



JRC POLICY BRIEF

Leading R&D Investors for the Dynamics of Innovation Ecosystems

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Key messages

- » Innovation is increasingly complex, systemic and organized through global scale networks driven by multi-technological firms and shaped by the interactions of multiple-players.
- » Knowledge integration is a key process to combine complementary and specialized knowledge and keep the edge in the global competition. Ecosystems of innovation are privileged 'places' where this can happen.
- » Innovation ecosystems involve new opportunities and risks around three main dimensions: Interdependence, Integration and Initiative. Leading R&D investors hold the specific assets to play a pivotal role along these dimensions.
- » Policies to support the functioning of innovation ecosystems should be adapted to the stage of development and the objectives set by the stakeholders of the ecosystem.

1. Introduction

This brief discusses the key role of large R&D investors in the dynamics of innovation ecosystems and highlights a number of policy relevant issues in the context of the design and implementation of industrial innovation policies.

Inspired by interactions with industrial representatives and academic experts, it sheds some light on two important concepts - the knowledge integration and the innovation ecosystems - reflecting the complex, interactive and systemic nature of innovation, and the transformations in corporate innovation models.

The increasing global competition and the higher speed of innovation cycles pose huge challenges on the organization of innovation processes, leading the firms to develop more and more complex innovative solutions in interaction with multiple-players. In this

environment, integrating dispersed and specialized knowledge becomes a key strategic dimension to keep the edge over competitors. Nowadays ecosystems of innovation are the privileged 'places' where the integration of knowledge from different parties can be organised in a way that ensure the creation of a higher collective value. However, innovation ecosystems also entail costs and specific risks that require specific capabilities and a critical mass of resources that are concentrated in few firms. In particular, large R&D investors operating on a global scale are pivotal actors in the dynamic of ecosystems. In this framework, policy makers should facilitate the functioning of ecosystems and foster the integration of local actors in these new knowledge networks.

2. The relevance of knowledge integration for innovation in a global context

The innovation context of firms: complexity and global dimensions

The investments in intangible capital constitute a key source of growth in knowledge-based economies. In addition to increasing research and development expenditures, firms are relying on a larger palette of intangibles assets such as patents, trademarks, copyrights, industrial designs, software and databases as well as various economic competencies such as market search, worker training, and organizational investments (Dernis et al., 2015; OECD, 2013). This shift reflects, on the one hand, the responses of firms to the higher replacement rates of old products, higher risks of imitation and the increasing complexity of innovations. On the other hand, as creative destruction occurs at a faster pace, firms have to integrate different types of (technological) knowledge and offer at the same time a wider variety of products based on the (re)combination of multiple technologies.

As a response to this new challenge, the international activities of firms are now increasingly shaped by knowledge-sourcing considerations, often for assets exploiting or assets augmenting purposes. In broadening the range of technologies they master, firms have diversified their knowledge sources and are now organizing R&D activities on a global scale. In the search for knowledge firms favour locations with high-quality labour (R&D personnel) and high potential for agglomeration economies including proximity to other companies' sites, technology poles and incubators, and suppliers (Moncada-Paternò-Castello et al., 2011; OECD, 2011; European Commission, 2014b).

The relevance of knowledge integration

In today's innovation-driven economies, firms rely more and more on the exploitation of external knowledge and technologies, and on the deployment of more sophisticated processes.

In this context, knowledge integration constitutes a key mechanism of corporate innovation strategies, which requires the management of individual, specialised, interdisciplinary knowledge, and specific organizational and inter-organizational capabilities. As knowledge becomes a key resource, knowledge integration becomes a key process in the organization of firms and for the development of their competitive advantages (Grant, 1996a,b; Spender and Grant, 1996). The process of

knowledge integration may be defined as “*the combination and integration of complementary knowledge bases which, in turn, may require both internal knowledge creation and absorption of external knowledge sources*” (Berggren et al., 2011 – p. 9)¹. The outcomes of such a process include the creation and the integration of new knowledge into new products and processes, and the further development of organizational capabilities (Enberg et al., 2006). Knowledge integration is a challenging process as firms are bridging the knowledge boundaries to develop their know-how. Within this perspective one of the main issues for organizations, perceived as integrators of specialized knowledge, is the coordination of the specialized knowledge.

