leading up to Work Package 8, we therefore anticipate that under a demand-based rather than ordinary supply-based approach to innovation, the international aspects of production take paramount importance exactly because of these displacement effects.

The empirical evidence provided by Antonelli and Fassio 3/2011 suggests that globalization has sped up the process of technological change in the advanced economies. In the years 1995-2006, it is the R&D intensive sectors, characterized by high levels of product innovation, increased levels of wages and skills and strongly biased in favor of skill-intensive

technologies, that expanded. This is also corroborated by other evidence showing that globalization has led to increasing polarization in particular between skilled and unskilled workers (Wood, 1998).

For example, with the emergence of many new market economies such as Brazil, China, India, Indonesia and Russia the demand for innovation as such may perhaps not change much in the product life cycle at least in the early phases of global change (Vernon, 1979). However, returns to innovation may be strongly affected as the benefits from deepening will no longer necessarily accrue to the eco-systems that invest in widening or radical innovation and this will put pressure on the viability of the trial-error process in the most innovative countries (Krugman, 1979, Segerstroem, et al, 1990). This observation is corroborated by the evidence in Antonelli and Colombelli 4/2011. The authors base their evidence on a panel of European firms over the period 1995-2003. The results here show that smaller firms are more vulnerable in the international economy as they will react more defensively, whereas large firms are better able to capture the benefits from globalization for their innovation programs. This is also corroborated by a cross-country comparison using firm level data across 18 economies as reported in OECD (2009).

All of these observations only strengthen the policy conclusion that small firms and in particular the most deserving ones, such as Gazelles, should be the target of policy.

The Gazelle type of firms as introduced above may therefore experience increasingly difficult conditions at home for various reasons (such as ‘mutant’ Gazelles that do not invest in widening but are good at deepening and alliances which can bridge factor market bottlenecks and lack of international experience more quickly) and be under pressure to go global from their inception. This is much more difficult than taking an existing product to the international marketplace (Madsen and Servais, 1997). This could be one explanation for their relative decline in Europe after 2000 as discussed earlier (see also Dautzenberg, 2012, Graph 4-1). This evidence was also corroborated by work package evidence on the relative decline of entrepreneurial firm populations in Italy after the market reforms introduced in the 1980s and 1990s.

### **2.3. Summing up the main policy lessons on Gazelles**

For the main policy lessons, the research by Colombelli et al 6/2011 is informative. It is based on a sample of 335 European firms from various EU countries (UK, Germany, France, Sweden, Italy and Netherlands) over the period 1988-2005. This study and several related

studies in the work package show robust evidence on Gazelles as being the most innovative firms – e.g. they follow an ‘exploration’ (innovation) strategy unlike their less rapidly growing peers. Colombelli et al 6/2011 suggest the following policy-implications of their findings: *“In terms of policy, this gives some important arguments to consider higher growth firms as a distinctive population, outperforming both in terms of sales and in terms of innovation, thus deserving a specific attention. Our results call for the integration of innovation policies with industrial policies directed towards the support of high-growth firms so as, first, to strengthen the dynamics that lead Gazelles to be innovative and, second, to take stock of their ability to widen the knowledge base to increase further their performance in terms of sales. Innovation policies are indeed often evoked as strategic tools to foster economic growth, by placing particular importance, on the one hand, on the interactive dynamics of knowledge production, hence implementing conditions fostering the creation of clusters, and, on the other hand, on the identification of key sectors. These are important issues and we think that our analysis adds another important dimension there.”*

The scientists in Work Package 4 thus underscore the importance in policy-making of getting the incentives right for Gazelles, especially fostering the creation of clusters. We fully support the Colombelli et al 6/2011 recommendation to *“explore incentives and tax credit towards high growth firms which are transversal to all industries, and supporting an innovation policy that could be classified as a horizontal industrial policy. High-growth firms should therefore be the target of innovation policies aiming at fostering the exploration of new technological fields susceptible to provide the basis for the elaboration of new business opportunities, exploration based on the screening of more complementary fields”*.

However, the “identification of key sectors” is not necessary to support Gazelles. On the contrary, any policy that picks the sectors to be supported in advance will not allow the most innovative Gazelles the freedom to choose to their own sectors based on their creativity and entrepreneurial instincts. Even if industrial policy has a rationale for large companies or national champions, it is mostly counterproductive for Gazelles as it rests on fundamentally supply-based assumptions. (See below where we return to the topic of spatial strategies.)

On the other hand, based on our readings of the broader literature and using the demand-based perspective, we would advocate for an integration of Gazelle or entrepreneurship policies with international trade policy. However, this is a separate problem that we return to in Work Package 8.

### 3. Factor markets I – Access to finance

One of the most commonly recognized problems of new start-ups and Gazelle firms concerns their lack of accumulated resources and thereby their ability to invest from their own earnings (King and Levine, 1993). Gazelles are therefore likely to suffer from problems of market failure in factor markets. Here we first discuss the problem of money capital as a resource and in the next section turn to factor markets for knowledge and human capital.

