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Selecting and Designing European ICT Innovation Policies

Andrea Renda (CEPS, Duke University)

Editors: Federico Biagi, Marc Bogdanowicz, Paul Desruelle, Nikolaus Thumm (JRC)

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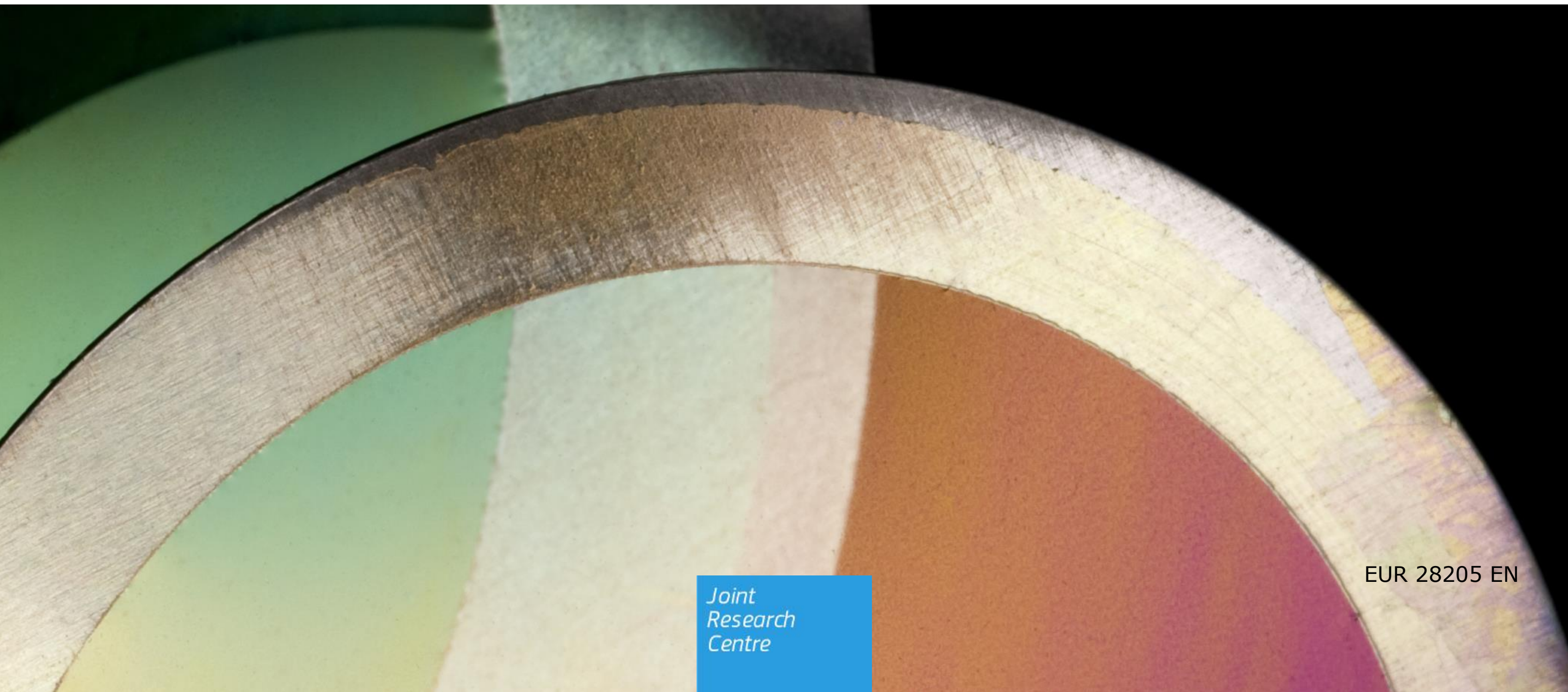

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Joint Research Centre

Contact information
European Commission, Joint Research Centre
Address: Edificio Expo. c/Inca Garcilaso, 3. 41092 Seville (Spain)
E-mail: b06-sec@jrc.ec.europa.eu
Tel.: +34 954488318

JRC Science Hub
https://ec.europa.eu/jrc

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Abstract
This report analyses the peculiarities of innovation in Information and Communications Technologies (ICT), an ecosystem composed of various layers: from infrastructure to applications and content, and including end users. The report observes that innovation is becoming more open and collaborative in all layers, with various degrees of R&D intensity (greater at lower, physical layers); a prevalence of system goods with platforms and complementors mostly competing "for" rather than "in" the market; pervasive network effects coupled with relatively low entry barriers; short product life-cycles; and a high degree of co-evolution and co-dependency across and between layers.

The nature of the ICT ecosystem determines a growing need for flexible, adaptive regulation, and the adoption of new policy instruments such as prizes and challenges. Policies should aim to create an environment favourable to the development of new, welfare-enhancing business models and avoid hindering the entrance of new players.

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Abstract

This report analyses the peculiarities of innovation in Information and Communications Technologies, which is described as an ecosystem composed of various layers, from infrastructure to applications and content, and including end users. The report observes that innovation is becoming more open and collaborative in all sectors. In the ICT ecosystem, this trend is especially evident, thanks to fundamental features such as the digital nature of information flows, the rapid drop of hardware costs, the end-to-end design of the Internet, and the modularity of ICT platforms and products. These factors in turn lead to various degrees of R&D intensity in the ICT ecosystem (greater at lower, physical layers); a prevalence of system goods with platforms and complementors, mostly competing "for", rather than "in" the market; pervasive network effects coupled with relatively low entry barriers; short product life-cycles; and a high degree of co-evolution and co-dependency across and between layers. In this context, platforms often play the role of entrepreneurs, orchestrating cumulative innovation and competing with other platforms to capture the attention of end users. These features call for a dedicated approach by EU policymakers. In particular, EU innovation policy should focus on infrastructure, basic research and a wholly new set of skills. At the same time, it should encourage the creation of mission-led platforms, needed to ensure that innovation addresses pressing societal challenges. The nature of the ICT ecosystem, and emerging trends such as artificial intelligence and the Internet of Things, also determine a growing need for flexible, adaptive regulation, and the adoption of new policy instruments such as prizes and challenges. Even more importantly, horizontal and sector-specific EU policies should aim to create an environment in which the need to protect user privacy does not hamper the development of new, welfare-enhancing business models. This has potentially far-reaching consequences for established policy domains such as copyright and data protection law. Finally, innovation policy and its related new instruments (the "innovation principle" and "innovation deals", among others) should avoid relying mostly on input from incumbents, thereby hindering the entrance of new players.

Foreword

This report was prepared in the context of the three-year research project on European Innovation Policies for the Digital Shift (EURIPIDIS) jointly launched in 2013 by JRC-IPTS and DG CONNECT of the European Commission. This project aims to improve understanding of innovation in the ICT sector and ICT-enabled innovation in the rest of the economy.[1]

The purpose of the EURIPIDIS project is to provide evidence-based support to the policies, instruments and measurement needs of DG CONNECT for enhancing ICT Innovation in Europe, in the context of the Digital Agenda for Europe, of the European Digital Single Market, and of the ICT priority of Horizon 2020. It focuses on the improvement of the transfer of best research ideas to the market.

EURIPIDIS aims to:
1. better understand how ICT innovation works, at the level of actors such as firms, and also of the ICT "innovation system" in the EU;
2. assess the EU's current ICT innovation performance, by attempting to measure ICT innovation in Europe and measuring the impact of existing policies and instruments(such as FP7 and Horizon 2020); and
3. explore and suggest how policy makers could make ICT innovation in the EU work better.

This report concentrates on point 3 above.

[1] For more information, see: https://ec.europa.eu/jrc/en/euripidis

Executive summary

During the past few decades, understanding of how innovation occurs has evolved significantly in social sciences. At least seven generations of models used to capture the features and determinants of innovation can be distinguished today. In these generations of economic models, innovation has been increasingly conceptualized as an ecosystem in which institutional, cultural, regulatory and market constraints are essential to determine the outcome and intensity of the innovation process. In this ecosystem, governments are playing a more and more proactive role in steering innovation towards societal challenges, and facilitating innovation by securing the availability of infrastructure, skills and an innovation-friendly regulatory environment. Most importantly, innovation changes along with the possibilities offered by technology. This is why Information and Communications Technology (ICT) has led to very significant changes to the way in which innovation can occur.

The ICT ecosystem

ICT can be defined as the integration of information processing, computing and communication technologies. We define it as an ecosystem, which makes it slightly broader than the ICT sector *stricto sensu* since it includes not only the companies that operate in the specific ICT NACE codes, but also their interdependencies. It also includes their institutional and architectural constraints, as represented by the main features of the networked environment in which these companies and institutions operate. In addition, end users in the ICT ecosystem play an increasingly active role in the generation of new products, services, and ideas. Moreover, the ICT ecosystem partly overlaps with the Internet and includes all hardware and network equipment companies that form the underlying infrastructure on which the Internet runs; however it is narrower than the Internet since it does not comprise a number of companies that operate in "bricks and mortar" sectors, but participate in the Internet by operating their own websites.

The foundational, differentiating features of the ICT ecosystem include computing power (in particular Moore's law), modularity, the end-to-end architecture (i.e., the possibility, for every end user to engage in communication and exchange information with every other end user) and neutrality of the Internet, and the digital nature of information goods. These foundational characteristics have determined the emergence of some of the features that are typically attributed to the ICT ecosystem by industry analysts:

- R&D intensity and innovation rates tend to be greater than in other sectors.
- innovation was initially largely incremental, due to modular architectural design.
- product life-cycles are becoming shorter due to the acceleration of technological change.
- the end-to-end architecture of the Internet and the digital nature of information goods have led to the emergence of network effects and large economies of scale in the ICT ecosystem. This, in turn, has led to the emergence of multi-sided platforms that are gradually changing the architecture of the network.

All these aspects have consequences in terms of innovation performance/dynamics, industry performance, competition, overall societal welfare.

These features should also be appraised in the light of the constant evolution of the ICT ecosystem. The report highlights six trends:

- the increasingly "platformized" ICT ecosystem;
- the ongoing virtualization of a growing number of functions made possible by technological evolution and underlying standardization;
- openness and collaboration as key elements of emerging business models;
- the importance of data analytics,

- the explosion of the Internet of Things, and
- the "Internet of Value".

All these trends are very important for the future of the ICT ecosystem. However, even more important is the fact that they are occurring at the same time. The combination of disruptive innovation in network architectures (e.g. BlockChain), new sensors and wireless communication technologies (e.g. 5G), nanotechnologies, robotics, and artificial intelligence is likely to create unprecedented possibilities for innovation, most often based on predominantly open standards and free/open source software, low entry barriers, and innovative funding and management arrangements.

ICT innovation: main features

In the ICT ecosystem, innovation takes place in different ways across layers. While openness seems to be an increasingly defining feature of all layers of the ICT ecosystem, the degree of granularity reached by more virtualized layers such as cloud-based platforms and applications, is unrivalled in the "physical layer". Moreover, the pace of innovation differs across layers*:* the higher the layer, the more intangible the investment behind new products and services, the faster the pace of innovation. The pace of innovation in each layer is also dependent on the evolution of other layers. The existence of a robust, high capacity network and the development of facilities such as Internet exchanges and data storage networks determine the evolution of the higher layers. For example, the App economy could develop only when the underlying mobile infrastructure and cloud platforms became well developed. And countries in which the infrastructure has greater capacity have more developed and dynamic application and content layers.

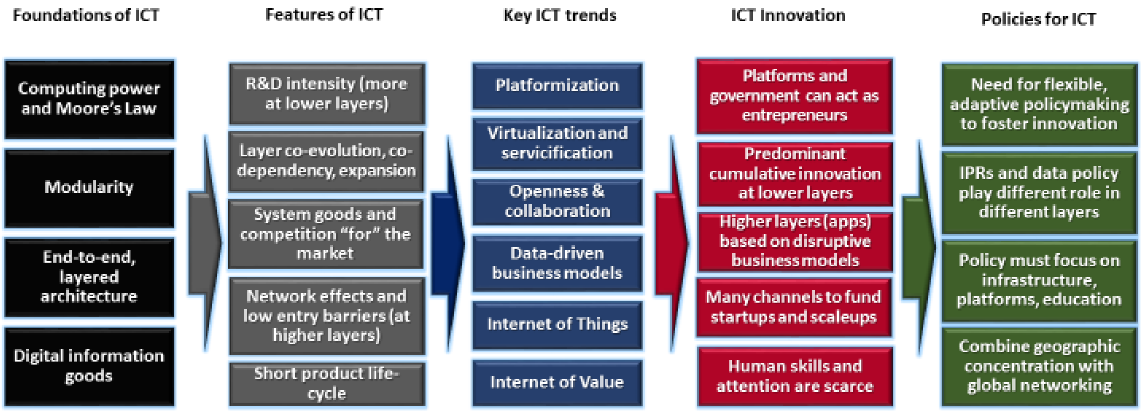
In the physical layer, large R&D-based companies seem to be increasingly playing the role of catalysts of external R&D through the development and refinement of open innovation models. Higher layers, however, depend on the essential role of platforms as online intermediaries, which means that platforms often end up becoming the real entrepreneurs of this part of the ecosystem, as they provide a market for nascent ideas. The public sector should also be considered as performing entrepreneurial functions: governments play the role of entrepreneurs both in terms of funding high risk-high reward basic research projects, but also by making it easier for digital innovators to use the facilities they would need to develop their ideas.

Against this background, funding channels for start-ups and new ventures abound. In ICT, venture capital is not the only source of financing available to ICT firms. A peculiarity of the ICT ecosystem is the greater importance of distributed platforms for the funding of innovative products. The relative ease with which prototypes and beta application versions can be developed in the ICT ecosystem, and the fact that innovation in higher layers probably has very low entry barriers and low start-up costs, is creating new opportunities for funding innovation, particularly through the proliferation of crowdfunding platforms. In addition, public support schemes for ICT start-ups and scale-ups are another channel available to entrepreneurs: schemes such as the U.S. SBIR, the UK SBRI, the Horizon 2020 SME Instrument, the Start-up Europe initiative and the innovation vouchers at the EU level, all aim to provide entrepreneurs with funding to test and commercialise their innovative business ideas. In addition, the use of prizes, pay-per-success schemes and challenges is on the increase, particularly in the United States and the United Kingdom. Finally, and importantly, funding and support for start-ups is provided by large ICT companies that adopt an open innovation model, and by platforms seeking to maximise the number of their applications so that they can beat the competition and establish themselves as *de facto* industry standards.

Finally, another key peculiarity of the ICT ecosystem, at least for the time being, is the growing importance of the human factor, considered as an increasingly scarce resource. In this respect, it is clear that challenges already perceived today will only become more pressing in the coming years. Evidence from global markets suggests that many industrialized countries no longer compete on low salaries, but rather on the availability of reliable authorities, world-class infrastructure and, most importantly, a highly educated and skilled workforce. This is why re-launching Europe's objectives in higher education is key to Europe's future innovation and employment policies.

Policy implications

The report maps interrelations between foundations, features and trends of the ICT ecosystem; and their consequences for ICT innovation and for ICT policies, as shown in the figure below.