In their search for new knowledge, firms may also rely on knowledge brokers or independent innovation intermediaries. Alternatively, it may be channelled by large R&D investors with resources and capabilities to acquire and absorb dispersed and specialized knowledge (Tell, 2014). In this process ICT technologies play a key role as they reduce the communication costs and facilitate a faster codification, exchange and treatment of information. As knowledge sources and complexity increase, firms may need to reduce the internal complexity in order to optimize the integration of external knowledge from the innovation ecosystems. In some cases, this involves an organizational split across specialized fields or the separation of innovation-knowledge fields within the company (Hervás et al., 2015). Indeed, as they are operating in increasingly open and multi-player environments, large multidivisional and international firms face, to a greater extent, a dual challenge in terms of internal and external knowledge integration.

In this context, the decision of knowledge acquisition is also subjected to the classical make-or-buy decisions as firms are willing to access the best knowledge at lower costs and, at the same time, keep their in-house absorptive capabilities (Cohen and Levinthal 1990). In their knowledge search and acquisition, firms also have to deal with the internal stickiness or the difficulty of transferring knowledge within the organizational boundaries of the firm (Szulanski, 1996). The diffusion of ICT has facilitated the internal codification of organizational routines, and thus the internal knowledge transfer. Yet, this may increase at the same time the odds of leakage due to a high codification that facilitates the transfer of capabilities (Kogut and Zander, 1995). Nowadays the access to external knowledge

¹ In the book, they also provide the multiples existing definitions of the concept of knowledge integration. See also Jetter et al (2006) for complementary references on knowledge integration in SMEs.

is decisive for new technological opportunities and for the creation of higher value, but internal R&D is necessary to absorb the external knowledge in order to unlock its potential and appropriate part of the value generated. Altogether, these elements point to the many challenges raised by the integration of knowledge in a competitive, networked and open innovation² context.

3. Innovation Ecosystem as a new organisational mode

Innovation ecosystems commonly refer to the collaboration of more or less interconnected actors – entrepreneurs, firms, universities, other education organizations and research centres, investors and funding agencies, intermediary agencies and regulatory organizations – whose main goals include the generation of synergies and the creation of new knowledge and innovations. The achievement of this goal implies that different actors should combine resources, capabilities, and products (technologies) to offer a coherent, customer-facing solution.

In addition to the organizational and interactive dimensions put forward in the knowledge integration perspective, innovation ecosystems very often entail strong geographical and/or technological dimensions, which are crucial in shaping the system dynamics. Said differently, ecosystems of innovation involve actors that could be either geographically localized or organized through international networks for the development of a specific technology (Tobias et al., 2006).

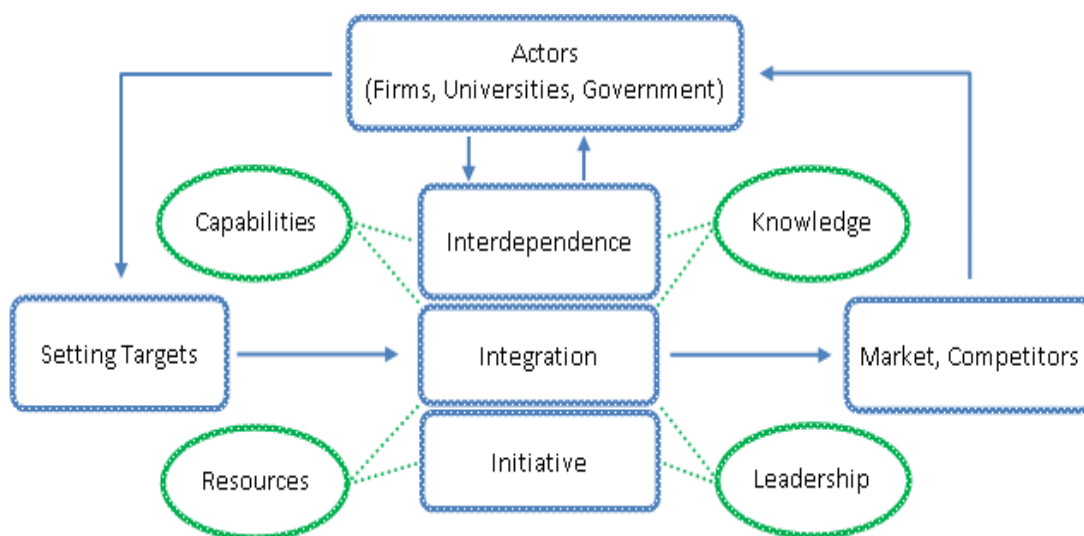
Ecosystems, when successfully managed, allow for the creation of a value higher than those of the single firms would have created alone, but also entails costs and risk (Adner, 2006). In particular, the risks as well as the benefits associated with innovation ecosystems reflect their three fundamental dimensions: *Interdependence, Integration and Initiative*.