The paper by Kraft, Quatraro and Saviotti 7/2011 investigates the co-evolution of new technologies (bio technology) and new organizational forms (alliances) using the global pharmaceutical industry as a case study. The authors use an exhaustive firm level database that enables them to compare experiences across the USA, the EU and Japan. From this paper we learn a practical case of how new technologies such as bio-technology can rejuvenate existing industries and thereby create a reversal or radical change in the industrial landscape. This paper therefore further confirms the idea that the transition between Schumpeter Marks I and II is not necessarily linear nor terminal, but constantly recurring or cyclical.

The emergence of new technologies and new organizational forms are closely interrelated. From a policy-maker's perspective what is perhaps lacking a bit in this picture is the question of causality. Where should we set in if we want to aid the process? For example is it the alliances that cause the innovation or is it the potential for innovation that cause the alliances? As the authors acknowledge this is considered a co-evolutionary process without any necessarily inherent cause-effect relationship.

However, the data and observations from the three geographically separate continents demonstrate some major differences. Entry rates, or the emergence of entrepreneurial firms, are intrinsically much higher in the US than in the EU and Japan. Meanwhile, the propensity to engage in alliances is highest in Japan.

One reason why the propensity for entrepreneurial firms to enter into alliances with consolidated players in the US may be lower is their easier access via the market to crucial resources such as venture capital (see next section). The opposite is true for Japan. Hence alliances may not necessarily constitute a solution to market failure (for combining knowledge) but could also be seen as a symptom in the factor markets.

### 3.1. Venture capitalism – any alternatives?

In this perspective the contribution by Antonelli and Teubal (16/2011) is interesting to discuss here as it opens up the possibility of allowing more variability for entrepreneurial firms to introduce new technologies by giving them alternatives to relying on established corporations and their established access to sales and finance.

Schumpeter, Antonelli and Teubal retrace the steps in the history of financial institutions as a means of raising capital for investment-hungry entrepreneurs. In Schumpeter I, finance is secured through the innovative banker, who is considered the ideal entrepreneur in the early stages of capitalism, since he has access to finance, knowledge and the critical skills that go into trying new things. Later in Schumpeter II, Antonelli and Teubal describe how Schumpeter increasingly finds praise and a significant role for the large corporation in reducing the distance between the capital market and the entrepreneur.

However, in today's perspective there is a relative disillusionment with the continued innovativeness of large corporations (or bureaucracies), which tend to be taken over by rational and process-oriented managers rather than innovative entrepreneurs (who often do not have the political clout and skills necessary to survive with radical ideas inside these firms).

Hence a renewed role for institutional innovations such as venture capitalism can fill the void for a reemergence of entrepreneurial firms that are looking for funding in the mature form of capitalism. Furthermore, venture capitalism may play an important role through the entrepreneurial and demand-oriented expertise that this particular form of equity investment gives rise to. For example, it is a 'qualified' type of lending from an innovation perspective compared to other more ordinary types of credit as venture capitalists are often experienced entrepreneurs themselves.

The German Mittelstand has become a model that many countries, especially in the industrialized world, observe with much interest. In effect, one of the main reasons why Germany was able to successfully overcome the financial crisis was its very solid and competitive Mittelstand basis. But the Mittelstand companies have not been open to growth. Since the majority of the companies are family businesses, the owners do not want to risk loss of control. Yet, recently, more and more German Mittelstand companies are financing their strategic expansion with venture capital. Venture capital firms focused on Mittelstand

companies therefore expect a positive development in the venture capital market despite intense competition for attractive investments and ever increasing company prices.

Several EU countries – including Germany – are not doing well relative to the US (OECD, 2010). Yet, from the Antonelli and Teubal analysis, we gain relatively little knowledge about how other countries and regions can learn from the US in this area which was the first region to develop venture capitalism in response to the ICT revolution. For example, what are the potential mixes of private and public sector engagement to stimulate the development of venture capitalism?

Commenting on Lerner et al (2012), Goldberg questions the basic tenet of the Lerner report, namely that the US venture capital-based model is necessarily the only, or even the best, option for Russia, as the report implicitly assumes. He argues that the Lerner Report should consider alternative models for Russia from other highly developed countries in Continental Europe such as Germany. The Continental model is not necessarily a better model than the US one but perhaps it is a more realistic model for Russia to emulate, given its diverse objectives and continued systemic problems due to a failed transition in many areas of the economy.

The Lerner Report argues that the response to the reluctance of company owners to share equity with venture capital could be that after dilution, “they (the owners) will have a smaller share but of a company that will be worth much more”. This logic does not seem to have influenced the German Mittelstand over the many years of their success. The German government (among many) is increasingly interested in such high growth firms. At Fraunhofer MOEZ in Leipzig, they believe that high growth firms have to be discussed in the context of the whole economy, particularly in the context of the question: “Why don’t the Mittelstand become high growth firms?” The success of the German economy has been traced back by many to the Mittelstand, which represents middle-sized, oftentimes family-owned companies with very modest ambitions for growth. Bjuggren and Sund (2001) show that family ownership decreases the probability of being a high growth firm. According to the literature (e.g. Poutziouris 2001), the family owners are frequently reluctant to dilute their ownership; in particular, they refuse venture capital. This presents a question: if the Mittelstand are not willing to raise funds via a public offering, how will they be able to expand beyond the scale allowed by bank loans or retained earnings? Does the public offering infrastructure support entrepreneurial firms? The German Mittelstand represent an important example of a unique type of corporate governance: a family founded and owned company that has been very successful in exporting worldwide.