Source: Author's elaboration

Analysing all the interactions and interrelations between the pillars shown in the figure above, leads to the formulation of a number of policy recommendations. In the physical layer, EU policy should prioritize the deployment of a robust, resilient ultra-fast broadband network throughout the European Union. Scalable technologies such as optical fibre networks could be used and more resources could be devoted to the development of the digital infrastructure, including both fixed and wireless networks and cloud storage facilities. This would be helped by a more coordinated spectrum policy throughout the EU28, and effective EU involvement in the 5G standard development. In addition, it is important that the regulatory framework for digital services be streamlined, by abandoning the current silo approach and implementing symmetric, principles-based regulation, rather than asymmetric access regulation. Overall, platform regulation such as platform neutrality should be avoided as it contrasts starkly with the Internet's current evolution. Instead, policymakers should engage with online intermediaries by developing principles of responsible cooperation in the monitoring and enforcement of specific legal rules, including counter-terrorism, copyright, and privacy.

In terms of innovation policy, the role of instruments for the promotion of public and private R&D seems to be most relevant for the physical (and partly the logical) layer of the ICT ecosystem. At higher layers of the ICT ecosystem, more agile instruments and innovative demand-side innovation policy are likely to be particularly effective. Instruments such as prizes and challenges, and pay-for-success schemes are potentially suited for the application layer. And policies should seek to facilitate data-driven innovation.

Importantly, the governance of innovation policy should be improved in order to create an environment that is more directly conducive to ICT innovation. At the moment, there seems to be an excessive level of complexity in the governance of innovation policy at the EU level. This can hamper the ICT ecosystem even more than other parts of the economy due to the former's fast product cycles, and the prevalence of very small and even individual ventures, especially at the higher layers. Possible improvements, not exclusive to ICT, would include the consolidation of existing research and innovation platforms; and the identification of a limited number of organizations in the management of ICT research and innovation projects, which could then develop technology roadmaps related to specific societal challenges. Most of these actions would become more effective if they were coupled with a strengthening of institutional capacity at the regional and local level.

Greater efforts must also be made to improve the availability of skills. Europe needs a major reflection on the future of jobs. Education is a fundamental driver of ICT uptake and competitiveness, and must include a high-quality university system, widespread e-skills and digital literacy among both firms (in particular, SMEs) and citizens. Importantly, the skills needed are not a single set, but rather a combination of notions, capabilities and attitudes that can help fill all the current gaps in the EU job market, at the various layers of the ICT ecosystem. The recommended skill set includes, i.a. coding skills; creativity skills; Science Technology Engineering and Maths (STEM) education; cross-disciplinary skills; managerial skills; financial and accounting education; and leadership and team-working skills. All these skills must be developed and constantly updated.

Finally, what matters for innovation is not exclusively innovation policy, especially at the EU level. There is considerable evidence in the EU that existing instruments and funding channels need to be simplified, and complicated and burdensome legislation eliminated (especially for SMEs). Apart from the need to simplify regulation by removing unnecessary red tape, it is important that regulation is made innovation-friendly. This also applies to important horizontal policy areas such as competition policy, data protection and copyright policy. In addition, policymaking should avoid bias in favour of incumbents and accommodate innovative business models that make use of big data and more generally transformational ICT applications. Possible ways to make policy more flexible and adaptive include:

(i) the use of regulatory sandboxes and other experimental approaches to allow ongoing monitoring of the market and social impacts of innovative techniques;

(ii) the consideration of technology roadmaps and the opinion of multi-stakeholder platforms in the policymaking process, to ensure that innovative, welfare-enhancing technologies are adequately represented in policy processes and outcomes;

(iii) the ongoing monitoring of policy impacts, including through open government techniques.

Résumé

Au cours des dernières décennies, la compréhension du processus d'innovation a considérablement évolué au sein des sciences sociales. Nous pouvons notamment distinguer au moins sept générations de modèles utilisés pour capturer les caractéristiques et les déterminants de l'innovation. Au cours de ces générations de modèles économiques, l'innovation a de plus en plus été conceptualisée comme un écosystème au sein duquel les contraintes institutionnelles, culturelles, réglementaires et de marché sont perçues comme essentielles pour déterminer le résultat et l'intensité du processus d'innovation. Dans cet écosystème, les gouvernements jouent un rôle de plus en plus proactif sur le pilotage de l'innovation, notamment pour répondre aux nombreux défis sociétaux, ainsi que pour garantir la disponibilité des infrastructures, des compétences et d'un environnement réglementaire favorable. Plus important encore, l'innovation change en fonction des possibilités offertes par la technologie. Ceci est la raison pour laquelle les Technologies de l'Information et des Communications (TIC) ont été un vecteur majeur, conduisant à des changements importants du processus d'émergence de l'innovation.

L'écosystème des TIC

Les TIC peuvent être définies par l'intégration d'outils de traitement de l'information, d'informatique et de technologies de communication. Le fait de les définir comme un écosystème implique une conception plus large que le seul secteur des TIC, car il comprend non seulement les entreprises TIC qui opèrent dans les codes NACE spécifiques, mais aussi les secteurs dépendants ainsi que leurs déterminants institutionnels et architecturaux, comme illustrés par les spécificités de l'environnement en réseau dans lequel ces entreprises et ces institutions opèrent. Mais l'écosystème des TIC comprend également les utilisateurs finaux, qui jouent un rôle de plus en plus actif dans la production de nouveaux produits, services et autres idées. De plus, l'écosystème des TIC inclut en partie l'Internet: l'écosystème des TIC englobe toutes les entreprises d'équipement matériel et de réseau qui forment l'infrastructure sous-jacente grâce à laquelle l'Internet fonctionne. Il est cependant plus restreint dans la mesure où il n'englobe pas un certain nombre d'entreprises de vente traditionnelle ayant pignon sur rue, bien que ces entreprises participent à l'Internet par l'exploitation de leurs propres sites Web.

Fondamentalement, les caractéristiques distinctives de l'écosystème des TIC comprennent la puissance informatique (principalement la loi de Moore), la modularité, l'architecture "de bout en bout" (rendant possible pour chaque utilisateur final de communiquer et d'échanger des informations avec n'importe quel autre utilisateur final) et la neutralité de l'Internet, ainsi que la nature numérique des produits d'information. Ces caractéristiques fondamentales ont déterminé l'émergence de certaines particularités généralement attribuées à l'écosystème des TIC par les analystes de l'industrie. Premièrement, l'intensité en R&D et les taux d'innovation ont tendance à être plus grands que dans les autres secteurs. Deuxièmement, l'innovation a d'abord tendance à être largement incrémentale, en raison d'une conception architecturale modulaire. Troisièmement, les cycles de vie des produits deviennent de plus en plus courts en raison de l'accélération du changement technologique. Quatrièmement, l'architecture de bout en bout de l'Internet, et la nature numérique des produits d'information ont conduit à l'apparition d'effets de réseau et de grandes économies d'échelle dans l'écosystème des TIC, conduisant ainsi à l'émergence de plateformes multi-faces qui changent progressivement l'architecture du réseau. Tous ces aspects ont des conséquences en termes de performances/dynamiques d'innovation, de performance industrielle, de concurrence, et de bien-être global de la société.

Ces caractéristiques doivent être évaluées à la lumière de l'évolution constante de l'écosystème des TIC. Le rapport met en évidence six tendances: la croissante « plateformisation » de l'écosystème des TIC ; la virtualisation continue d'un nombre croissant de fonctions, rendue possible par l'évolution technologique et la standardisation

sous-jacente; l'ouverture et la collaboration comme éléments clés des modèles d'affaires émergents; l'importance de l'analyse des données en vue de l'explosion de « l'Internet des objets » et de ce qu'on appelle « l'Internet de la valeur ». Toutes ces tendances sont primordiales pour l'avenir de l'écosystème des TIC, et le fait qu'elles se produisent en même temps est encore plus important. En effet, la combinaison de « l'innovation de rupture » dans les architectures de réseau (par exemple le « *BlockChain* »), des nouveaux capteurs et des technologies de communication sans fil (par exemple le 5G), des nanotechnologies, de la robotique et de l'intelligence artificielle, est susceptible de créer des possibilités sans précédent en terme d'innovation ; d'autant plus grâce aux normes ouvertes et aux logiciels en source libre, à des barrières à l'entrée basses, et à des modalités de financement et de gestion complétement innovants.

L'innovation des TIC: principales caractéristiques

Au sein de l'écosystème des TIC, l'innovation intervient de différentes manières selon les couches. Tandis que l'ouverture semble être de plus en plus applicable à toutes les couches de l'écosystème des TIC, le degré de granularité atteint par les couches les plus « virtualisées » (telles que les plateformes et les applications basées sur le « *cloud* ») reste inégalé dans les couches physiques. Par ailleurs, le rythme de l'innovation varie selon les couches: plus haute est la couche, plus intangible est l'investissement supportant de nouveaux produits et services, plus rapide est le rythme de l'innovation. De plus, le rythme de l'innovation au niveau de chaque couche est dépendant de l'évolution des autres couches: l'existence d'un réseau robuste, à haute capacité, et le développement d'installations telles que les points d'échanges Internet et les réseaux de stockage de données, déterminent l'évolution des couches supérieures. Par exemple, « l'économie des applications » a pu voir son essor uniquement après que les infrastructures mobiles et les plateformes en nuage (*cloud*) sous-jacentes se soient développées. Ainsi, les pays où les infrastructures ont une plus grande capacité voient leurs couches d'application et de contenu plus développées et plus dynamiques.

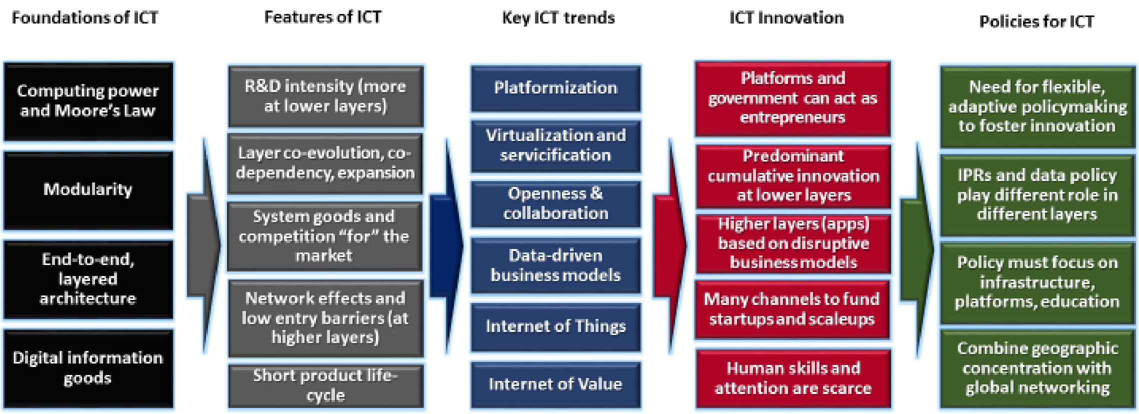
D'autre part, alors qu'au sein de la couche physique, de grandes entreprises bénéficiant de large financement en R&D semblent davantage jouer le rôle de catalyseurs en R&D externe, notamment à travers le développement et le raffinement des modèles d'innovation ouverte, les couches supérieures dépendent du rôle essentiel des plateformes comme les intermédiaires en ligne. Ceci implique que les plateformes finissent souvent par devenir les véritables entrepreneurs de cette partie de l'écosystème, car ils fournissent un marché aux idées naissantes. Par ailleurs, le secteur public doit aussi être considéré comme exerçant des fonctions entrepreneuriales: les gouvernements jouent des rôles d'entrepreneurs tant en termes de financement de projets de recherche fondamentale à haut risque et haute récompense, mais aussi en permettant au innovateurs du numérique d'utiliser les installations dont ils ont besoin pour développer leurs idées.

Dans ce contexte, les canaux disponibles pour financer les startups et les nouvelles entreprises abondent. En ce qui concerne les TIC, le capital-risque n'est pas la seule source de financement disponible pour les entreprises: une des particularités de l'écosystème des TIC est le rôle important joué par les plateformes distribuées pour le financement de produits innovants. La relative facilité de développement des prototypes et des versions d'applications « bêta » dans l'écosystème des TIC, ainsi que le fait que l'innovation dans les couches supérieures soit davantage marquée par de très basses barrières à l'entrée et de moindres coûts pour les startups, favorisent la création de nouvelles opportunités pour le financement de l'innovation, notamment par la prolifération de plateformes de financement participatifs. En outre, les plans de soutiens publics pour les startups et scaleups du secteur des TIC sont un autre canal disponible aux entrepreneurs: des programmes tels que le « SBIR » aux États-Unis, « SBRI » au Royaume-Uni, ainsi que l'instrument PME dans Horizon 2020, l'initiative « Startup Europe » et les « bons d'innovation » mis en œuvre par l'UE, tous visent à fournir aux entrepreneurs un financement pour tester et commercialiser leurs idées d'affaires novatrices. De même, l'utilisation de récompenses, telles que des prix ou des programmes basés sur le principe du « payer pour réussir » (« *pay-per-success* » *or* « *pay for success* » *schemes*), sont de plus en plus fréquents, en particulier aux États-Unis et au Royaume-Uni. Enfin, et surtout, le financement et le soutien aux startups sont fournis par les grandes entreprises des TIC qui adoptent un modèle d'innovation ouverte, ainsi que par les plateformes cherchant à maximiser le nombre de leurs applications pour battre la concurrence et s'imposer en tant que normes et standards industriels de fait.

Enfin, une autre particularité clé de l'écosystème des TIC, du moins pour le moment, est l'importance croissante du facteur humain, considéré comme une ressource de plus en plus rare. À cet égard, il est clair que les défis déjà perçus aujourd'hui deviendront encore plus pressants dans les années à venir. Comme en témoignent les marchés globaux, il semble que la concurrence de nombreux pays industrialisés ne se fait plus sur les bas salaires, mais plutôt sur la présence d'autorités fiables, d'infrastructures de premier plan, et surtout, d'une main-d'œuvre hautement éduquée et qualifiée. Voilà pourquoi relancer les objectifs européens de l'enseignement supérieur est primordial pour les futures politiques d'innovation et de l'emploi en Europe.

Implications politiques

Le rapport cartographie les interrelations entre les fondements, les caractéristiques et les tendances principales de l'écosystème des TIC, ainsi que les conséquences pour l'innovation et les politiques en matière de TIC, comme l'illustre le schéma ci-dessous :



Source: Author's elaboration

L'analyse de toutes les interactions et interrelations entre les piliers tels qu'indiqués sur le schéma ci-dessus, conduit à la formulation d'un certain nombre de recommandations. En ce qui concerne la couche physique, la politique de l'UE devrait accorder sa priorité au déploiement à travers toute l'UE, d'un robuste réseau à large bande ultra-rapide, à l'utilisation de technologies évolutives telles que les réseaux de fibres optiques, et à consacrer davantage de ressources au développement de l'infrastructure numérique, y compris les réseaux fixes et sans-fils, et les installations de stockage en nuage. Ceci serait d'autant plus réalisable grâce à une politique du spectre plus coordonnée au sein de l'UE28, et avec une participation effective de l'UE dans le développement des normes 5G. En outre, il serait important de simplifier le cadre réglementaire des services numériques, en abandonnant l'approche en silo actuelle et la mise en œuvre d'une réglementation fondée sur des principes et une symétrie, plutôt qu'une réglementation d'accès asymétrique. Dans l'ensemble, une réglementation suivant un principe de « neutralité des plateformes » devrait être évitée car elle entre en contradiction avec l'évolution actuelle de l'Internet: inversement, les décideurs devraient collaborer avec les intermédiaires en ligne pour développer des principes de coopération responsable et durable, notamment pour la surveillance et la mise en œuvre de règles juridiques spécifiques, dont celles relatives à la lutte contre le terrorisme, au droit d'auteur et à la vie privée.