Figure 1 provides a synthetic description of the elements operating in an innovation ecosystem. The blue rectangles represent the dimensions and actors involved, and the green ovals are the assets required for the functioning of an innovation ecosystem.

First of all, as defined, innovation ecosystems involve some degree of interdependence between the actors involved. The complementarity among knowledge blocks (or technologies) brought to the system by each actor creates strong dependencies among them. Actually, the success of an innovation ecosystem depends, to a great extent, on the probability that all the different actors will be able to timely satisfy their commitments and, therefore, requires strong coordination and interaction efforts and capabilities.

Secondly, an innovation ecosystem requires the integration (or adoption) of the new solutions along the value chain. This postulates that integration capabilities and knowledge are necessary but not sufficient conditions.

Figure 1: The anatomy of an innovation ecosystem



Source: Authors' elaboration from Adner (2006)

² See Chesbrough et al (2006) for detailed discussion on the notion of open innovation, and Huizingh (2010) for a review of the literature on the concept.

Indeed, in order to ensure a rapid adoption of the new solutions, the key player(s) should consider the possible bottlenecks along the value chain and eventually dedicate a special attention to them; this requires both (monetary) resources and leadership. Allocating resources to solve bottlenecks throughout the ecosystem could be a more cost effective strategy than trying to optimize its own internal process; again, this requires leadership in both identifying where is optimal to intervene and in providing options to solve the possible bottlenecks.

Finally, initiative is a key element of every ecosystem. Initiative entails a leadership role similar to the one discussed above, which is also central to set the targets of the system and facilitate its success. In the innovation ecosystem this will also depend on the state of the competing technologies (of other actors or systems), and consequently, on the resources needed for scanning/controlling alternative developments, which represent another key asset for meeting the targets of the ecosystem.

The view sketched above could be helpful in explaining the decision of Tesla Motors to open its patent portfolio. Innovation ecosystems, especially when considering their technological dimension, which involves a global competition, may require large resources to be successful and therefore change the perspective on the relevant competitors and competition. As pointed out by Chambers when commenting this choice (Forbes, 2014) *"It's not the companies that are the competition, it's the internal combustion engine itself that is Tesla Motors' competition and he is not beating it, yet"*³. In a pre-competitive perspective, Tesla Motors would benefit from pooling relevant stakeholders, thereby increasing the likelihood of the emergence of a new technological paradigm: in generic terms, the lack of sufficient resources and/or the high related risks may push firms to support the emergence of an (informal) innovation ecosystem with other key players, including (future) competitors. In this view, the recent Tesla Motors' open patent strategy intended to accelerate specific technological developments through the generation of an 'ecosystem-like' dynamics around electric car technologies. The Tesla case illustrates the example of a company trying to initiate an informal innovation ecosystem on the basis of cost- and technology-driven motivations.