Yet, a key argument for the US venture capital-based model is presented in Lerner's section on Externalities of Venture Capital which states that the (Lerner, 2009, pages 67-68): *"arena created for innovative firms and speculative investors by venture capital can be especially critical in unlocking economic potential in countries controlled by established family firms."*

In a more history-friendly perspective, the main problem today for governments and policy-makers in the European Union is to understand: 1/ the specific needs for developing better institutions to accommodate the matching of risk-willing capital with innovative ideas, 2/the particular mechanisms such as venture capital whereby they can be filled and 3/opportunities and constraints imposed by current technologies. The latter could also include some consideration of how new technologies sometimes lead to unintended and unplanned for outcomes from the perspective that institutions are always running behind new technologies trying to find better means of regulating things that are still not fully understood.

Governments increasingly may need to be able to establish special task forces or expert groups that can add insight to why existing institutions run astray under the combined pressures of new technologies and globalization. For example, the present banking crisis in Greece, and in particular Cyprus, seems to be a combination of such factors.

Finally, venture capitalism as a specific mechanism for solving the matching problem in Europe may also be met with cultural barriers to its adoption, as exemplified by the German Mittelstand discussion above. The willingness to take and share risk is culturally embedded (see e.g. Wennekers et al, 2010) and depends both on culture and formal institutions such as insurance (Park et al, 2002). Hofstede's measurement of uncertainty avoidance as a universal aspect of culture may determine and itself be co-determined by formal institutions as ways to ensure against risk in all aspects of society (Hofstede, 1983, Bruton et al, 2005).

The ability to ensure or hedge against risk may be quite important for lenders. Societies that rely heavily on insurance may not be willing to adopt venture capitalism – e.g. there will be a lack of demand for it – simply because venture capital as an institution does not incorporate any mechanism of insurance to the lenders.

Lenders under venture capitalism per definition therefore also need to be more knowledgeable than average lenders and such lenders (e.g. lender entrepreneurs) may be in undersupply outside the US. A stronger priority for economic equality via mechanisms of redistribution may also act as a deterrent to the emergence of such lender entrepreneurs in

egalitarian Europe in particular, though in recent years the class of super-rich has been expanding even in Scandinavia (The Economist, October 13, 2012.)

Of a much more fundamental nature is the problem that firms and lenders in the capital market do not trust each other (the claim here is also that insurance can help build trust), including the government and its institutions. Under such a scenario, the demand for venture capital is likely to be low as well.

A fourth yet complementary governance form in terms of securing finance for innovation is discussed in the paper by Antonelli, Amidei and Fassio 5/2012 which offers a historic perspective on the traditional role of state-owned enterprises in Italy in the national innovation system. However, pure reliance on the public sector as caretaker of finance for and the creation of knowledge has been strongly declining over the last 30 years and is not considered to be important for policy implications.

In summary, different strategies for finance for innovation exist which are mirrored by different governance systems. One prominent form is venture capitalism. This is likely to be more in demand in eco-systems that accept risk, have preference for efficiency over equity, and exhibit high degrees of trust combined with low reliance on insurance as an institution. Another much discussed form is the German Mittelstand or corporate governance of entrepreneurial firms through family ownership. This model is more likely to be in demand in eco-systems that are risk averse.

## **4. Factor markets II – Access to knowledge and skills**

An equally important problem concerns the availability of knowledge and skills in factor markets as inputs to the innovating firms. Compared to the looming literature on finance, problems with the demand for skills among entrepreneurial firms seems greatly under-researched in economics (LeBrasseur et al, 2003). We first discuss the general problem of creating markets for knowledge and then turn to the role of the education sector in supplying skills that are critical for Gazelle firms.

### **4.1. Ontology of knowledge – internal and external forms of knowledge**

The remaining part of the papers in work package 4 that take a focus on the firm are centered on the question about the ontology of knowledge and the further development of foundations for the economics of innovation.

Antonelli (19/2011, page 5) describes the main concern as follows: *'the new growth theory fails however to accommodate the heterogeneity in time and space of the actual rate of introduction of technological innovations. Much evidence shows that the rates of technological change are far from being evenly distributed across historic times, industries and regional spaces. On the opposite they concentrate in historic time within well identified gales that are located in defined portions of the industrial system and regional space that do keep changing (Abramovitz and David, 1996; Mokyr, 1990, 2002).'*

In Romer (1994), space does not play any role where innovation or technological change takes place. Antonelli 19/2011 breaks with the neoclassical tradition by assuming that “A” in the production function is partly determined by where and therefore also who produces it.

Standard approaches have been either as in Solow (1957), who assumes that “A” or total factor productivity in the production functions falls as manna from heaven, or as in some of the more important applications which model “A” or total factor productivity as mainly consisting in intra-mural R&D and its spillovers (Griliches, 1992). In Romer’s elegant neoclassical model it is not possible to confront the question of why some firms are more innovative than other firms.