En terme de politique d'innovation, le rôle des instruments publics et privés pour la promotion de la R&D semble être plus pertinent pour la couche physique (et partiellement pour la couche logique) de l'écosystème des TIC. Quant aux couches supérieures de l'écosystème des TIC, des instruments plus agiles et des politiques d'innovation plus novatrices, davantage centrées sur la demande, pourraient être particulièrement efficaces. Des instruments tels que des défis et des récompenses, ainsi que des programmes sur le modèle « payer pour réussir » sont potentiellement plus adaptés à la couche supérieure des applications. Ainsi, les politiques publiques devraient chercher à faciliter l'innovation basée sur l'exploitation des données.

Il est important de souligner que la gouvernance des politiques d'innovation devrait être améliorée afin de créer un environnement qui soit plus directement vecteur d'innovation des TIC. *Aujourd'hui, il semble y avoir un niveau de complexité excessif dans la gouvernance des politiques d'innovation au niveau de l'UE.* Cela peut être d'autant plus nuisible à l'écosystème des TIC, étant donné les courts cycles de vie des produits, et la prévalence de très petites entreprises, voire individuelles, comme c'est souvent le cas au niveau des couches supérieures. Parmi les améliorations possibles, non-exclusives au secteur des TIC, la consolidation des plateformes de recherche et d'innovation existantes; ainsi que l'identification d'un nombre limité d'organisations de gestion des projets de recherche et d'innovation des TIC, pourraient alors favoriser le développement de plans d'actions technologiques plus ciblés et plus étroitement liés aux défis sociétaux particuliers. La plupart de ces actions seraient plus efficaces si elles étaient accompagnées par un renforcement du support institutionnel au niveau régional et local.

D'importants efforts doivent être faits afin d'améliorer la disponibilité des compétences. L'Europe a besoin d'engager une réflexion cruciale sur l'avenir des emplois. L'éducation est un facteur fondamental pour l'adoption et pour la compétitivité des TIC. Elle doit être conçue plus largement pour inclure un système universitaire de haute qualité apte à répandre les compétences requises et permettre « l'alphabétisation numérique » tant au sein des entreprises (en particulier les PME) qu'au niveau des citoyens. Il est aussi important de noter que les compétences nécessaires ne sont pas un ensemble unique, mais plutôt une combinaison de notions clés, d'aptitudes et d'attitudes qui peuvent aider à combler l'actuel déficit de compétences qui caractérise le marché européen de l'emploi, à plusieurs niveaux de l'écosystème des TIC. L'ensemble des compétences recommandées comprend par exemple le codage, les aptitudes de créativité, les « Sciences, Technologie, ingénierie et mathématiques (STEM) », les compétences transversales et managériales, la finance et la comptabilité, ainsi que le leadership et les compétences liées au travail en équipe. Toutes ces compétences doivent être développées et constamment mises à jour.

Introduction

This report was commissioned in 2015 by the Institute of Prospective Technological Studies (IPTS) at the Joint Research Centre of the European Commission, in the context of the three-year research project on European Innovation Policies for the Digital Shift (EURIPIDIS)[2]. The purpose of EURIPIDIS is to provide evidence-based support to the policies, instruments and measurement needs of DG CONNECT for enhancing ICT Innovation in Europe, mainly in the context of the Digital Single Market policy agenda and of the ICT priority of Horizon 2020. It focuses on the improvement of the transfer of best research ideas to the market. More specifically, the aims of EURIPIDIS are: (1) to better understand how ICT innovation works, at the level of actors such as firms, and also of the ICT "innovation system" in the EU; (2) to assess the EU's current ICT innovation performance, by attempting to measure ICT innovation in Europe and measuring the impact of existing policies and instruments (such as FP7 and Horizon 2020); and (3) to explore and suggest how policy makers could make ICT innovation in the EU work better.

Against this background, this report takes stock of the research carried out so far within the EURIPIDIS project and couples it with literature related to innovation and specifically ICT innovation, in the attempt to develop a theoretical framework for the design of ICT innovation policies in the EU. At the same time, the report discusses the most important policy implications of the papers produced so far by the EURIPIDIS project.

The report is structured as follows. Section 1 below introduces the so-called "innovation systems" literature and identifies the main evolution in the literature on innovation policy. Section 2 discusses ICT innovation and the peculiarities of the ICT ecosystem, and also discusses whether, and how, ICT is different from other sectors when it comes to innovation. Section 3 then provides an inventory of existing instruments of ICT innovation policy at the EU level, and discusses potential improvements. Section 4 concludes by offering some policy recommendations for the design and implementation of ICT innovation policies at the EU level.

[2] This project was launched jointly in 2013 by JRC-IPTS and DG CONNECT of the European Commission in order to improve understanding of innovation in the ICT sector and of ICT-enabled innovation in the rest of the economy, see: https://ec.europa.eu/jrc/en/euripidis

1 The evolution of innovation studies: from the "linear model" to a focus on environments, actors, and interactions

This section explores various aspects of the academic literature on innovation, without making specific reference to the ICT sector (for an analysis of ICT innovation, see Section 2 below). As a matter of fact, scholarly literature on innovation has made important steps over the past decades in the understanding of the various factors that lead to the emergence of innovation and entrepreneurship. In the coming sections, we explore the "innovation systems" debate, as well as the triple and quadruple helix models, and the emerging literature on entrepreneurship ecosystems.

1.1 Innovation and the firm: from linear to open models of innovation

Economists and social scientists have devoted significant efforts to the understanding of the dynamics and phenomenology of innovation. Initially, efforts were mostly devoted to the analysis of the so-called "innovation process", with peculiar emphasis on what happens inside a given firm. One of the leading authors in the analysis of developing innovation process models is Roy Rothwell, who distinguished between various generations of innovation process models.

The first generation is what he calls "linear technology push model", widely used until end of 1960s. These models interpret innovation as a linear process, with research, development and the outputs of new successful products standing on the same level. The chronological alignment of each phase starts from elementary research, and encompasses the preparatory phase of production, production, marketing and final sale.

The second generation is what Rothwell calls "Market Pull Model". This model reflects the fact that in the 1960s and 1970s innovation changed to include what was seen as a result of perceived customers' needs, sourced through market research. The needs and demands of the market determined the work of R&D departments in companies. As a result, during that phase many companies engaged mostly in incremental, rather than in disruptive innovation.

The third generation was characterized by the coupling of R&D and marketing (leading to the so-called "interactive model"), and refers to a period (the end of the 1980s) in which it became clear that neither technological push nor market pull strategies were enough to successfully handle the innovation process. The combination of technology push and market pull models was improved with the addition of feedback loops between science and innovation, and labelled as the "interactive" model of technological opportunities and the needs of the market.

Later, a fourth generation of innovation process models led to the identification of a more integrated, "chained" model of innovation (Kline and Rosenberg 1986), characterized by the parallel use of integrated research teams, and the involvement of the supplier and important customers. This generation of innovation clearly stands out from the previous one, and models a stronger parallel process of innovation. Cooperation between research, development and production is enhanced, and horizontal collaboration, regardless of the company's boundaries, is also considered. Due to the constantly shortening product lifecycle, this generation of innovation process models include time as a strategic variable. The (chained) model represents a further step towards a comprehensive innovation process actively involving research and existing knowledge. This model demonstrates the necessity of integrating knowledge into the innovation process, where knowledge is not understood as a result of scientific activities, but rather as a result of interaction between the individual units of a company, the company itself and its environment. The novelty of this model lies mostly in the fact that the market represents both the beginning and the end of the innovation process, and knowledge is integrated in all phases of the innovation process (though mainly in the research phase) and, therefore, considered as a necessary prerequisite for innovation.

The fifth generation of innovation process modelling is characterised by the identification of system integration and networking as dominant features of innovation. This also entails much stronger interaction with external research facilities and cooperation in the marketing area. This model also emphasizes the vertical linkages with suppliers and customers along the whole innovation process (e.g., suppliers are involved in the co-development of new products and/or share the technical systems used for it), and the horizontal linkages take place in a variety of forms (joint ventures, alliances, consortia, etc.). For these reasons the fifth model represents a first step in the emergence of distributed innovation. This generation marks also the transition towards a vision of innovation that is broader and more systemic than the one adopted in the previous four generations. As such, this model contains some elements than the subsequent open innovation models would capture more explicitly.[3]

The sixth generation of innovation models is what is often termed "Open innovation". Open innovation implies, *inter alia*, the use of internal and external R&D sources; openness to external business models, a variety of IP generators and collaborations (SMEs, academics, etc.), and a proactive IP asset management. This is leading to an increase in the number of companies collaborating in innovative activities. In the words of Henry Chesbrough, the academic that coined the term, open innovation is a paradigm that assumes that firms use external ideas as well as ideas developed in-house, and internal and external paths to market, as firms look to advance their technology[4]. Open innovation is not only concerned with sourcing of external knowledge into the firm ("outside-in") but also with exploring new channels of revenue generation by granting usage rights (joint ventures, licensing or outright sale) of in-house developments to other firms ("inside-out"), "especially when the technology has future potential but is not part of the firm's core strategy"[5].

While the original perspective of innovation primarily focused on research and development of firms, open innovation has outgrown this narrow view and today integrates different streams and perspectives[6]. Chesbrough, Vanhaverbeke and West (2014) explain that open and closed innovation are to be understood as two extremes of a spectrum, along which most business models can be found. The spectrum they describe is a function of the extent to which in-house R&D is involved in product development. Figure 1 below shows Chesbrough's latest description of open innovation.

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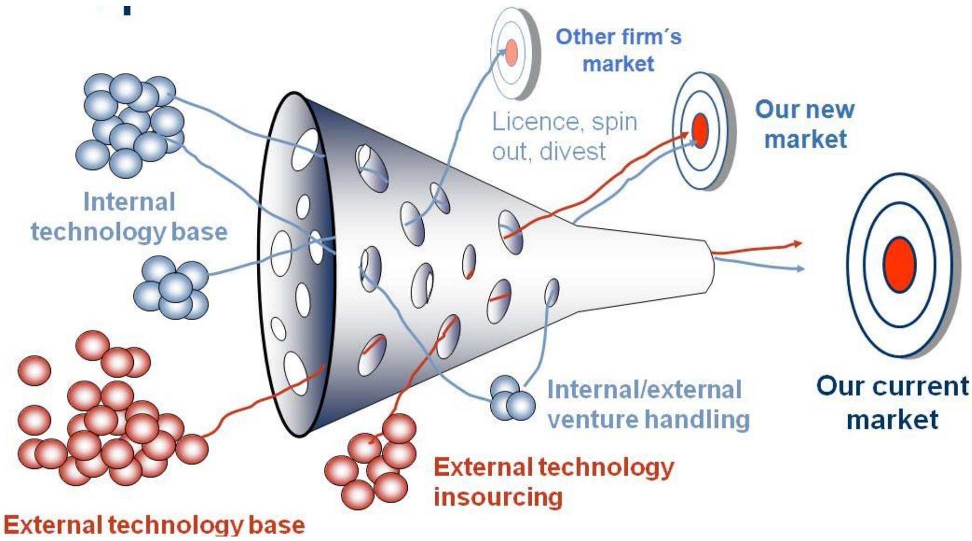
3 As reported also by the OECD, "the organisation of innovative activities (technological as well as non-technological) across firm boundaries is clearly on the increase, with more balance between internal and external sources of innovation ... Industries such as chemicals, pharmaceuticals and information and communication technology (ICT) typically show high levels of open innovation". See OECD (2008) Open innovation in global networks. OECD, Paris

4 Chesbrough, H.W., West, J. and Vanhaverbeke, W. (2006) Open Innovation: Researching a New Paradigm. Oxford: Oxford University Press.

5 OECD (2008), *supra* note 126, at 11.

6 Gassmann, O., Enkel, E., Chesbrough, H.W., 2010. *The future of open innovation*. R&D Management 40 (3), 213–221.

Figure 1 – Chesbrough's description of open innovation



Source: Chesbrough, Vanhaverbeke and West (2014)

In its original definition, open innovation was mostly referred to large corporations, which could act as catalysts of innovation efforts by becoming purchasers and orchestrators of streams of R&D, which involved much smaller companies, whose agility and flexibility usefully complement the capacity and organization of larger firms.

Box 1 - Models of distributed innovation: a EURIPIDIS paper by Garry Gabison and Annarosa Pesole

In a recent EURIPIDIS report, Gabison and Pesole (2014) point out that most of Chesbrough's work implies a vision of open innovation as a linear process, whereas subsequent developments in the literature (including Chesbrough's later works) have added feedback loops between the main phases of the innovation process (R&D, product, development, marketing, and distribution) and from/to the main actors that intervene in it, such as competitors, users, governments, and universities. Gabison and Pesole (2014) also report that subsequent developments in the literature have made open innovation a special case of what they define "distributed innovation" models, which include also social and user innovation (see below at the end of Section 1.1.). This is even more relevant since open innovation has moved from large manufacturing companies to services over the past years, and this shift inevitably implied stronger interaction with customers. Another important feature of open innovation is that it seems to be relatively more suited for large compared to smaller companies. Gabison and Pesole (2014) survey a blossoming stream of literature that shows that open innovation requires a company that plays a pivotal role, coordinating the innovation process and the flows of information and ideas from a central position: this company can be a large manufacturing or service company, or an intermediary. The findings of this literature are relevant for the analysis of the innovation in the ICT sector (see Section 2 below).

Since the emergence of the open innovation model, a number of trends have led to the emergence of even more distributed forms of innovation, some of which reach a peak of openness in the ICT sector, as will be explained in Section 2 below. Such trends include the following:

- ***Increasingly proactive user involvement.*** The emergence of open innovation as a dominant mode of generation of new market solutions in several sectors of the economy was just the beginning of a new trend, which has led to the gradual involvement of many actors along the supply chain as key contributors to idea generation and testing. This lead at once to the gradual rise of the end user as a protagonist of the innovation landscape, and to enhanced possibilities for organisational innovation as an important new phenomenon, which is even more evident in ICT markets (see Section 2 below). Part of this emerging paradigm of innovation is the so-called "user innovation" (Von Hippel 1988, 2005). As explained *i.a.* by Henry Chesbrough, the difference between open and user innovation is that the user innovation model advocates a decentralization of innovation that changes the locus of innovation from firms to users and leads to the "democratisation of innovation". In the user innovation model, innovation results from a collaborative and co-creation process, where users share tasks and the cost of developing innovative products and services, and then reveal their results. In other words, the motivation for innovation revolves around the concept of user utility gains rather than pecuniary returns. According to von Hippel (2013), users are firms or individuals that "expect to benefit from using a product or a service, in contrast to manufacturers that expect to benefit from selling a product or a service." Therefore, users who contribute to the development of the innovative product or service (users-innovators) will adapt the innovation to their specific needs. The user-innovators, although they freely reveal the innovation, will receive greater utility from the use of this innovation than free-riders, as the innovation may not completely fulfil the needs of the latter.