³ Founded in 2003, Tesla Motors is a US company specialized in the design and production of electric cars. The press reference can be found at: <http://www.forbes.com/sites/briansolomon/2014/06/12/tesla-goes-open-source-elon-musk-releases-patents-to-good-faith-use/>

Moreover, innovation ecosystems also emerge on broader resources-related grounds; in this case the emerging or prevailing industrial/technological specialization is likely to be strongly historically path-dependent, with respect to the material, physical and/or human capital endowments of the given territory. In other cases their creation can be favoured by policy actions aiming at strengthening local capabilities through the participation in international innovation networks. In either case, the role of the business sector and more concretely the existence of large R&D-oriented companies can play a crucial role in the dynamics of ecosystems. Indeed such firms often combine the necessary leadership, sufficient resources (or easier access), and capabilities that may benefit or spill over the whole value chain, including the suppliers of the main inputs (e.g. through technological upgrading and demand) or the clients through the access to more innovative and cutting-edge technologies. Of course, the extent of these benefits and spillovers also depends on the local absorptive capabilities (Cohen and Levinthal 1990).

4. The role of Top R&D investors in innovation ecosystems

The arguments presented above clearly point to the important role of large R&D investors in the functioning and success of innovation ecosystems. Since 2006, the European Commission, aware of the important role played by large R&D investors for an innovation-driven growth, monitors and analyses on an annual basis the top R&D investors worldwide (EU Industrial R&D Investment Scoreboards). Their contribution is partly reflected in the innovative activities they undertake; companies in this sample actually represent about 90% of world total R&D investments financed by the business sector (European Commission, 2014a). A recent EC JRC-OECD report (Dernis et al, 2015) further characterizes the contribution of these companies in terms of innovative outputs and technological developments. Overall, the 2000 top corporate R&D investors own 66% of all patent families (IP5 families⁴) in the world.

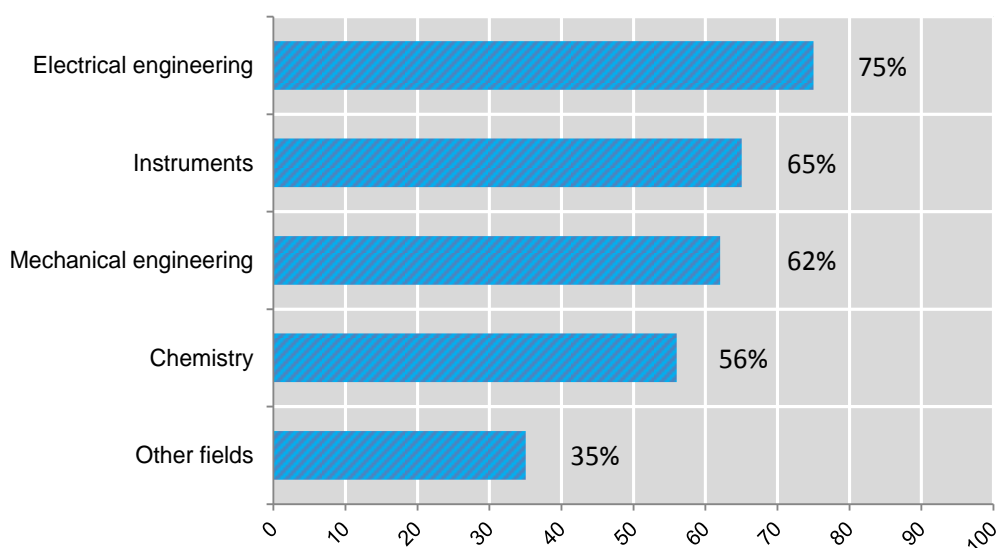
Figure 2 shows their contribution across the five technological areas of the WIPO classification⁵.

⁴ See, Dernis et al. (2015) for a definition of IP5 families, and other methodological aspects.

⁵ The classification of the World Intellectual Property office (WIPO) can be found at: www.wipo.int/classifications/ipc/en/.

Figure 2: Distribution of patent families across technological areas, 2010-12

Share of IP5 patent families of world top R&D investors by technological area in world patent portfolios



Source: IPTS-OECD, calculations based on EU R&D Scoreboard data, 2013; and the Worldwide Patent Statistical Database, EPO, December 2014.