The relative size of the R&D sector in Romer is solely decided by the returns to innovation (that are again fundamentally driven by the interest rate since a lower interest rate gives the capital goods firms incentive to develop more variants and thereby demand more designs from the R&D sector). The returns to innovation form the basis on which human capital decides where to take up work. Hence Romer’s main policy conclusion is to secure finance capital at a low cost for the capital goods sector that pays the R&D sector in order to attract more workers into the R&D sector.

Without emphasizing the “who” question, we are also more prone to get linear predictions for the knowledge production function which, as Antonelli explains, so poorly mirrors the reality of the knowledge landscape of the real world.

Instead Antonelli assumes that “A” or total factor productivity is a composite of external and internal knowledge. The question of how much to use of each is decided in this model by a similar cost-minimizing problem of choosing between capital and labor in standard production theory. Therefore, Antonelli implicitly provides a foundation that opens up a new way of understanding firm strategizing problems in relation to innovation. This new way has a very

strong character of a public good provision type of problem for the firm, its city, region, industry etc.

Hence according to Antonelli, and with the help of Marshall, we can add to the Schumpeterian problem of creative-destruction (page 6 above) a 5<sup>th</sup> item: give firms incentives to contribute to the public good aspects of their own internal knowledge.

Knowledge as a fundamentally public good (though partly excludable) or formed partially through a social innovation process (Taylor, 1970) is subsequently a central theme in several papers in this work package. Implicitly, we now also understand that innovation is much more prone to happen in those cities, regions or industries where firms for some reason or another are willing to contribute to the public good.

Anyone who has tried to work in an innovative or a non-innovative type of organization or economic environment can relate to this problem. This is exactly what Google did for the state of California (Vise and Malseed, 2008).

## **4.2. What can policy-makers do to crowd-in investment in knowledge?**

These foundational ideas are followed up by a number of empirical papers in the work package. The first paper is by Antonelli and Scellato 18/2011. The authors test the idea that innovation as in this paper proxies with total factor productivity or that “A” may be explained in part by pools of knowledge that are external to the firm and residing in different places of the eco-system.

For this purpose the authors use a large panel dataset for 7,020 Italian firms over the 1995-2006 period. External knowledge is decomposed into a region-specific, a sector-specific and a combined (both region and sector-specific) effect which is hereafter termed localized effect. The results underscore the importance of external pools of knowledge in driving the development of firm-specific total factor productivity levels. All the aforementioned effects are positive. In one regression (without controlling for potentially spurious effects due to the way the agglomeration variables are specified), the authors find the following relative ranking of external pools of knowledge: sector>region>localized. Controlling for the methodological problems of double counting in some of these effects (there are both arguments for and against that this should be a methodological problem) – suggests instead the following ranking: sector>localized>region. Either result suggests that the most important form of external knowledge resides with the sector and secondarily with the location.

A related paper by Antonelli and Fassio 5/2011 has a similar objective but measures innovation using the results from the Community Innovation Surveys from the period 2002-2004. The dependent variable in this study is the introduction of a product or process innovation by the firm. The data coverage is cross sectional but now includes a wider dimension of European Union innovation environments: Belgium, Czech Republic, Germany, Italy, Norway and Spain. In principle the research question is quite similar to the previous one, even though the angle and focus are somewhat changed. Another important addition to this paper is the notion that spillovers are not freely captured. In fact, in this paper the access to usage of external knowledge is also considered the deliberate outcome of the firm's investment in what Cohen and Levinthal have coined 'absorptive capacity' and proxies very precisely in this paper as well with investment in extramural R&D.

The results demonstrate again how innovations by firms may be explained by external pools of knowledge. In this paper, the external pools of knowledge are proxies at the sector level (horizontal pools of knowledge) using either the sum or the average of sector R&D, whereas they are proxies for the pecuniary relationships among users and producers (e.g. through up- and downstream relationships in the value added chain) with firm-specific investment in capital goods. The results show that innovation is generally spurred by both types of external knowledge. Furthermore, the authors also find that to produce innovation, horizontal or sector level external knowledge is relatively more important, unlike in process innovation where the vertical dimension (or user-producer relations) of external knowledge is relatively more important.

The paper by Antonelli, Crespi and Scellato 6/2012 uses the aforementioned sample of 7,020 Italian firms over a period of almost a decade to investigate the question of innovation persistence. They argue that if innovation is purely based on internal processes in firms (e.g. as explained by the resource-based theory), there should be no role for external factors in terms of explaining innovation persistence.

Hence they add content to the concept of 'path dependence' as a combined outcome of innovation in firms taking place in a specific contextual or embedded setting that may be co-explained by what takes place in the external environment (hence the importance of externally available knowledge).

The dependent variable is still total factor productivity but the analysis now shifts to become centered on the Transition Probability Matrix which is an advanced method that takes into account something similar to the various sources of serial correlation (correlations over time)

in economic data. In simple words, the authors investigate whether the total factor productivity of a firm in the present period is more strongly correlated with its own past total factor productivity, the past total factor productivity of the sector (and hence of external origin), or both.

The authors find that the persistence of innovation is explained by a number of factors, not only the firm's own past record of innovation but also BOTH the co-existence of externally available knowledge and the competitive pressure or the intensity of rivalry in the same product market.