- ***Cumulative innovation.*** A specific case of user innovation, sometimes presented as a stand-alone category, is "cumulative innovation" in which innovation is generated incrementally and collectively by a community of users that share similar values and are bound by formal or informal rules. The typical examples here are open source communities (Von Hippel 2001) for software development, and creative commons communities for content production and sharing. Often these communities emerge on a local scale due to geographical proximity; the advent of the Internet, however, has made it possible to create global-scale communities and even industry clusters without a need for geographical proximity; in addition, the nature of information goods allows for easy versioning and reconfiguration, as well as incremental changes: this is a key feature for what concerns software and online content production. Importantly, users in this form of innovation may include both intermediate users (for example users firms, downstream firms in the supply chain), and final users such as end consumers (Bogers et al., 2010; Berthon et al. 2006). User innovation is normally considered as an opportunity for innovating firms, as user creativity can be usefully employed in a co-creation process: however, in some cases user innovation can also threaten the firm, in particular for what concerns its intellectual property (Baldwin and Von Hippel 2011). The consequences of a massive shift towards user innovation and co-creation, especially in some sectors or sub-sectors of the economy (as will be illustrated in Section 2 below as regards the application layer of the ICT ecosystem), are potentially disruptive also for the ability of firms to secure intellectual property protection.

- ***Social Innovation.*** Social innovation refers to new ideas, institutions, and innovation processes that meet societal needs through new forms of civic participation and collaboration. The challenge of social innovation is to involve society in finding alternative and novel ways to face current societal challenges such as climate change, epidemics, increasing inequality, and poverty. Social innovation is not confined to ICT settings, but exploits Internet network effects and Internet collaborative power to harness the collective intelligence of communities in order to tackle these social challenges. Among the benefits of social innovation are the fact that "the involvement of users on a voluntary basis in the co-creation process reinforces people's recognition by their communities, increases motivation and commitment, and results in the development of more solid innovation practices" (Murray, Caulier-Grice, & Mulgan, 2010). The ultimate goal of social innovation models is "systemic innovation", which entails "fundamental changes to the social system, affecting many elements which shape society: e.g. social movements, business models, laws and regulations, data, infrastructures, and the development of new frameworks and new ways of thinking and acting". This definition is different from other existing definitions, which tend to portray social innovation as a "novel solution to a social problem that is more effective, efficient, sustainable, or just than present solutions and for which the value created accrues primarily to society as a whole rather than private individuals"[7]; or as "new strategies, concepts, ideas and organizations that meet the social needs of different elements which can be from working conditions and education to community development and health — they extend and strengthen civil society"[8]. Social innovation can take place within government, the for-profit sector, the non-profit sector (also known as the third sector), or in the spaces between them. Research has focused on the types of platforms needed to facilitate such cross-sector collaborative social innovation. Typical examples of social innovation are microcredit (e.g. the Grameen bank) and the Indian frugal innovation model, which refers to innovative products and services that "seek to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal) with the objective of reducing the cost of ownership while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards" (Tiwari and Herstatt, 2012).

- ***Distributed co-creation.*** Recently, scholars have observed even more open forms of innovation, called "distributed co-creation". This practice mostly consists in organizing R&D along a number of independent groups working on parallel and complementary streams of research, and composed by both providers and customers looking for tailored solutions. Once again, this will require a cocktail of new talents, researchers and users (often in constant online contact), and with the need for clear and transparent rules on revenue-sharing and IPR management. The peculiarities of this form of organisation and production are summarized by Yochai Benkler (2006) in his description of granularity, as being an even more advanced form of modularity, allowing for micro-contributions to an ever-growing innovative product, the typical example being that of Wikipedia and the creative commons approach to content production[9]. A number of companies have implemented co-creation strategies over the past few years, including notable examples such as LEGO and Threadless[10]. In the software sector, open-source platforms developed through distributed co-creation since the very beginning, and ended up forming entire stacks of products such as the "LAMP" (Linux, Apache, MySQL, and PHP/Perl/Python), which have become standard components of the IT infrastructure at many corporations.

The resulting phenomenon is our seventh generation of innovation models: the so-called "Open Innovation 2.0" model. In particular, Curley and Salmelin have brought together the concepts of Open Innovation, User Innovation and Social Innovation in new a model they call Open Innovation 2.0 (OI2)[11]. The authors emphasise three main points:

- ***Co-opetition****,* i.e. collaboration between competitors[12]. This goes beyond joint ventures: interdependent competitors work together to find solutions and develop new products (mashed-up products of multiple concepts and ideas).

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7 See Phills, J. A., K. Deiglmeier and D. T. Miller (2008), "Rediscovering Social Innovation, Stanford Social Innovation Review; Fall 2008.

8 See OECD (2011), Fostering Innovation to Address Social Challenges, OECD: Paris.

9 See Benkler (2006), p. 100-101.

10 LEGO, for instance, famously invited customers to suggest new models interactively and then financially rewarded the people whose ideas proved marketable. The shirt retailer Threadless sells merchandise online—and now in a physical store, in Chicago—that is designed interactively with the company's customer base.

11 Curley, M., & Salmelin, B. (2013). Open Innovation 2.O: A New Paradigm. Opgehaald van EU Open Innovation Strategy and Policy Group: http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=21

12 Brandenburger and Nalebuff (1996): *Co-opetition*, New York: Currency Doubleday.

- ***The user as an integral member of the innovative process***. The user, the fourth element of the quadruple helix, intervenes earlier in the innovation process to experiment, even before the innovation reaches the pilot stage, and actively participates in the co-creation of new markets for innovation. According to the authors, the co-creative process embedded in the quadruple helix approach leads to a win-win situation, as users get the products and services they need, and the suppliers get scalable products and services. This allows immediate feedback on which innovation is successful and enhances the probability of success, speeding up the scalability and quickly dismissing innovation in unsuccessful areas.
- ***Value networks and inter-disciplinarity.*** Intermediaries must connect value networks to form value constellations. They point out that interdisciplinary approaches must be taken that go beyond the traditional boundaries of disciplines such as ICT, chemistry, or mechanics, which should be mixed together.

The European Commission points at five main elements that define Open Innovation 2.0, to be intended as "a new paradigm based on a Quadruple Helix Model where government, industry, academia and civil participants work together to co-create the future and drive structural changes far beyond the scope of what any one organization or person could do alone"[13]: networking; collaboration (involving partners, competitors, universities, and users); corporate entrepreneurship (enhancing corporate venturing, start-ups and spin-offs); proactive intellectual property management (creating new markets for technology); and research and development (achieving competitive advantages in the market).

In summary, models of innovation used in the literature have significantly evolved over the past few decades, along with the modes of innovation observed in reality. Needless to say, and as already mentioned above, open innovation has been strongly facilitated by the development of new networking technologies, and in particular by the Internet and *i.a.* the versioning possibilities that the information economy has brought. In cyberspace, modularity and end-to-end communication have determined the emergence of entirely new patterns of innovation, such as open source software and creative commons. This stimulated both collaboration between programmers, distributed and collective creation of new products, and also co-innovation between customers and creators, shifting the frontier of intellectual exchange and co-creation towards previously unattainable levels. Table 1 below summarizes the main features of the seven models of innovation described in this section.

[13] https://ec.europa.eu/digital-agenda/en/growth-jobs/open-innovation

Table 1 – Seven generations of innovation process modelling

Generation	Period	Authors of fundamental ideas	Innovation model	Essence of the model
1	1950s-late 1960s		Technology push	Linear Process
2	Late 1960s-First half of 1970s	Myers and Marquis (1969)	Market Pull	R&D on customer wishes
3	Second half of 1970-end of 1980s	Mowery and Rosenberg (1979); Rothwell and Zegveld (1985)	Coupling model	Interaction of Different Functions; Interaction with research institutions and market
4	End of 1980s-early 1990s	Kline and Rosenberg (1986)	Interactive model	Simultaneous process with feedback loops; "Chain-linked model"
5	1990s	Rothwell (1992)	Integrated model	System integration and networks (SIN)
6	2000s	Chesbrough (2003)	Networking Model	Innovation collaboration and multiple exploitation paths
7	2010s	Chesbrough (et al.) (2014)	Open	Focus on the individual and framework conditions under which to become innovative

Source: Kotzemir and Meissner (2013).

Box 2 – Case studies on open innovation: findings from a EURIPIDIS paper

In a recent EURIPIDIS paper, Di Minin et al. (2016) analyse 13 case studies of open innovation. The authors start from the concept of Open Innovation 2.0 as introduced by Curley and Salmelin (2013) and described by Gabison and Pesole (2014) for the EURIPIDIS project. The case studies cover a wide range of different sectors and firm sizes, from new firms that have successfully leveraged the potential of the collaborative economy (BlaBlaCar) to established ICT giants (Philips). The authors find a prevalent approach to open innovation, which they term "open but controlled", since the pivotal company adopts a collaborative model but at the same time try to implement strategies to ensure a proper return on their investment. The analysis highlighted a number of drivers and barriers to open innovation models. Among the drivers, particularly important are the role of large EU consortia in enabling Open Innovation Strategies, particularly as regards explorative R&D activities; the use of IP as an enabler of greater control of innovation, which in turn makes companies more prone to build alliances and collaborate; the positive role attributed to the Horizon 2020 SME; and the fact of being embed in an ecosystem characterized by easy access to complementary assets, and by an intense flow of knowledge and information. Among the barriers, the case studies mostly highlighted constraints due to internal management (in particular, achieving the right balance between internal R&D and external sourcing of knowledge and technology); and the lack of institutional support and/or the presence of rules and regulations that prevent.

The authors draw a number of policy implications for the EU institutions, ranging from the need to promote local innovation ecosystems to the parallel need to orchestrate global ecosystems through open relationships. This echoes findings from previous IPTS research, including that on Poles of Excellences, characterized by local concentration, and global interconnection. The authors also conclude that formal IP protection mechanisms facilitate collaboration, even if SMEs often struggle to find the appropriate partners. Easing the patent search process and exploring alternatives to the patent system for SMEs are seen as important tasks for EU policymakers. Moreover, policymakers are invited to take action to facilitate user involvement in Open Innovation 2.0 communities, and strive to achieve a balance between encouraging basic research, applied research, and innovation models. This implies that policymakers look at the whole value chain, including access to funding (e.g. through venture capital), and refrain from awarding, explicitly or implicitly, priority to specific innovation models. This leads again to what is essentially a facilitating role of policymakers, which focuses on creating the conditions for the growth and the diffusion of a strong Open Innovation culture.

1.2 Conceptualizing places for innovation and entrepreneurship: systems and ecosystems

While gradually improving and refining the understanding of innovation processes, the academic literature on innovation has also gradually expanded the view of innovation and entrepreneurship to understand the context in which these phenomena take place, as well as to capture the environmental interactions that make innovation and entrepreneurship possible. The overall premise of this line of thinking, as remarked by Wintjes (2015), is that innovation is a social phenomenon, and as such "it does not occur in a vacuum, nor can it be regarded as an external given, which becomes accessible to us all like 'manna from heaven'"[14]. This has prompted scholars to gradually develop the concept of "innovation systems". Carlsson et al. (2002) compare the various concepts of innovation systems and conclude that they all involve the creation, diffusion, and use of knowledge. The various innovation systems concepts, which have been developed, include: national innovation systems (Freeman 1987; Lundvall 1992; Nelson 1993), regional innovation systems (Cooke, 2010), and sectoral innovation systems (Malerba, 2002; 2004).

The original concepts of national, regional and sectoral innovation system had a focus on firms as the main actors and on the economic benefit of innovations, and had an economic purpose of innovation in mind, while more recent applications of the concept have broadened the perspective of innovation by emphasising its diffusion and impacts on societal challenges, e.g.: green challenges, healthy aging, or social issues. In addition, at least in some sectors of the economy, the increasingly global and granular nature of innovation has uncovered the limitation of adopting a national/regional and firm-centric approach: on the one hand, private actors increasingly build their own innovation systems (alternatively termed platforms, see Fransman 2014) across national territories, and this creates an inevitable tension between what a government can do to stimulate innovation within its territory, and what the market develops as inherently global and interconnected; moreover, the increasing importance of users and institutions in innovation systems had led scholars to start using the term "ecosystem" to emphasize the multi-dimensional, integrated and user-centric nature of modern innovation processes. Below, we explore the "systems" concept, and then move to describing entrepreneurial ecosystems.

1.2.1 National and regional innovation systems

As reported by Wintjes (2015), many authors have used the concept of National Innovation Systems and have contributed to its development as a theoretical concept, but there is no commonly agreed definition, not even at the OECD level[15]. In the academic literature, after the pioneering work of Freeman (1987), Lundvall (1992), and Nelson (1993), the concept has been operationalized by several academics including,

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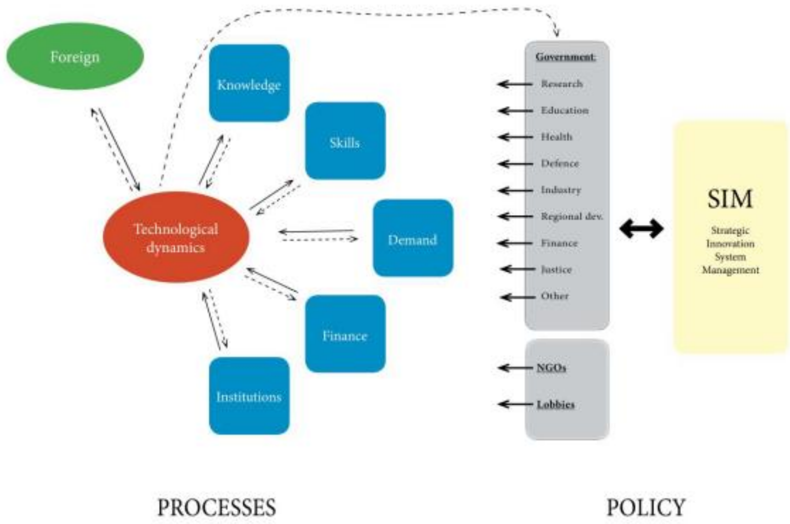
14 See Vintjes (2015), Section 2.1.

15 The Oslo manual (3rd edition; OECD 2005), which is a cooperation between OECD and Eurostat on how to measure innovation, shows that the development of the national innovation system concept has changed the conception of innovation: "innovation is a more complex and systemic phenomenon than was previously thought. Systems approaches to innovation shift the focus of policy towards an emphasis on the interplays between institutions, looking at interactive processes both in the creation of knowledge and in its diffusion and application. The term "National Innovation System" has been coined for this set of institutions and flows of knowledge" (OECD 2005).

among others, Porter and Stern (2002) and Archibugi et al. (2009), who develop indexes of national innovative capacity that rely heavily on the specific role played by each of the main actors that shape innovation patterns and success in a given country. These actors are mostly large businesses and SMEs, university and research institutes, venture capitalists and business angels, and government.