These companies account for the vast majority of all IP5 patent families in *Electrical engineering* (76%) as well as *Mechanical engineering* (62%), *Instruments* (65%) and *Chemistry* (56%), and for the 35% of all IP5 patent families in other technological domains.

Beyond the figures presented above, large R&D investors also contribute to the dynamics of ecosystems of innovation by bringing in organizational and structural knowledge and financial assets or by stimulating knowledge creation through their knowledge search. Particularly interesting were the views presented by the representatives of companies listed in the EU Scoreboard during the 4th IRIMA workshop, as discussed in the rest of this section.

The increasing complexity in the management of external knowledge and parties for innovation success may put the internal arrangements (Williamson, 1985) under pressure and therefore require firms to lighten and (re)focus their internal organisation. This rationale may explain the recent decision to split the business lines that occur in Bayer and Philips. The two companies are actually refocusing their organisation to create distinct companies along different business lines: health and lighting solutions in Philips and, life sciences and material sciences in Bayer. This will allow the new companies to better focus on their own innovation ecosystems.

Complementary to the internal organizational (re)arrangements, corporate representatives also stressed the importance of external R&D collaborations as a pillar of knowledge sourcing and transfer strategy. Commonly implemented by large

R&D investors, often on a global scale, these collaborations are driven by both potential efficiency gains and strategic advantages. They may involve large and small firms from the same or different sectors, and also (future) competitors. Also, they extend beyond the inter-firm frames encompassing knowledge creation-oriented institutions (to give an idea, Philips is actually cooperating with hundreds of universities/institutes) and governmental actors or organizations.

With respect to the collaboration with SMEs, large firms may act, due to their resources and capabilities, as a relevant channel for the technological developments of SMEs by setting up dedicated incubators and venture capital funds⁶. Provided that a winner-winner strategy is developed, large firms may commit themselves in these collaborations to fasten the technology developments and enlarge the opportunities from technology scouting. This latter concept refers to the actions implemented by firms essentially to monitor in a structured way the technological advancements and the know-how related to a technology. The relevance of such a strategy has been underlined by Air Liquide and Fincantieri representatives as a relevant strategic frame to accelerate innovation and increase the likelihood of discovering disruptive technologies and innovative customer-oriented solutions.

It is also important to consider that knowledge and technologies flows between sectors are an integral

⁶ Most firms represented at the 4th IRIMA Workshop have actually mentioned the importance of such structures in their development of new technologies and customer solutions.

part of today's industrial development. In particular, the Volvo representative stressed the importance of technological advances from other industries, especially from the supplier side and from ICT sectors⁷, in complementing the technological knowledge developed within the industry. In the same vein, the Volkswagen representative pointed out the recent successful public-private partnership - the European Technology Platform (ETP) for Road Transport⁸ (ERTRAC) supported by the European Commission - and its importance in providing a strategic vision for road transport research and innovation in Europe.

Last but not least is the importance of public actors' initiative with respect to the adoption of EU-wide standards and the commercialization of products. In particular, the Boehringer Ingelheim's representative stressed the potential benefits deriving from the uniformization of health technology assessments, actually carried out at national and regional levels.

In light of the arguments presented, it is clear that government intervention can operate through different channels, including the initiation, the financial support, the coordination of innovation ecosystems and their targets, provided that the duplication or crowding out effects are minimized, or better, cancelled out. Such a perspective on the role of public policy interventions in promoting innovation ecosystems is also highlighted in the frames of large scale European research and innovation programmes. Based on public-private partnerships, these programmes have turned out to be relevant bases for the development of sustainable ecosystems of innovation (European Commission, 2015).