Taken together these three papers (as complementary and mutually supportive from a methodological viewpoint) render very robust results to the importance of external pools of knowledge in the innovation process.

From a policy-making perspective, the results suggest that investment in geographical clusters or national communities of industries and/or combinations hereof are likely to be good strategies to facilitate community-building among firms, which, in turn, may make them more likely to contribute to the public good that is "knowledge". These observations are also strongly corroborated by earlier evidence in the literature – see for example Audretsch (1998) and Rocha (2004) even though Gordon and McCann (2005) produce some evidence to the contrary at the city level for London but they focus specifically on startups.

In order to contribute with more complete answers for policy-makers as to what the best sector and spatial strategies are, it would be necessary to evaluate particular policies in this area such as the building of special economic zones or geographical clusters with and without a sector focus, including e.g. building national communities of firms in certain sectors without an implicit geographical strategy etc.

Oughton et al (2002) discuss the paradoxes involved in combining spatial strategies or regional policy with innovation policy. The regional innovation policy paradox here concerns the problem of transferring technology and innovative capability to lagging regions in combination with the fact that they are the least capable of absorbing public support such as R&D funds. Overall there does seem to be an acute lack of knowledge about how these policies work based on actual data beyond the case study level.

Taken together with the foundational and empirical evidence, there is little doubt that policies that are generally able to give firms incentives to both contribute to and benefit from external

pools of knowledge can offer returns for national innovation outcomes. However, there are also many barriers and problems to the successful implementation of such policies that need to be understood much better and especially in Europe where regional history is dense and often complicated.

These ideas therefore also make room for a more responsibility-based type of public policy-making in the area of support for innovation. For example, if firms receive public support they must also give part of the knowledge they generate back to society. This should increase the public return from innovation policy. The uncertain factor seems to be how this will affect the firm strategizing problem and whether firms would respond to such incentives in unpredictable ways.

Culture may be very important in this respect, e.g. how much we trust our peers and our community in general is one of the fundamental explanatory factors of why people are willing to contribute to public goods in mainstream research, including the novel area of experiments and behavior. Communication, network, peers and trust may be overshadowing factors in understanding why geography or locality should matter so much relatively to innovation.

### **4.3. Supply of skills from the education system**

While firms play a central role in the innovation system as the main actors, the education sector may perhaps play a much more important role if entrepreneurs and Gazelles are considered critical in moving the economy and innovation forward. The education system can help foster entrepreneurship in its own right and supply skills for Gazelles that are in need of attracting highly skilled workers (Toner, 2011).

In Furman et al (2002), one of the only existing cross-country studies of innovation, manpower and skills stand out as some of the most important factors contributing to both a higher demand for innovation and higher R&D productivity at the country level.

First, successful innovation depends to some extent on excellence in education and strong and active links between knowledge generation, knowledge exchange, and knowledge exploitation (i.e. between universities and firms).

From the US experience we know that Stanford University has had a tremendous impact on the emergence of high-tech companies in Silicon Valley, starting with Hewlett Packard all the way to Google. The research performance of Europe's universities seems to lag behind that

of their US counterparts, particularly in the top 50 universities in the Academic Ranking of World Universities, also known as the 'Shanghai ranking' (Aghion et al, 2008).

Care should be taken in interpreting the results of any index since they inevitably contain biases. Moreover, it should be noted that even in the Shanghai ranking, a European 'top' university tends to be among the best 25% in the world in at least one discipline, although the number of disciplines in which it is world leader is on average substantially lower than that calculated for a top US university (Moed, 2006). In other words, while there are centers of elite academic research in the EU, there are simply many more in the USA. These centers of excellence may well be the engine of innovation. Moreover, it is around these centers that clusters of innovative companies have formed, such as around MIT and Stanford.

Recent case studies of these clusters show that the past matters relatively more than present policy context for starting up new clusters (Bresnahan et al, 2008). Cumulative business history may therefore be a fundamental barrier to innovation that is strongly embedded in the locality.

A number of papers in Work Package 4 deal specifically with the education sector and how it affects the innovation system. The focal questions here are on the education sector as a contributor to the massive amount of knowledge available in the economic environment and to the firms, and secondarily but no less importantly, the role of the education sector in delivering knowledge workers to the firms or the 'R&D sector'.

Antonelli and Fassio 1/2012 discuss the choice between different models of the education system related to the impact that the education system has on the innovation system. Here some models are set up mainly with the objective of education delivering the human capital that the innovation system demands.

The empirical evidence in Antonelli and Fassio 1/2012 focuses mostly on the question of whether certain disciplines are more effective in terms of delivering human capital or skills of a type that will generate higher output? In other words, the authors hypothesize that different types of academic knowledge exert different effects on economic growth.

This is tested using OECD data for the period 1998-2008 covering 16 countries. The results suggest that investment in human capital in the hard sciences and social sciences give positive returns, whereas medical sciences and human sciences have no independent or even a weakly negative effect on economic growth.

Similarly in Antonelli et al 4/2012, we are provided with quite robust historical econometric evidence for Italy (1900-1959) that economic growth responds more strongly to advances in hard sciences such as engineering and chemistry compared with societal investment into other disciplines.