Although in the early studies on innovation systems the comparison between countries is based on descriptions of rather static profiles, more in-depth and qualitative studies have focused on the dynamics and (path-dependent) change of systems over time, also including a policy perspective (e.g. Fagerberg et al. 2013). The idea that the institutions of various policy domains influence the innovation performance of innovation systems has been part of the NIS concept from the beginning, but over the years the number of policy domains which are considered relevant have increased, moving beyond the ministries of industry and economy and the ministries of science and education.

Figure 2: The National Innovation System: Dynamics, processes and policy



Source: Fagerberg et al. (2013).

Focusing on the geographical aspect, several authors have applied the NIS concept to study regional innovation systems However, synthesizing the Regional Innovation Systems literature, Doloreux and Parto (2004, p.21) state that "most analyses can be criticized for failing to adhere to a unified conceptual framework and clear definition or conceptualization of such key terms as region, innovation system, and institutions".

Similar to the conceptualization of innovation "systems" and largely consistent with it is the literature on the so-called "triple" and "quadruple helix", which focuses on a subset of actors within the System of Innovation that are especially relevant for innovation in fields where science and technology play an important role (i.e. this explains the focus on Universities and research centres). In particular, the Triple Helix model has evolved and gone through three different development phases (Torkkeli et al. 2007). In Triple Helix I, the three helices are defined institutionally. In Triple Helix II, more attention is attached to communication within the system and to the different knowledge systems. The Triple Helix III focuses in the hybrid organizations of academia, government and industry. Later, contributions such as Yawson (2009) observed that the Triple Helix of state, university and industry was missing an essential fourth helix, the "public" or the "user". The user-driven innovation approach can be seen as largely consistent with the most recent models of innovation described in Section 1.1 above, and has become an essential element of the new "broad-based innovation policy" approach (see Edquist et al. 2009), which emphasises the need to broaden the concept of innovation to include product innovations in services, as well as organizational process innovations, and does not only relate to economic significance, but also to wider societal benefits, as well as measures targeted to support innovation in public services. This new innovation policy conception takes also all determinants of the development and diffusion of innovations into account when designing and implementing innovation policies. This would then include policy instruments operating from the demand side. It would also contemplate a wider spectrum of sources of knowledge and more versatile interactions with producers and users of knowledge (Edquist *et al.* 2009).

The current frontier in the study of innovation and innovation policy is heavily reliant on the concept of "smart specialisation". This concept fundamentally relies on two core pillars[16]:

- *Knowledge ecology.* This assumes that "context matters" for the potential technological evolution of an innovation system. In other words the potential evolutionary pathways of an innovation system depend on the inherited structures and existing dynamics including the adaptation or even radical transformation of the system.
- *Identification of knowledge-intensive areas as those areas that feature the highest presence of key players in the innovation eco-system.* Players such as researchers, suppliers, manufacturers and service providers, entrepreneurs and users use their entrepreneurial skills to acquire and disseminate knowledge and detect existing profit opportunities, and ultimately act as catalysts for driving the emerging transformation of the economy.

The smart specialisation concept encompasses both sectoral and geographical aspects, and is applied mostly in the concept of regional innovation today: its peculiarity lies in the strong link with governance and policy, and its prescriptive, rather than merely descriptive, power. Regions can adopt a smart specialization approach only after a thorough reconsideration of their fundamentals in terms of knowledge assets, capabilities and competences; as well as a detailed mapping of the relative strength and development of the main actors of innovation. According to McCann and Ortega-Argilés (2011), translating smart specialization into regional policy requires a careful analysis of the role of the entrepreneurial agents and catalysts, the relationships between the generation, acquisition and transmission of knowledge and ideas at the geographical level, the regional systems of innovation, and the institutional and multi-level governance frameworks within which such systems operate[17]. In addition, the issues of externalities and interdependency between the region and the rest of the world must be solved. Finally, indicators must still be developed in order to link inputs, outputs and outcomes of the bottom-up activities taking place within the smart specialization approach to regional innovation policy.

The smart specialization approach appears as an evolution of the slightly older concept of "regional innovation systems", which argues that "firm-specific competencies and learning processes can lead to regional competitive advantages if they are based on localized capabilities such as specialized resources, skills, institutions and share of common social and cultural values"[18]. As observed by Doloreux and Parto (2005), among others, the theoretical model of regional innovation systems mostly looks at the main

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16 http://ec.europa.eu/invest-in-research/pdf/download_en/kfg_policy_brief_no9.pdf.

17 Philip McCann & Raquel Ortega-Argilés, 2011. "Smart specialisation, regional growth and applications to EU cohesion policy," Working Papers 2011/14, Institut d'Economia de Barcelona (IEB).

18 See Malmberg A, Maskell P (1997) Towards an explanation of regional specialization and industrial agglomeration. European Planning Studies Stud 5:25–41; and Maskell P, Malmberg A (1999) Localized Learning and industrial Competitiveness. Cambridge Journal of Economics 23:167–185.

ingredients that explain the difference in the performance of regions based on the availability of key elements such as human resources, infrastructure and learning processes through the interaction of different actors[19]. However, the fact that defining a region has proven quite controversial so far does not allow for a precise categorization and measurement of innovation across regions.

In this respect, part of the literature (including research by the JRC on European poles of excellence[20]) observed that, rather than regions as a whole, it is metropolitan areas that are the best location for innovation because they offer firms spatial, technological and institutional proximity and specific resources[21]. In addition, more concentrated areas allow for a better implementation of emerging concepts such as that of industrial ecology (Frosch and Gallopoulos 1989; Erkman 2004; Fischer-Kowalski 1998; Fischer-Kowalski and Hüttler 1998). The natural evolution of these latter contributions is the development of approaches that tend to favour the development of "smart cities"[22].

Box 3 – Innovation systems – a EURIPIDIS paper by Rene Wintjes

In what can be considered as the most general paper of the series produced y the EURIPIDIS project so far, Wintjes discusses how the concept of Systems of Innovation can be fruitfully applied to ICT innovation. Based on a review of the literature on (national, regional and sectoral) Systems of Innovation, the author focuses on the need to look beyond R&D investments, beyond intra-mural firm activities, and beyond market-transactions, to capture the broader (global, national, regional, sectoral) context in which firms interact with other firms and non-firm actors, and with market and non-market factors. The result is that innovation becomes subject of study micro, meso and macro level, which in turn leads to acknowledging the inherent complexity of innovation and the impossibility of developing a "simplistic 'one-size-fits-all' set of scientific laws or equations which can explain it all". This finding applies both to ICT-producing and ICT-using sectors.

After a literature review of the literature on Systems of innovation, Wintjes introduces a focus on sectoral systems of innovation, which anticipates his subsequent focus on ICT. In defining sectoral innovation systems, the paper potentially overlaps with what Fransman defines as sector-level ecosystems, although the two authors use rather different language, and different references. In the case of Wintjes, the key reference is the work of Malerba (2002), which adopts a systemic view by arguing for the need to focus more strongly on the demand-side of innovation and defining sectoral systems of innovation and production as *"a set of products and the set of agents carrying out market and non-market inter-actions for the creation, production and sale of those products"*, but then focusing mostly on manufacturing rather than services, and providing a rather static view of the interaction between the different actors that operate within the system. Also, Wintjes presents this literature by emphasising that the sectoral dimension is less studied and mentioned than the geographic dimension (national, regional): it is apparent that the sectoral dimension is very often approached as being a further specification of a system that is geographically defined, which potentially clashes with the global nature of the systems that are observed especially in ICT-producing

[19] DOLOREUX, D. & S. PARTO (2005) Regional innovation systems: Current discourse and unresolved issues. Technology in Society 27, 133-153.

[20] http://is.jrc.ec.europa.eu/pages/ISG/EIPE.html.

[21] See Audretsch DB, Feldman MP (1996) R&D spillovers and the geography of innovation and production. Am Econ Rev 86:630–640; and also Maskell and Malmberg (1999), *supra* note 119.

[22] Caragliu A, Del Bo C, Nijkamp P (2009) Smart Cities in Europe. VU University Amsterdam, Faculty of Economics, Business Administration and Econometrics, Series Research Memoranda 0048/2009; and Komninos N (2009) Intelligent cities: towards interactive and global innovation environments. Int J Innov Regional Dev 1:337–355.

sectors, but also – thanks to technological innovation – in ICT-using sectors (e.g. Global Value Chains)[23]. Wintjes then refers to the literature on ecosystems as basically using a different word for the same concept of innovation systems: however, an important difference is exactly the geographical dimension.

1.2.2 Entrepreneurship ecosystems

Although the topic of entrepreneurship and related settings has gained the attention of academics since the early contributions of Joseph Schumpeter, the measurement of entrepreneurship and the analysis of systemic conditions that favour entrepreneurship have been subject to significant efforts only recently. As remarked by Bogdanowicz (2015), significant efforts were made in particular by OECD and EUROSTAT (Entrepreneurship Indicators Program, EIP) to lead to a consensual definition of entrepreneurship, a structured perspective on the determinants of entrepreneurship and on its economic and social impacts. Likewise, there is now a large body of surveys, analysis and research on data included in the Global Entrepreneurship Monitor (GEM) and the Global Entrepreneurship Index (GEDI), but current measurement efforts still fall short of adequately capturing systemic factors such as the impact of entrepreneurship on innovation, and the role of "intra-preneurship".

Some of these systemic aspects are currently being factored into a nascent literature on entrepreneurship ecosystems, which is linked with the innovation systems literature, with a peculiarity: the focus specifically and explicitly on the systemic factors that foster entrepreneurship [24]. In the literature, a variety of definitions of entrepreneurial ecosystems can be found. Isenberg (2010) defines them as a set of individual elements – such as leadership, culture, capital markets, and open-minded customers – that combine in complex way to stimulate entrepreneurship. According to Isenberg (2010, 2011), the key to sustainable entrepreneurship lies in the specific combinations of the elements of an entrepreneurial ecosystem. Figure 3 below shows the composition of an entrepreneurship ecosystem according to Isenberg (2011). It consists of six domains which in turn comprise further elements: (1) politics, including leadership and government, (2) finances, (3) culture, including entrepreneurial success stories and social norms, (4) infrastructural, professional and non-public support, (5) human capital, including education and personnel, and (6) markets, consisting of networks and early customers. For a healthy entrepreneurial ecosystem each of the six domains should be available in the region and be entrepreneurship-friendly. However, there is no easy path towards a sustainable, fully functional entrepreneurial ecosystem that is at the same time innovative. The creation of an entrepreneurship-friendly environment will be extremely difficult in particular if there is no explicit political support of and no high social and/or political priority on entrepreneurship.

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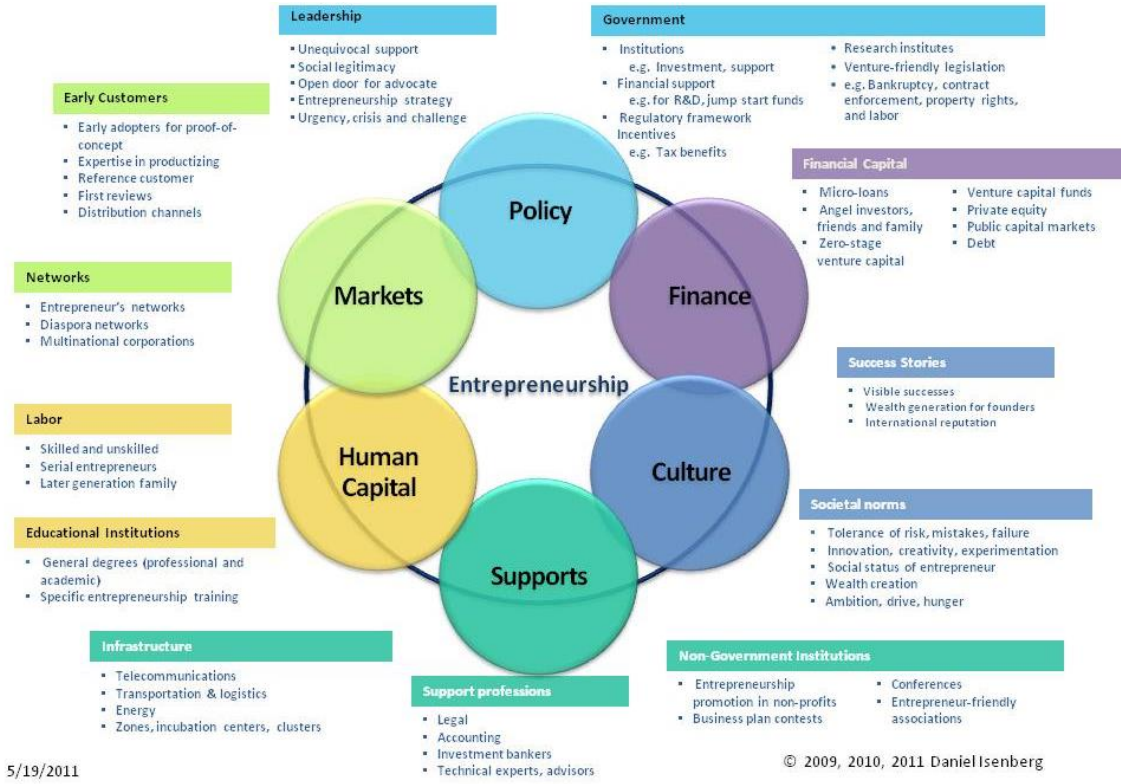
[23] For example, Wintjes (2015) reports two OECD studies, such as the one titled: 'Boosting Innovation: The Cluster Approach' describes clusters as sector-specific systems of innovation, which operate under National Systems of Innovation. Also the OECD study: 'Innovative Clusters: Drivers of National Innovation Systems', belonged to the second phase of the OECD NIS project which was devoted "to deepening the analysis" of National Innovation Systems.

[24] Models of entrepreneurial ecosystems have focused so far on "Entrepreneurial Personality"(Valdez 1988), the "Entrepreneurial process" (Gnyawali and Fogel 1994), and "Elements" and "Evolution" (Neck et al. 2004).

Figure 3 – Isenberg's entrepreneurship ecosystem



Source: Introducing the Entrepreneurship Ecosystem: Four Defining Characteristics, Daniel Isenberg, May 25, 2011, FORBES.COM[25]

1.3 From innovation to innovation policy: recognizing the changing phenomenology and governance of innovation

Over the past few years the understanding of innovation as a policy subject has followed new, important trends, in addition to the ones highlighted in the previous sections. First, innovation (and our understanding of it) has become more multi-faceted, systemic, and open, as already described in Section 1 above.

Second, the modelling of the interaction between players that compose the innovation system has become more sophisticated, and the notion of ecosystem, rather than merely system, is now adopted (not without a degree of uncertainty and variance in definitions) to encompass *i.a.* the institutional and policy interrelations and constraints that characterise the life and activity of entrepreneurs and innovators, the proactive role of end users, and the involvement of several players in innovation projects.

Third, scholars have increasingly argued that not all innovation exerts a significant impact on long-term policy goals such as sustainable development and growth. More in detail, there are innovative products, processes and services that contribute more than others to addressing grand societal challenges, such as climate change, water scarcity, and for Europe unemployment and the needs of the ageing society. This has led to growing emphasis being attached to the so-called "purpose" of innovation, which bears substantial relevance for innovation policy. As a matter of fact, both innovation and entrepreneurship should be approached in public policy as intermediate, not ultimate goals, and as such functional to social welfare in the long run. In particular, the diffusion

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25 See: http://www.forbes.com/sites/danisenberg/2011/05/25/introducing-the-entrepreneurship-ecosystem-four-defining-characteristics/#70606ad538c4

of innovation, and its widespread availability to end consumers is as important as the innovation process itself.