5. Implications for policy

Inspired mainly from the fourth IRIMA workshop on "Leading R&D investors and the European manufacturing industry" and in-house monitoring and interactive activities on the behaviour and dynamics of top R&D investors, this policy brief has pointed to a series of strategic and organisational challenges faced by firms in their innovative processes. In a context of accelerated technological change and increasing global competition, firms should develop complex innovative solutions requiring the interaction of multiple players. Therefore, knowledge integration becomes a key strategic dimension to keep the edge in the global competition and ecosystems of innovation are

privileged 'places' where it can be organised in a way that ensures the creation of a higher collective value (High Level Group - HLG, 2014). However the participation to (or the development of) innovation ecosystems is not free of risks. Indeed, the advantages from such organizational models constitute at the same time the main sources of potential failures and very few firms appear sufficiently endowed both in terms of resources and capabilities to trigger and dynamize these systems. With this respect, this policy brief has argued that leading R&D investors can activate such dynamics in knowledge intensive sectors.

A better understanding of - and research on - the conditions for the emergence of successful innovation ecosystems, their impact on the dynamics and performances of firms and on the society as a whole is imperative to design well suited policy actions. Such policies should facilitate the establishment and functioning of innovation ecosystems, creating the right conditions to attract key global players, fostering the participation of local firms (incumbent and new entrants) and of other knowledge providers and actors (such as universities and research centres).

In designing the support to innovation ecosystems, policy makers will have to identify the different bottlenecks, which can take place along the development stages. In the earlier phases, ensuring the active involvement of local actors may require prior building or upgrading of absorptive capabilities. This can be achieved through the access to relevant (international) knowledge pools (e.g. France Brevets) or technical repositories, the empowerment of technology transfer offices, technology/entrepreneurial trainings, and the participation to international collaborative programmes.

In the setting-up, policy intervention may be justified by specific innovation funding needs and coordination failures - i.e. the non-alignment of the multiple actors' objectives. In the first case, easing the credit access or in general lightening the innovation (search) costs can be implemented through financial guaranty or dedicated public venture capital funds, provided that duplication or crowding out effects with the private investment are limited, even better, cancelled out. In the case of coordination failures, policy makers should ensure that the ecosystem is not only beneficial for few interest-groups. This could be achieved by an inclusive definition of targets and by monitoring contractual participatory rules to ensure that the ecosystem benefits a wide (local) societal base. In addition, in order to limit coordination failures, the inclusion of pre-collaborative or interactive and intermediary structures should be encouraged.

⁷ The importance of intersectoral links in the production of innovation has been earlier underlined and illustrated by the seminal contribution of Pavitt (1984).

⁸ See at <http://www.ertrac.org/>

In the later phases, policy action should foster the commercialization or adoption of the new products/technologies by promoting the developments of standards and facilitating the access to information, certification and training services. This would be of utmost importance especially when the market for new technologies does not exist yet.

As underlined in this brief, large firms can contribute to the development and dynamics of innovation ecosystems. As the home of many of the world's leading innovative companies, Europe is in a privileged position to grasp the coming growth opportunities (about 1/3 of the 2000 top R&D investors are from EU), and promote the shift of the European industrial structure towards knowledge-

intensive activities. For policy authorities, the involvement of large innovative firms should be perceived, as a way to lower the risks of failures or technological lock-in for local actors. Thus, policy should improve the conditions to foster and maintain the attractiveness of territories to the best or most appropriate large R&D firms. In a context of scarce resources and constrained budgets, these innovation territorial policies would certainly entail a non-neutral dimension by targeting specific activities or technologies. In a vertical approach to territorial attractiveness policies, the resources and the institutional and industrial conditions would define the opportunities of partnering and the potentialities for attracting the most appropriate industrial actors.

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Abstract

This Policy brief discusses the key role of large R&D investors in the dynamics of innovation ecosystems. In a context of accelerated technological change and increasing global competition, firms should develop complex innovative solutions requiring the interaction of multiple-players. Therefore, knowledge integration becomes a key strategic dimension to keep the edge in the global competition and ecosystems of innovation are privileged 'places' where it can be organised in a way that ensures the creation of a higher collective value. Evidence shows that leading R&D investors can play a pivotal role in the establishment and development of such ecosystems, by bringing the necessary assets (resources, knowledge, capabilities and leadership) to activate their dynamics (along the three dimensions of interdependence, integration and initiative). This brief identifies a number of policy interventions to support the functioning of such innovation ecosystems and calls to tailor the interventions in accordance to the stage of development of the given ecosystem.

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