## 5. R&D subsidies

We can classify government interventions in the innovation system into four distinct groups:

1. Providing supporting institutions for R&D in private companies
2. Conducting R&D in state-owned laboratories or similar organizations
3. Providing subsidies to R&D in private companies
4. Offering public procurement of R&D from private companies

Most of the papers in Work Package 4 focus on the supporting institutions for R&D in private companies, but de facto public policies to subsidies R&D in private companies are an important aspect of the innovation system. A few papers in Work Package 4 focus in particular on the role of these policies in the eco-system.

Another central problem in the literature on giving out R&D subsidies is the question of selection which relates more strongly to a demand-side policy perspective. For example, if Gazelles should be the target of policy, the next crucial question becomes how to more specifically target them using particular policy tools such as R&D subsidies?

This is discussed specifically in the context of Work Package 4 by Antonelli and Crespi 15/2011 as the so-called Matthew effect. The effect concerns the fact that early on in the development of an industry, a bifurcation takes place, separating high and low performing firms into two groups that tend to be sustained over time. Translated to the problem of the policy-maker, the question then becomes how to detect, as early as possible, which firms are in the winner group (picking winner strategy) and select them for R&D grants.

The evidence emerging from Antonelli and Crespi's study of Italy for a sample of 750 manufacturing firms in the period 1998-2003 concludes: *'The empirical results show that past grants increase the probability to access further funding. Both the descriptive and econometric evidences confirm our hypothesis on the persistent character of R&D subsidies, that can be interpreted as an indication that some mechanisms related to a Matthew effect is at work for the observed firms. Moreover, the results suggest that the stable pattern in the*

*access to R&D public subsidies by firms is associated with a 'picking the winner' strategy adopted by public authorities, which, positively contributed to the effectiveness of the policy instrument.'*

These findings corroborate the evidence in Lerner (1999) who finds that firms receiving R&D grants under the US government-funded Small Business and Innovation Research program grow significantly faster than other firms after the policy was introduced. But Lerner's results are ambiguous as well in suggesting that the effect may relate more to 'quality certification' by the government enabling the firms to raise funds from private sources. Wallsten (2000) found that the Small Business Innovation Research program crowds out the firm's own research spending about dollar-for-dollar, reversing Lerner's findings (1999) for this same program.

Trajtenberg (2001) reviewed a number of studies of Israel's R&D grant programs and found that there is some evidence, though limited, of a positive relationship between the grant programs and productivity improvements in R&D intensive industries. Lach (2002) found that research support of commercial firms in Israel increased the firms' total R&D expenditure by \$1.41 for every dollar of public research expenditure received. Branstetter and Sakakibara (2000) found that Japanese funding of research consortia increased the R&D of participating firms. Ali-Yrkkö (2004 and 2005) showed that the increase of public funding in Finland did not lead to a crowding out of private R&D funding. Crepon, Duguet and Mairesse (1998) estimate a model composed of three equations: (a) an equation explaining the amount of R&D, (b) an innovation output equation where R&D appears as an input, and (c) a productivity equation, in which innovation output appears as an explanatory variable. This model has been estimated for a number of countries individually: Chile, China, Estonia, France, Germany, Italy, the Netherlands, Portugal, the Russian Federation, Scandinavia and Spain. It has also been run on a pooled sample for France, Germany, Spain and the United Kingdom. Using the French CIS dataset, Mairesse and Mohnen (2005) find that R&D is positively correlated with all measures of innovation output and that innovation is generally more sensitive to R&D in low tech than high tech sectors. They explicitly treat R&D as endogenous and account for the selection of R&D performing firms. They argue that common causal factors of R&D and innovation do not bias their R&D coefficient estimates to the extent that the explanatory variables in the R&D equation are indeed exogenous. Further, Garcia and Mohnen (2010) quantify the effect of public support for innovation on innovation inputs and outputs in Austria. They conclude that government support for R&D to private firms has impact elasticity on sales shares derived from new products with up to 3.4.

## 6. Summary and Conclusion

In the new growth theory or endogenous growth theory that currently forms the state-of-the-art in terms of informing policy-making for innovation, consumers will deterministically absorb all inventions once they have been discovered (Antonelli and Gehringer 09/2012). Hence, endogenous growth theory does not confront one of the important problems of innovation: barriers to the absorption of new ideas on the demand side<sup>1</sup>. A lot of trial and error goes into the process of innovation. The heroes of the Schumpeterian process of creative-destruction, the entrepreneurs and Gazelles, are absent from these theories.

The PICK-ME project as a whole seeks to further the idea that policy incentives should also target the demand-side in order to improve the trial-error process that creative-destruction or innovation is since it will increase innovation, improve innovation efficiency, and reduce wastage of otherwise employable resources.

The main conclusions from the project are that a demand-oriented approach can only be achieved by placing small and fast-growing firms at the forefront of policy-making. Institution building for innovation at all levels should cater to the needs of these firms which do the important job of widening the economy according to what the market demands whilst providing the foundation or seed for future large successful corporations (Pyka and Saviotti 13/2011).

The intervening firm in this process is the Gazelle firm (Colombelli, Kraft and Quatraro 6/2011). This is the catalytic firm that can close the gap between the widening and deepening of the economy which is important for economic growth<sup>2</sup>. This is because (as Colombelli, Kraft and Quatraro's study demonstrates) the Gazelle firm in itself is an expression of demand-pull growth. Only in a combination of its entrepreneurial capacity and a rapid expansion due to sales growth can a Gazelle firm come about.