The consequences of this shift in the approach to innovation as an essential element of a sustainable development strategy are far-reaching. As a preliminary set of remarks:

- *Innovation policy cannot focus only on product and process innovation*, but rather on many other forms, including social and organisational innovation. This leads some authors to refer, more generally, to "systemic innovation" (Mulgan and Leadbeater 2013). The OECD recently observed that "social and organisational innovations, including new business models, are increasingly important to complement technological innovation"[26].
- *Innovation policy cannot focus only on the supply-side*. Demand side policies such as the strategic use of public procurement, policies that incentivise the consumption of sustainable and innovative products, and policies that aim at improving the accessibility of innovative products (including education policy, and even trade policy) are as important as traditional supply-side innovation policies such as R&D subsidies and tax breaks, patent law, or public funding of innovation and entrepreneurship.
- *Innovation policy is chiefly related not only to the development, but also to the diffusion, of new products, processes and services*[27]. Public policy in support of innovation (especially in Europe) should look beyond the so-called "innovation deficit", to encompass the "diffusion deficit" that prevents new technologies and business models to reach the market, or to become affordable for the majority of consumers. The recent Staff Working Document published by the European Commission on "Better Regulation for Innovation-Driven Investment" acknowledged the key role of public policy in removing obstacles to the commercialization and diffusion of existing technologies, which lack a sufficiently large market in Europe[28].
- *Innovation policy cannot rely exclusively on sector-specific industrial policy*, since this would not constitute the best approach to trigger those organisational, transformational, disruptive changes that often create innovation by displacing existing business models[29]. In short, innovation policy has to take a systemic view, not a sector-specific view. This is important also in order to avoid so-called "incumbency" problems, which emerge whenever policies crafted for a specific sector end up hampering disruptive innovation by empowering existing players and disadvantaging new entrants (OECD 2015).
- *Relatedly, innovation policy is increasingly in need of "direction"* (Fagerberg 2015), in addition to facilitation of private sector entrepreneurship, R&D investment and knowledge transfer. The direction element implies that governments steer innovation efforts towards emergent and urgent societal challenges. This is done, as a matter of fact, by the Horizon 2020 programme (in particular in setting up European Innovation Partnerships) and even more explicitly in the U.S. strategy for American Innovation adopted by the Obama administration, and recently updated and re-launched in October 2015. This requires that governments choose to support those technologies that are more likely to bring social, economic and environmental benefits over time, and avoid creating biases or mis-alignments in their policies, which would disadvantage sustainable, systemic innovation.

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[26] http://www.oecd.org/sti/OECD-Innovation-Strategy-2015-CMIN2015-7.pdf, at 6.

[27] Freeman, C. (1994), The Economics of Technical Change, Cambridge Journal of Economics, 18: 463-514.

[28] See European Commission Staff Working Document, "Better regulations for innovation-driven investment at EU level", SWD (2015) 298 final, 15 December 2015.

[29] See http://ec.europa.eu/economy_finance/publications/economic_paper/2011/pdf/ecp438_en.pdf

- *Moreover, history and geography appear to be very important for a proactive innovation and entrepreneurship policy*: the innovation and entrepreneurship ecosystems literature (which, broadly speaking, encompasses the literature on innovation systems and the one on entrepreneurship ecosystems) suggests that not every portion of territory can become as innovative, and as such the role of government should be that of selecting those environments in which entrepreneurship can flourish more easily, and strengthen the ties between the various players that populate those environments whenever possible. This finding is potentially in line with the "smart specialisation" approach adopted in EU regional policy.

2 The ICT ecosystem: features, trends, and policy consequences

This section builds on the general findings of Section 1, but focuses specifically on the ICT "ecosystem", and describes its main features, existing and expected trends, and related policy consequences. The ICT ecosystem is slightly broader than the ICT sector *stricto sensu*, as defined for example in the PREDICT report, i.e. as comprising NACE codes related to both manufacturing and services (see table 2 below)[30]. It is broader, following Fransman (2015), since it includes not only the companies that operate in the specific NACE codes, but also their interdependencies; and their institutional and architectural constraints, as represented by the main features of the networked environment in which these companies and institutions operate. In addition, the ICT ecosystem includes also end users, which play an increasingly active role also in the generation of new products, services, ideas (see above, Section 1.1 on distributed innovation). Accordingly, the next sections will focus on the broader concept of ecosystem, as a more appropriate way to encompass, in the analysis, all factors that determine the phenomenology, direction, and intensity of ICT innovation. Moreover, the ICT ecosystem also partly overlaps with the Internet: again, the former is broader since it includes also all hardware and network equipment companies that form the underlying infrastructure on which the Internet runs; and is narrower since the Internet can be comprises also a number of companies that operate in "brick and mortar" sectors, but participate to the Internet by operating their own websites. In this respect, it is fair to state that the ICT ecosystem does not encompass the whole Internet root zone, i.e. all its domain names. For example, Veugelers (2013) and Fransman (2010) identify five layers of the overall digital ecosystem: Equipment; Network; Connectivity, Navigation and middleware; and Applications including content. Of these, the ICT sector represents the first three only, whereas the ICT ecosystem encompasses all of them.

Table 2 – ICT in the International Standard Industrial Classification

Nace Rev. 2	Description
261-264, 268	**ICT manufacturing industries**
261	Manufacture of electronic components and boards
262	Manufacture of computers and peripheral equipment
263	Manufacture of communication equipment
264	Manufacture of consumer electronics
268	Manufacture of magnetic and optical media
465, 582, 61, 62, 631, 951	**ICT total services**
465	**ICT trade industries**
4651	Wholesale of computers, computer peripheral equipment and software
4652	Wholesale of electronic and telecommunications equipment and parts
5820, 61, 62, 631, 951	**ICT services industries**
5820	Software publishing
61	Telecommunications
62	Computer programming, consultancy and related activities
631	Data processing, hosting and related activities; web portals
951	Repair of computers and communication equipment

Source: PREDICT report (2015)

The remainder of this section is structured as follows. Section 2.1 describes the features and evolution of the ICT sector, defined as an ecosystem composed of players, users, institutions, technologies, and their multiple interactions. Section 2.2 describes the main features of innovation in the ICT ecosystem, by highlighting the relevance of platforms

30 See https://ec.europa.eu/jrc/en/predict/predict2016

and their impact on business models and entrepreneurship. Section 2.3 discusses whether the ICT sector can be considered as different from all other sectors for the purposes of innovation policy. Section 2.5 briefly summarises the main findings of this chapter.

2.1 The defining features of the ICT ecosystem

ICT can be defined as the integration of information processing, computing and communication technologies. As such, its birth can be traced back to the 1940s, with the development of the first computers; however, when it comes to the actual diffusion of ICT products and services on the market, the sector appears much younger[31]. Designed in the mid-1970s, so-called "minicomputers" entered the scene in the early 1980s in small businesses, manufacturing plants, and factories[32]. The market for microcomputers increased dramatically when IBM introduced the first personal computer in the fall of 1981: the choice to endow the new personal computer with a modular architecture, in which components (or "complementors") produced by different firms could interoperate within the same system, was essential for the success and diffusion of this product. Since then, the "layered" architecture of the personal computer (i.e. hardware, operating system, middleware, software applications) became the standard way of organising production and business in the IT world. This feature became even more prominent once information technology started to gradually merge with communications networks in the late 1980s and early 1990s, giving birth to a full-fledged ICT sector by mid-1990s, with computers (of various sizes and powers) being connected by means of telecommunications networks across the globe. The choice to adopt common, non-proprietary standards such as HTML and HTTP as the foundations of information exchange on the Internet proved essential for its diffusion and development, as well as for the transformation of the ICT sector into a full-fledged ecosystem. At the same time, the decision not to regulate the emerging Internet as a telecommunication service (e.g. in the U.S. 1996 Telecommunications Act) and to defend, at least in the early days of Internet policy, the neutrality of the network (e.g. in the 1996 WIPO Treaties, in the 1998 US Digital Millennium Copyright Act, and in the EU e-commerce and Information Society Directives in the early 2000s) proved essential for the diffusion of the "network of networks".

Against this background, the foundational, differentiating features of the ICT ecosystem can be summarized as follows:

- *Computing power and Moore's law*. The ICT ecosystem is largely based on the increase in computing power, which has for decades been governed by Moore's law. According to this law, formulated in 1975 by Gordon Moore, the number of transistors – the fundamental building blocks of the microprocessor and the digital age – incorporated on a computer chip will double every two years, resulting in increased computing power and devices that are faster, smaller and lower cost. In other words, computing dramatically increases in power, and decreases in relative cost, at an exponential pace. While this feature of computing power initially concerned mostly hardware devices, with the advent of the Internet age and cloud computing exponential improvements are increasingly observed also in terms of broadband connectivity and digital storage.

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31 The first commercial computer was the UNIVAC I, developed by John Eckert and John W. Mauchly in 1951. It was used by the Census Bureau to predict the outcome of the 1952 presidential election. For the next twenty-five years, mainframe computers were used in large corporations to do calculations and manipulate large amounts of information stored in databases. Supercomputers were used in science and engineering, for designing aircraft and nuclear reactors, and for predicting worldwide weather patterns.

32 In 1975, the Massachusetts Institute of Technology developed microcomputers. In 1976, Tandy Corporation's first Radio Shack microcomputer followed; the Apple microcomputer was introduced in 1977.

- *Modularity*. The development of increasingly complex products has led engineers to adopt a modular architecture since the early days of microcomputers. As already mentioned, the personal computer launched by IBM in 1981 became an enormous success in terms of market uptake in particular due to its modular architecture, which led many industry players to converge on a single *de facto* industry standard (Bakos and Brynjolfsson 1999; Shapiro and Varian 1998). The Internet adopted a similar modular structure, with multiple tiers of Internet Service Providers, hardware component that run the network and allow for data processing, storage and communication, a "logical layer" that determines traffic flows and exchange protocols, operating systems that govern the interaction between users, devices, the network and information flows; applications that allow end users to carry out a growing number of activities; content generated by users or by third parties; and the users themselves.
- *End-to-end architecture and neutrality*. Being based on the telecommunications network and on open protocols, the ICT ecosystem features an end-to-end architecture. An end-to-end architecture implies the possibility, for every end user, to engage in communication and exchange information with every other end user. The early Internet coupled this feature with the so-called "neutrality" principle, according to which no central intelligence would be able to filter or manage traffic flowing between end users, thus making the Internet a "dumb" network, in which intelligence would be distributed only at the edges (i.e. end users). The Internet Protocol governs the way in which content is protected from inspection through a feature called "protocol layering" (see Yoo, 2013). However, as the Internet started to diffuse and permeate several other economic sectors, its neutrality features started to be increasingly questioned: the impossibility to inspect traffic on the network and to differentiate between applications that require real-time delivery and the ones that are more tolerant to delays have started to constrain technological development in a number of fields, from content and video streaming to online payments. Today, the end-to-end architecture appears as a crucial feature of the ICT ecosystem, whereas (as will be explained below) neutrality has been largely abandoned in favour of more complex and potentially more effective architectural design.
- *Digital information goods*. The ICT ecosystem is essentially based on digital technology, and as such features many of the characteristics that information displays from an economic perspective. Since Kenneth Arrow's characterisation of information and the advancement of theories of common pool resources and the so-called "information semi-commons" (Heverly 2003), the understanding of the peculiar economics of information has evolved significantly in social sciences. The fact that goods and services offered on the Internet are made of 0s and 1s (i.e. digitized in binary language) bears significant consequences for the economics of the sector. These include: (i) *endless replicability and non-rivalry in consumption*: information goods can be replicated with no significant loss in quality, and can be accessed by different users from multiple locations at the same time, thus enabling sharing: (ii) *near-zero or zero marginal costs*: replicating the information embedded in an information good normally costs nothing (today, in most cases there is no need for a physical device to contain the information good, as in the case of downloaded content and software); (iii) *plasticity and granularity*: digital information (and related goods) can be decomposed, rebuilt and repackaged *ad libitum*, thus leading to endless possibilities for versioning, sampling, re-use, including through user-generated content, text and data mining and many other activities.

These foundational characteristics have determined the emergence of some of the features that are typically attributed to the ICT ecosystem by industry analysts.

First, *R&D intensity and innovation rates tend to be greater than in other sectors*. This depends on a number of factors, including the acceleration in computing power (Moore's law); the possibilities for diffusion guaranteed by the common architecture (Metcalfe's Law); and the possibilities for participation secured by the choice of open protocols (i.e.

anyone can in principle develop a software or hardware that is compatible with existing Internet protocols).

Second, *innovation was initially largely incremental, due to modular architectural design* that followed "big bang" inventions such as the computer chip and the Internet protocol: this feature is however not as evident today due to the platformization of the Internet and the permeation of a number of economic sectors by new and disruptive business models (see below).

Third, *product life-cycles become increasingly shorter due to the acceleration of technological change*: several companies in the ICT ecosystem (and even more, the ones active at the higher layers, such as operating systems, other middleware, and applications) reportedly work on at least three successive generations of products (the current one, the next one, and the one after that).

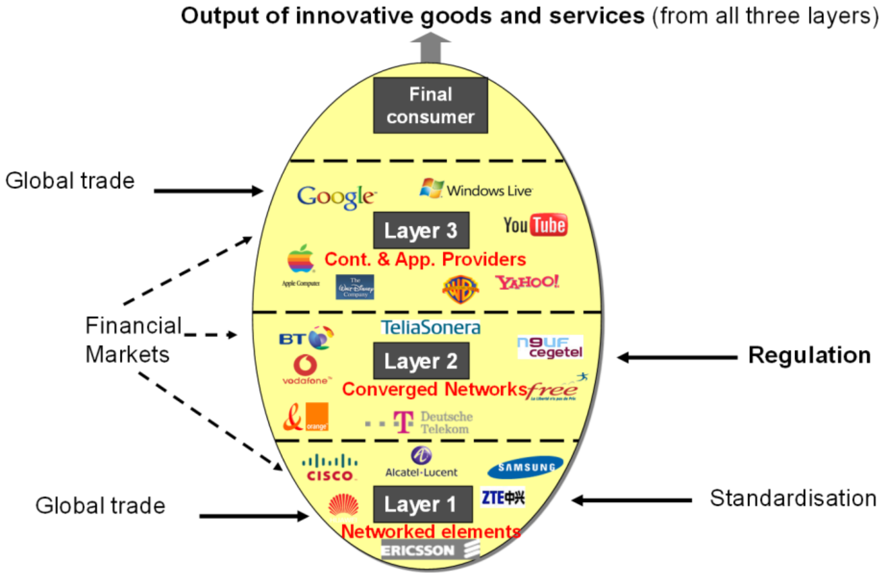
Fourth, *the end-to-end architecture of the Internet and the digital nature of information goods have led to the emergence of network effects and large economies of scale* in the ICT ecosystem: this, in turn, has led to the emergence of multi-sided platforms that are gradually changing the architecture of the network (see below).

All these aspects bear consequences in terms of innovation performance/dynamics, industry performance, competition, overall societal welfare.

Box 4 – Global ICT ecosystems – a EURIPIDIS paper by Martin Fransman

The EURIPIDIS paper on global innovation ecosystems authored by Martin Fransman (2015) defines ecosystems as groups of symbiotically interacting 'players' which include companies and other players such as the providers of knowledge, resources, and 'rules of the game'. It is the companies which constitute the economic 'engine' of the ecosystem since they create value for consumer-users, output, and employment. In doing so, however, the companies are also influenced by the other players in the ecosystem. Moreover, two levels - the sector level and the company level – in the ecosystems are considered to interact with the result that it is not possible to fully understand the one without the other. One of the main contributions of this paper is to demonstrate the necessity, if the process of innovation is to be properly understood, of a simultaneous analysis at both sectoral, cross-sectoral and company levels. The analysis proceeds hence in two stages. The first stage involves the identification of the main players within the company who are collectively involved in the company's innovation process. Crucially, this analysis includes not only researchers and developers (accounting for the R&D on which most studies of innovation conventionally focus) but also other players such as those involved in company strategy, sales and marketing, design, software development, and distribution - players who are left out of most analyses. The second stage of the analysis involves situating the intra-company players within the broader context of the key external players who are part of the company's Global Innovation Ecosystem. Increasingly (for both large and small companies) knowledge that is relevant for the company's innovation process will be found not only outside the company's legal boundaries but also outside its home country. This means that in order to benefit from this external knowledge, the company's Global Innovation Ecosystem needs to be designed so that it can effectively access and use knowledge globally. The analysis shows that there are different kinds of company Global Innovation Ecosystems in the ICT ecosystem defined by Fransman (see Figure 4 below).

Figure 4 – A simplified model of the ICT ecosystem



Source: Fransman (2010, 2015)

In Layer 3 – the platform, content and applications layer – there is a unique hotbed of Internet related entrepreneurship and innovation along with massive entry by new companies. In order to explain this hotbed of activity, the report develops the argument that the key determinant is the emergence of what is called the Internet Innovation Platform. Furthermore, six key characteristics of this platform are identified that together make it ideally suited to facilitating the entry of new, innovative companies: availability of network services; open low-cost access; relatively low fixed costs; very low marginal costs; high consumer surplus; high scalability. Very different structural conditions exist in Layer 2 (the network operator layer). More specifically, this layer is driven by economic forces which include: very high fixed costs coupled with low marginal costs; economies of scale; and substantial entry barriers. The result of these forces is that Layer 2 is dominated by a small number of large operators. But this is not all. The inevitable focus of the operators on their networks has required a set of capabilities that are fundamentally different from the capabilities that the software-based Internet companies in Layer 3 need in order to become and remain competitive. This explains the inability of the dominant Layer 2 network operators to successfully diversify their activities into Layer 3 (despite their serious efforts to do so) in an attempt to avoid becoming the simple providers of 'dumb pipes' that carry data for others who make money from the use of that data. In addition, the innovation activities of the network operators in Layer 2 are also shaped by their reliance on innovation by ICT equipment providers in Layer 1. Having said this, the report also shows that telecoms operators such as Vodafone and Telefonica, have been making good use of their global networks as innovation platforms in their company Global Innovation Ecosystems. Finally, Layer 1 players (the equipment manufacturing layer) may be divided into those that have managed to establish significant innovation platforms and those that have not. This has been one factor shaping their different company Global Innovation Ecosystems. A further force for change has been the entry of new, innovative competitors, notably Chinese companies such as Huawei and ZTE, but also new players from the US. The increasing prevalence of company Global Innovation Ecosystems challenges conventional policy in several key areas including: technology transfer, intellectual property rights, financing, taxation, public procurement and even evidence-based policy-making. The essential point is that in Global Innovation Ecosystems innovation is a joint product rather than being the result of the effort of a single firm. This means that the designers of policies in these areas must now take account of the incentive effects on multiple rather than single players. Furthermore, they also have to understand the cooperative and competitive relationships between these players if they are to design effective incentives. All this can significantly increase the cost of formulating and implementing innovation policies in these three areas.

2.2 The changing ICT ecosystem: six trends

In this section six main trends that are affecting the ICT ecosystem are described: the "platformization" of the ecosystem, which implies the emergence of large online digital intermediaries; the increased vritualization of various parts of the ecosystem, in particular due to the emergence of cloud computing and software-defined networking; the emergence of increasingly open and collaborative business models, often involving (at the higher layers) open IP strategies such as open source software and open patent portfolios; the growing prominence of big data and data-driven innovation; the Internet of Things, which is rapidly leading to a world in which tens of billions of objects are connected; and the Internet of Value, powered by distributed architectures such as BlockChain, and being increasingly indicated as a new paradigm for many sectors (in particular, banking).

2.2.1 Trend 1: From the "neutral" to the "platformized" ICT ecosystem

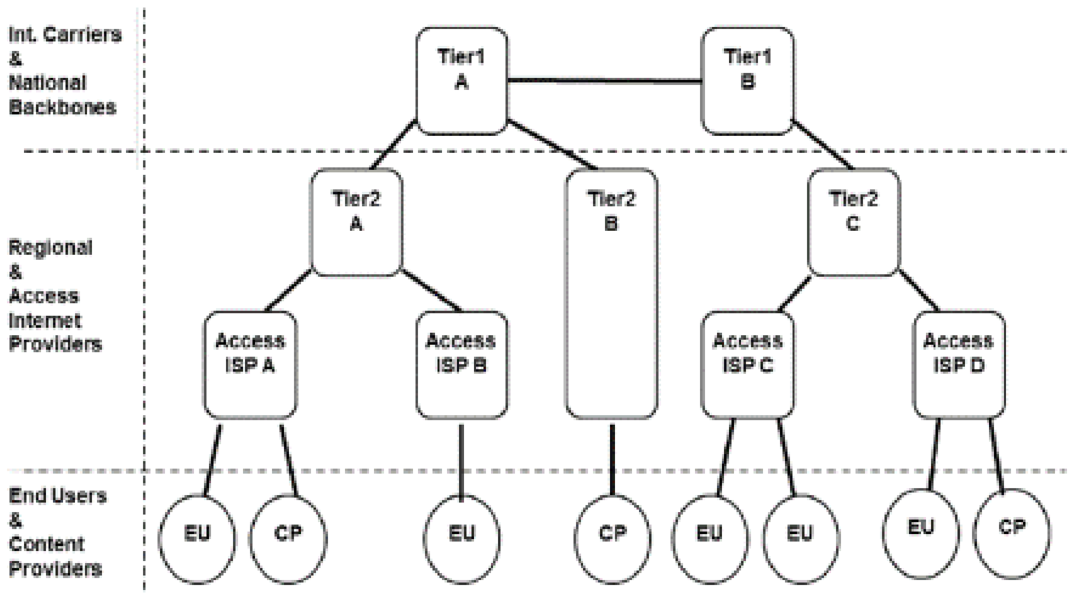
A number of authors have illustrated the ongoing transformation of the ICT ecosystem, mostly due to the advent of the Internet as a major form of communication between ICT products. The explosion of Internet traffic in the 1990s and 2000s, powered by parallel streams of evolving technologies (data storage, broadband communications, data compression, innovation in traffic management) led to an emerging need for solutions that would reduce complexity: this solution was spontaneously developed by market forces, and mostly took the form of industry convergence towards a limited number of *de facto* industry standards at the higher layers of the architecture.

Examples of *de facto* ICT industry standards in the pre-Internet age include Lotus 123, WordPerfect and other applications based on the original IBM PC architecture and the MS-DOS. Later, Windows 3.1 and Windows 95 (which ushered the Internet age) became widely diffused *de facto* industry standards. The case of Microsoft Windows is perhaps the most telling in the evolution that the ICT went through during the 1990s: the modular architecture of the personal computer entailed the existence of one layer (at the time, the OS layer), which would end up being essential in terms of connecting hardware with software and determining the compatibility and interoperability requirements of the whole system. Learning effects, direct and indirect network externalities determined the need for the market to "tip" in favour of one standard, rather than preserving a wide array of competing products. Microsoft adopted for its Windows application (later, OS) an architecture that would maximise the potential of indirect network externalities: just as VHS won the standards war with Betamax in the video-recorder era due to a greater number of applications, Windows won over its competitors by focusing on the number of applications that would be compatible with its standards, be they developed in-house or by third parties. By becoming a platform for third party applications, Windows could exploit self-reinforcing, centripetal forces: the more an OS becomes popular among its end users, the more developers will want to develop applications compatible with that OS; and vice versa, the more apps are available to end users, the more the latter will find switching to another OS unattractive. The age of platforms had officially begun: today, the economics of platforms has become a stand-alone field of research in economics and in other social sciences, encompassing management, strategy, industrial economics, social network analysis and many more.

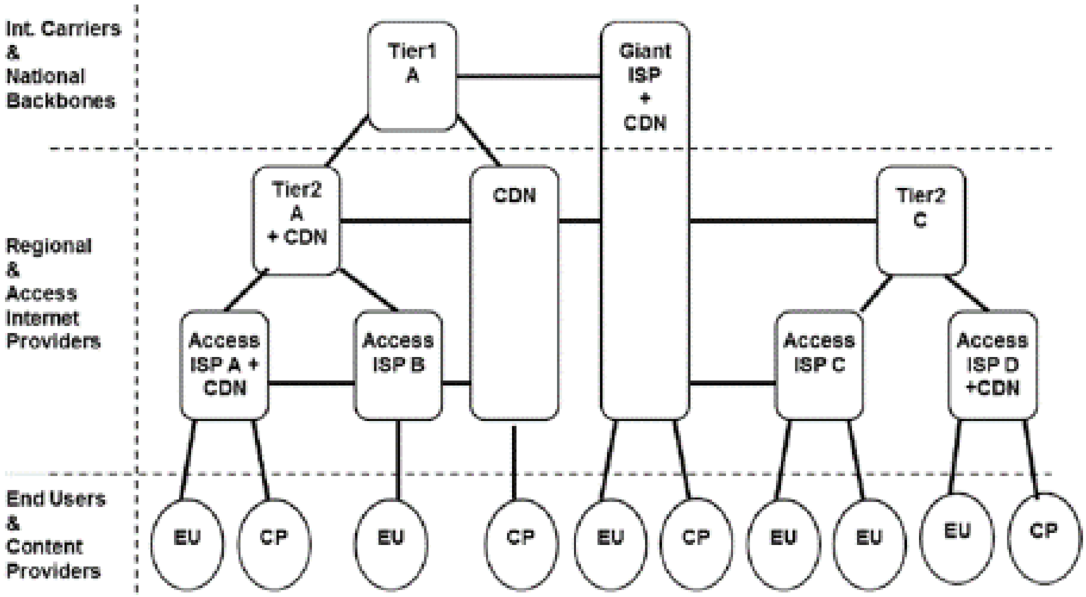
The emergence of the Internet has exacerbated this nascent feature. The addition of network effects in broadband communications to the existing direct and indirect effects generated by platforms and applications has made the ICT ecosystem a peculiar environment, in which leading platforms would rise and fall in just a few years; and in which catalysing user attention becomes the most important source of competitive advantage. Terms like "economics of attention" or "competition for eyeballs" have become commonplace when describing the strategy followed in the ICT ecosystem by companies like Amazon, Google, Microsoft, or Facebook. These companies present themselves as the new protagonists of the "platformized Internet". Today, the ICT ecosystem has evolved into a much more diverse environment in which original open internet architecture co-exists with various multi-sided platforms, which coordinate, steer and manage the innovation taking place at the higher layer of the Internet architecture.

As observed *i.a.* by Palacin et al. (2013) and by David Clark and KC Claffy (2014, 2015), this transition is now evident if one confronts the original (three-tier) model of the connectivity and logical layer of the ICT ecosystem with the emergence of vertically integrated platforms that make extensive use of traffic acceleration techniques, and developed their own semi-walled gardens to improve their customers' experience and capture the bulk of the end users' attention (figure 5 below). For example, a company like Apple uses Content Delivery Networks (CDNs) like the ones provided by Akamai to deliver faster traffic to its FaceTime users; and at the same time hosts more specialized providers such as Netflix, which in turn use traffic acceleration techniques to enable video streaming services to subscribers through a multitude of existing platforms (iOS, Android, public Internet). A company like Spotify can be defined as a two-sided specialized platform (matching users with rights holders), but access to it mostly occurs through existing large platforms (iOS and Android). This phenomenon, often called "platformization" of the ICT ecosystem, bears far reaching consequences for both innovation, and innovation policy. In particular, understanding the economics of platforms is essential to understand the direction and pace that innovation might take in various parts (layers) of the ICT ecosystem, as will be discussed in the next section.

Figure 5 – Old v. new Internet: platformization



Source: Palacin et al. (2013)



Source: Palacin et al. (2013)

2.2.2 Trend 2: Virtualization and the cloud

A second, important trend that is evident in the history of the ICT ecosystem is the ongoing virtualization of a growing number of functions, again made possible by technological evolution and underlying standardization. With this standardization come significant cost reductions, shifting of market power and user attention, and the disruption of existing business models. Perhaps the most evident trends in this respect are cloud computing and software-defined networking.

With cloud computing, technology has made it possible for small companies to avoid buying or leasing hardware and downloading software and applications: these traditional transactions were replaced by "everything as a service", which led to enormous advantages both for individuals and businesses. The transition towards a "cloud era" has led personal devices become increasingly light, while users were able to lease software located in the cloud, as well as access their files that are stored somewhere in cyberspace, and managed by a cloud provider: put more simply, a limitless "office LAN" where the main server was not located downstairs, but potentially on the other side of the globe[33]. An industry report defined "cloud implementation" as "an elastic execution environment involving multiple stakeholders and providing a metered service at multiple granularities for a specified level of quality (of service)"[34].

Cloud architectures are conceived to be very simple for end users, but feature a very complex architecture "behind the curtains". As an example, Apple's iCloud allows the

[33] Cloud computing is a general purpose technology of the IT field which became widely available in the late 2000. VAQUERO *et al*. (2009) define it as "a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements"

[34] The most widely used definition of cloud is that provided by the US National Institute for Standards and Technology (NIST) in 2009: "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction".