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<sup>1</sup> The "knowledge Filter" introduced by Audretsch et al (2006) argues similarly that knowledge will not flow automatically from research institutions, universities and large corporation to entrepreneurs.

<sup>2</sup> Where widening stands for the process of adding new products or activities (radical innovation) to the economy and deepening stands for the process of expanding and/or improving (e.g. through learning or incremental innovation) on existing products, processes and activities. Some researchers in the Schumpeterian tradition also see this as synonymous with adding new firms – see e.g. Breschi et al (2000). However, this tautological assumption is more a research question than an established empirical fact.

A Gazelle is a young high-growth firm. David Birch (1990) found in the 1980s that rapidly growing firms, which he termed “Gazelles”, are responsible for most of the employment growth in the economy. While Birch’s definition of Gazelles was based on outliers in terms of an unusually high revenue growth rate, Acs (2011) examines firms with significant revenue growth and expanding employment. Acs uses the terms “high-impact firms” to distinguish them from Gazelles.

Besides building fundamental institutions that support Gazelles, policy-makers can target bottlenecks in factor markets that hinder their growth rates. A demand-side policy will give better incentives for skilled people that are open to risks to work for Gazelles, and better incentives for risk-willing capital to lend to Gazelles. Policies for giving Research & Development (R&D) subsidies should, in a demand-side policy perspective, be constructed so as to target the Gazelle firms.

There is a relative lack of policy-relevant knowledge (e.g. fact-based) about which rules and mechanisms more specifically can help achieve such an important goal. For an early review, see Mowery and Rosenberg (1979)<sup>3</sup>. Mowery and Rosenberg argue that policy needs to combine both the supply and demand perspectives. The traditional supply perspective is well-served by the view that markets generally lead to an under-supply of innovation (market failure).

An alternative policy action program that emerges from giving more attention to the demand side does in our opinion lead to the perspective that policy-makers must facilitate a different kind of process which is more related with coordination and matching demand and supply.

Towards the end of the policy paper for Work Package 4, we try to give some qualified answers to the particular question of how to achieve this. Government interventions and instruments *to support both demand-led innovation instruments (e.g. Public Procurement for Innovation (PPI)) and supply side instruments are important and thus we consider them below in conjunction*. We classify these interventions into four distinct groups:

1. Providing supporting institutions for R&D in private companies
2. Conducting R&D in state-owned laboratories or similar organizations

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<sup>3</sup> Mowery and Rosenberg argue that better policies will emerge from combining the demand and supply side perspectives on innovation. Neither can be ignored in the formulation of policy. Exclusive preoccupation with one or the other side of the market for innovation is what they criticize for often leading to failed attempts at formulating sound innovation policy.

3. Providing subsidies to R&D in private companies
4. Offering public procurement of R&D from private companies or PPI

Group 1 aims to improve the investment climate for innovative firms, which includes reinforcing the regulatory reform agenda, removing barriers to competition, setting standards that aim in particular for product quality and fostering skills development.

Venture capitalism can, in this perspective, be thought of as a novel type of credit institution of late 20<sup>th</sup> century capitalism which serves as an exchange for buying and selling the rights to participate in the development of new ideas or innovations (Lerner, 1999). Venture capitalists step in as a different kind of entrepreneur, representing the demand side by casting their vote for what the expected verdict of the market will be on a given innovation.

In parallel with launching initiatives that support institution building, policymakers should adopt policies to spur participation in world R&D, as collaboration with researchers and multinational corporations abroad is an effective way to tap into the global knowledge pool, enabling both the technological and intellectual transfer of know-how. These policies include: a collaboration-friendly intellectual property rights regime, subsidized exchange study abroad programs for scientists and those with doctoral degrees, free immigration of researchers, and incentives for multinational corporations to establish their R&D centers in host countries (Goldberg et al, 2011, Page 11).

Group 2 uses state ownership as the main tool for supporting innovation. Famous examples include renowned national research labs such as the Department of Energy and the Department of Defense in the USA, the Fraunhofer Society in Germany and the Centre National de la Recherche Scientifique in France. The rationale behind state ownership is that key areas vital to state security and energy are where direct state control over R&D may be highly desirable.

Group 3 includes: matching grants, loans, incubators, industrial parks, loans, guarantees, equity in venture capital funds, special economic zones etc.

Group 4 includes public procurement for innovation (PPI). Here the public sector steps in at the user rather than the producer side of innovation – e.g. the role is exactly the opposite of traditional state-ownership under number 2. Instead, PPI aims to stimulate the demand-side of innovation and alleviate barriers for markets to emerge in the first place. The aim is that

through PPI, the government can provide the necessary demand-side incentives to bring about and/or sustain the innovation process at its very early and critical stages.

Each of these instruments might be appropriate in a specific country situation or policy setup. For example, PPI and state-ownership could, under certain conditions, be preferable to subsidies because they involve more direct forms of interventions, allowing closer control over the early stages of the innovation process in particular.

However, subsidies are more appropriate when flexibility is required of the instrument and allow for stimulating products or services that governments cannot procure or for which there is no immediate demand within the public sector.

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## Appendix

Main topic	Sub theme	PICK-ME Work Package 4 papers
Framing the problem	Transition to a knowledge economy	Antonelli, Cristiano (02/2012) <a href="#">The foundations of a slow growth economy: Globalization and induced technological change towards a knowledge economy</a>
The Firm	Entry	Pyka, A. and Saviotti, P.P. (13/2011) <a href="#">Economic Development – Less Destruction than Creation.</a> Colombelli, A., Krafft, J. and Quatraro, F. (6/2011) <a href="#">High Growth Firms and Technological Knowledge: Do Gazelles follow exploration or exploitation strategies?</a>
	Entry and finance	Krafft, J., Quatraro F. and Saviotti, P.P. (7/2011) <a href="#">Knowledge characteristics and the dynamics of technological alliances in Pharmaceuticals: Empirical evidence from Europe, US and Japan.</a> Antonelli C. e M. Teubal (16/2011) <a href="#">From the corporation to venture capitalism: new surrogate markets for knowledge and innovation-led economic growth</a>
	Ontology of knowledge	Krafft, J., Quatraro F. and Saviotti, P.P. (8/2011) <a href="#">Evolution of the Knowledge Base in Knowledge Intensive Sectors</a> Antonelli, C. (1/2011) <a href="#">The economic complexity of technological change: interactions, knowledge and path dependence.</a> Krafft, J. and Quatraro, F. (10/2011) <a href="#">The Dynamics of Technological Knowledge: From Linearity to Recombination.</a> Colombelli A. e F. Quatraro (03/2012) <a href="#">Persistence of innovation and knowledge structure: Evidence from a sample of Italian firms</a>
	External pools of knowledge	Antonelli, Cristiano (19/2011) <a href="#">Knowledge Governance Pecuniary Knowledge Externalities and Total Factor Productivity Growth</a> Antonelli C. e G. Scellato (18/2011) <a href="#">Complexity and Technological Change: Knowledge Interactions and Firm Level Total Factor Productivity</a> Antonelli, C. and Fassio, C. (5/2011) <a href="#">The role of external knowledge in the introduction of product and process innovations.</a> Antonelli C., Crespi F. e G. Scellato (06/2012) <a href="#">Internal and external factors in innovation persistence</a>

Main topic	Sub theme	PICK-ME Work Package 4 papers
		Quatraro, F. (9/2011) <a href="#">Knowledge Structure and Regional Economic Growth: The French case</a>
	Mechanisms for knowledge governance	<p>Antonelli, Cristiano (19/2011) <a href="#">Knowledge Governance Pecuniary Knowledge Externalities and Total Factor Productivity Growth</a></p> <p>Krafft, J., Quatraro F. and Saviotti, P.P. (7/2011) <a href="#">Knowledge characteristics and the dynamics of technological alliances in Pharmaceuticals: Empirical evidence from Europe, US and Japan.</a></p> <p>Antonelli C., Barbiellini Amidei F. e C. Fassio (05/2012) <a href="#">The mechanisms of knowledge governance: State owned enterprises and Italian economic growth, 1950-1994</a></p> <p>Antonelli C. e G. Scellato (18/2011) <a href="#">Complexity and Technological Change: Knowledge Interactions and Firm Level Total Factor Productivity</a></p>
The Education Sector	Evaluation of public strategies	<p>Antonelli C. e C. Fassio (01/2012) <a href="#">Academic knowledge and economic growth: Are scientific fields all alike</a></p> <p>Antonelli C., Crepax N. e C. Fassio (04/2012) <a href="#">The cliometrics of academic chairs. Scientific knowledge and economic growth, the evidence across the Italian regions 1900-1959</a></p>
	University-industry relations	<p>Antonelli C. e C. Fassio (07/2012) <a href="#">The heterogeneity of knowledge: University-industry relations and the evolution of knowledge governance. The Italian evidence in the first part of the XX century</a></p> <p>Antonelli C., Crespi F. e G. Scellato (08/2012) <a href="#">Inside innovation persistence: New evidence from Italian micro-data</a></p>
The Government	R&D subsidies	<p>Antonelli C. e F. Crespi (15/2011) <a href="#">The "Matthew Effect" in R&amp;D Public Subsidies: The Italian Evidence</a></p> <p>Antonelli C. e F. Crespi (17/2011) <a href="#">Matthew Effects and R&amp;D Subsidies: Knowledge Cumulability in High-Tech and Low-Tech Industries</a></p>
	Procurement	Antonelli C. e A. Gehringer (09/2012) <a href="#">Knowledge externalities and demand pull: The European evidence</a>
Other	Globalization	<p>Antonelli, C. and Fassio, C. (3/2011) <a href="#">Globalization and innovation in advanced economies.</a></p> <p>Antonelli, C. and Colombelli, A. (4/2011) <a href="#">Globalization and directed technological change at the firm level. the european evidence.</a></p>

Main topic	Sub theme	PICK-ME Work Package 4 papers
	Institutions	Antonelli, C. and Ferraris, G. (11/2011) <a href="#">Innovation as an emerging system property: an agent based simulation model</a>