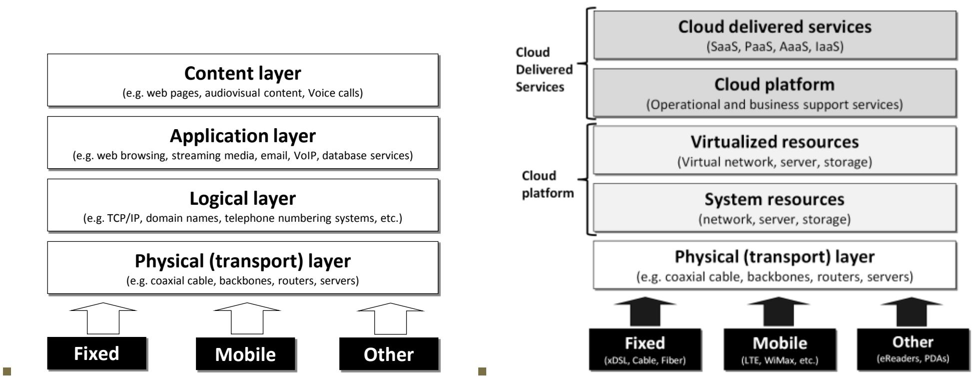
syncing of various devices with the cloud, such that the end user always enters the same environment regardless of the device used to connect to the network. Similar strategies have been pursued for the end user market by Google (Android), Microsoft (Azure) and Amazon (AWS). The most widely acknowledged taxonomies of cloud computing are those that relate to the basic cloud "modes" (i.e. Public, Private, Hybrid); and the main cloud "types" (i.e. Saas, AaaS, IaaS, PaaS). The provision of platform as a service (PaaS), for example, leaves more control of the configuration to the client that mere application as a service (AaaS) or software as a service (SaaS) modes[35]. At the same time, private clouds are certainly more customized to the client's needs than hybrid or public clouds, which however enjoy clear economies of scale.

Already in the 1990s, cyber law scholars started to understand that the Internet would have led to the emergence of an "age of access", in which products and services will be dematerialized to an extent that would make ownership and property rights less important, and access rights gradually more dominant[36]. The progress observed in ubiquitous connectivity and in compression techniques, coupled with enhanced possibilities to capture end users' attention, has gradually led to the emergence of access-based services. These include a variety of new business models, from pure streaming-based content access services (Netflix, Spotify) to intermediate forms (Apple Music + iTunes + appleTV) which contemplate both ownership and access; and the so-called "sharing economy", based on a combination of network effects, granularity, and reputational effects (e.g. Airbnb, Uber). Many of these services rely on the "cloud" as a key resource for virtual access and use of IT resources.

Figure 6 shows the changing appearance of the standard "OSI 4-layer architecture" (infrastructure, logical, applications and content) under the transition to a cloud environment, where figure 5a shows the layered structure of the best-effort Internet and figure 5b shows a prototypical cloud architecture. As shown in the picture, cloud platforms are juxtaposed to the physical layer of the Internet, and govern the provision of a number of services in a dedicated environment, in which cloud providers process and, to some extent, control continuous data flows. Given the definition of "cloud implementation" given above, it is also clear that cloud providers must also guarantee a minimum quality of service (QoS) for the services they provide.

Figure 6 - Old v. new Internet architecture: virtualization

- (a)
- (b)



Source: Author's own elaboration

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[35] Renda, A. (2012), Competition, Neutrality and Diversity in the Cloud, Communications & Strategies, No. 85, 1st Quarter 2012, pp. 23-44.

[36] See i.a. Gomulkiewicz, R.W. (1998), "The License Is the Product: Comments on the Promise of Article 2B for Software and Information Licensing", *Berkeley Tech. L. J.*, Vol. 13, Issue 3, p. 891.

2.2.3 Trend 3: Openness and collaboration

Another trend that has characterised the evolution of the ICT ecosystem, especially after the advent of the Internet, is openness. The most fast-growing, innovative parts of the ICT ecosystem include the emergence of the collaborative economy and distributed architectures. Here are some important examples to keep in mind.

First, open source software is evolving and growing from the initial models of "copyleft" licensing, based on reciprocity and the voluntary commitment to refrain from claiming the exclusive right to commercially exploit a given invention, towards a variety of models, which include the making available of entire patent portfolios for free exploitation by users and small entrepreneurs. Today, open-source platforms developed through distributed co-creation, such as the "LAMP" stack (for Linux, Apache, MySQL, and PHP/Perl/Python), have become a standard component of the IT infrastructure at many corporations. The exact combination of software included in a LAMP package is not fixed and may vary depending on developers' preferences: for example, PHP may be replaced or supplemented by Perl, Python or Ruby, the OS can be replaced with Microsoft Windows, Mac OS, Solaris, iSeries, or OpenBSD and others; database component also can be replaced, and webservers other than Apache are being used. All this creates a collectively developed environment in which programmers and users co-develop software that powers a large amount of new Web applications.

Second, openness has become an increasingly dominant paradigm in research and innovation, thanks to the Internet evolution. Key examples include, in the public sector, the recent decision by NASA to make hundreds of patents available for free for developers[37]; and in the private sector, the decision by Google to open up its Android patents[38]; as well as the decision by Tesla's Elon Musk (later followed by other car manufacturers such as Ford) to open up for free the company's patent portfolio to external developers[39]. This example is being followed by governments: for example, the United States Open Government strategy is increasingly geared towards the diffusion of all information held by public administrations for use by researchers and individual citizens as users or contributors to innovative projects (Renda 2016). Overall, this trend leads to the identification of a new strategy for the launch of innovative, disruptive platforms, which chiefly depends on making technical information available royalty-free to maximise diffusion and achieve first-mover advantage. A similar strategy is being used by Toyota for the hydrogen car[40].

Third, the open, collaborative economy is emerging in many more sectors than the often-mentioned taxi (Uber, BlaBlaCar) and hotel/accommodation (Airbnb). Owyang and McClure (2015) describe the ever-changing landscape of collaborative economy champions as now composed (based on the jargon used in Silicon Valley) three Pegasus companies (Uber, Airbnb, Wework); a few Unicorns (Didi, LendingClub, Ola Cabs, HomeAway, Lyft, Instacart, Beepi, Blue Apron, Prosper, GrabTaxi, Thumbtack, BlaBlaCar, Etsy Tuja, Rocket Taxi); and Centaurs (Freelancer, Chegg, Rent the Runway, Postmates, Shyp, Inspirato, Circle, Hailo, RelayRides). The authors do not list the "ponies", defined as companies with a capitalisation of less than 10 billion USD; and the hundreds of start-ups that have the legitimate ambition to join one of those other categories. Most likely, these companies will further proliferate in the coming years. The total capitalisation of sharing economy players calculated by the authors as of October 24, 2015 totalled 128.7 billion USD.

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37 http://www.nasa.gov/press-release/nasa-offers-licenses-of-patented-technologies-to-start-up-companies/

38 http://techcrunch.com/2015/07/23/google-offers-to-sell-patents-to-startups-to-boost-its-wider-cross-licensing-initiative/

39 http://www.digitaltrends.com/business/ford-to-open-electric-vehicle-patents-news-pictures/

40 http://www.zdnet.com/article/toyota-pushes-hydrogen-fuel-cell-cars-with-open-patent-portfolio/

2.2.4 Trend 4: The data-driven economy

Another important trend that bears consequences for the evolution of the ICT ecosystem is the breath-taking surge in the availability of data, coupled with the already-mentioned dramatic reduction in the cost of data storage and processing. The power of big data analytics, according to many experts, still has to be fully discovered, especially if one considers that the overwhelming majority of data available for analytics (some say, 99%) has been produced in the past two years; or, as others have observed, "the amount of data generated in two days is as much as all data generated in human history before 2003"[41]. Coupled with the already existing move towards access-based services, the use of big data can lead to important changers in the value chain of almost every sector, from retail (e.g. the "intelligent shelves") to healthcare, insurance, and even agriculture. As already demonstrated by pilot projects such as PredPol, now implemented and adopted also in some European cities (e.g. Milan) after its first experiments in Los Angeles, also police enforcement can make extensive use of big data to improve its nowcasting abilities[42]. The list of sectors is anyway much longer, and as long as the economy is.

When looking at the evolution of big data over the past years, there are important elements that suggest that open business models are being chosen to maximise the impact of existing and emerging platforms. For example, Google has been at the forefront of big data development, but without imposing a closed architecture on the market (exactly as it did with its Android OS). After Google introduced MapReduce and BigTable, a distributed storage system for structured data, the open source implementation of MapReduce, called Hadoop, emerged on the market and attracted the attention of Yahoo. The OECD reports that "Hadoop is now provided as an open source solution (under the Apache License) and has become the engine behind many of today's big data processing platforms". Besides Yahoo, Hadoop is powering many data-driven goods and services deployed by Internet firms such as Amazon, eBay, Facebook, and LinkedIn. But even traditional providers of databases and enterprises servers such as IBM, Oracle, Microsoft, and SAP have started integrating it, together with other open source tools into their product lines, making them available to a wider number of enterprises including Wal-Mart, Chevron, and Morgan Stanley. The key innovation of MapReduce is its ability "to take a query over a data set, divide it, and run it in parallel over many nodes" (Dumbill, 2010), often (low-cost) commodity servers that can be distributed across different locations".

The emerging ecosystem of big data processing tools can be described as a stylised stack of storage, MapReduce, query, and analytics application layers as illustrated in Figure 6 (OECD 2014). Increasingly the whole stack is provided as a cloud based solution by providers such as Amazon (2009) and Microsoft (2011). With Dumbill (2010), one could argue that this evolving stack has enabled and democratized big data analytics in the same way "the commodity LAMP stack of Linux, Apache, MySQL and PHP changed the landscape of web applications [and] was a critical enabler for Web 2.0" (see Section 2.1.3 above).

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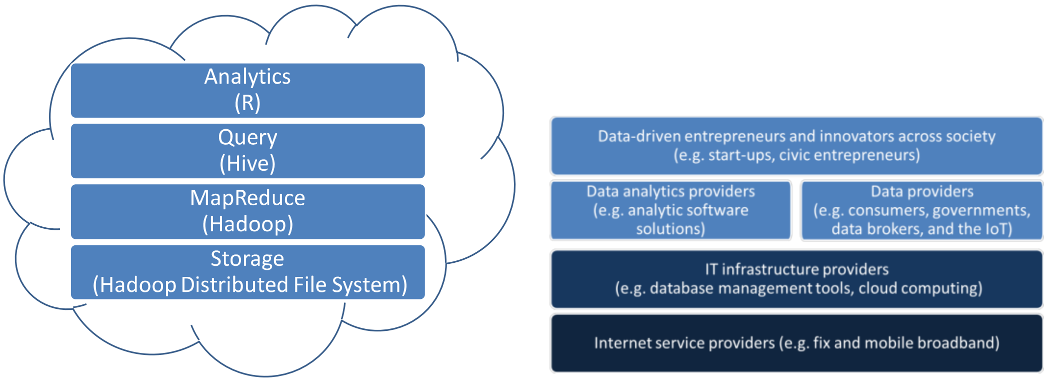
41 See: https://www.uschamberfoundation.org/sites/default/files/Data%20Report%20Final%2010.23.pdf

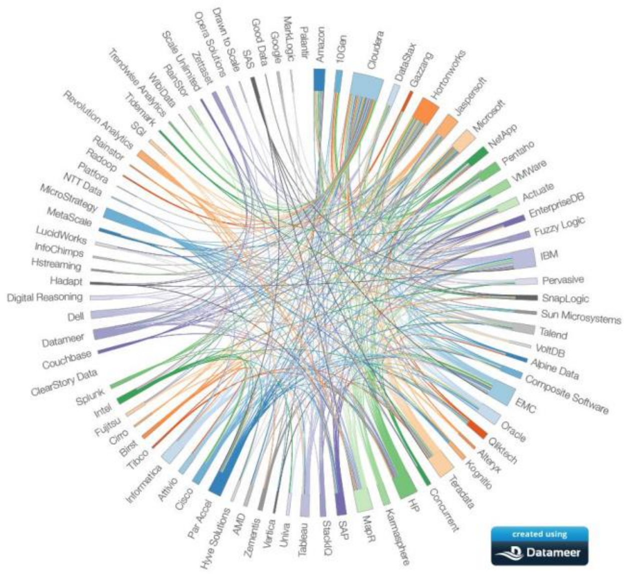
42 See www.predpol.com for more information. For a non-technical introduction, see the article published in The Economist on predictive policy, "Don't even think about it", available at http://www.economist.com/news/briefing/21582042-it-getting-easier-foresee-wrongdoing-and-spot-likely-wrongdoers-dont-even-think-about-it.

Figure 7 - The storage, MapReduce, query and analytics stack of "big data"



Source: OECD (2014).

Figure 8 – Hadoop's collaboration platform



Source: OECD (2014).

Big data applications are encompassing many sectors of the economy, but also many forms of innovation, including, increasingly, open innovation 2.0. The OECD reports the example of Ushahidi, a non-profit software company based in Nairobi, Kenya, which develops free and open-source software for data collection. Ushahidi's products are provided as open source cloud computing platforms that allow users to create their own services on top of it. They are free services that enable programmers to collect information from multiple sources (i.e. "crowd-sourcing") to create timelines and provide mapping services. In addition, a key component of the website is the use of mobile phones as a primary means to send and retrieve data.

2.2.5 Trend 5: Connecting everything (the IoT)

A parallel trend to the emergence of big data is the gradual extension of connectivity to objects and humans. Machine-to-Machine communication (M2M) is an enabler for Data Driven Innovation in many industrial applications and services, including logistics, manufacturing, and even health care. With 50 billion devices expected to be connected at the end of the decade, it is easy to recognize why M2M is considered as an upcoming revolution, likely to connect the "remaining 99%" of things and humans that have not yet been connected. Again, the "internet of everything" revolution will mean essentially an extension of the features of ICT (in particular, network effects, platformization and re-intermediation) to many other sectors of the economy, even those that are typically characterised by more "linear" models of innovation, e.g. automotive and more generally manufacturing. Not surprisingly, large car manufacturers already call themselves "data companies", and banks are reportedly trying to reconfigure their business models to become "digital platforms".

Such a transition is likely to bear very important consequences for the industrial organisation of several sectors, especially due to the foreseen transition towards the so-called "factory of the future". Many of the major economies are working on strategies for the creation of public-private platforms aimed at coordinating efforts and establishing standards for the Internet of Things and advanced manufacturing. This will imply a "cocktail" of many different technologies, including smart objects (the Internet of Things), advanced and secure cloud computing for central data storage, infrastructure and frequencies for multi-tech, always-on connectivity (starting with 5G wireless communications, but including sensor infrared technologies and others, e.g. Bluetooth); advanced robotics; 3D printing; and of course Big Data Analytics for optimized management of the supply chain. This will be coupled with granular business models that will enable mass customization and real-time reconfiguration of the supply chain. In Europe, this trend has been accompanied by an ambitious strategy originated by Germany with its *Industrie 4.0* initiative launched already in 2011, and currently being scaled up at the pan-European level.

2.2.6 Trend 6: The Internet of Value

The last trend identified in this report for what concerns the evolution of the ICT ecosystem is the emergence of distributed architectures that promise to revolutionise the universe of transactions at the global level. In emerging sectors such as FinTech, distributed architectures born thanks to the Internet are reaching new levels of sophistication, and empower unprecedented, disruptive innovation. One key example is the BlockChain technology that backs all crypto-currencies such as BitCoin, and which empowers distributed processing of data, robust transaction verification and potential applications on a variety of platforms, including on virtual reality systems such as Oculus Rift or Google Cardboard. Among others, Taylor (2015) explains that both permissioned and unpermissioned BlockChains have tremendous potential in fields such as smart contracts, virtual transactions, dis-intermediated mortgage and investment markets, and many more, creating what some commentators have defined as the "Internet of Value"[43].

2.2.7 The real disruption: the combination of these trends

All six trends outlined above are very important for the future of the ICT ecosystem. However, even more important is the fact that they are occurring at the same time. The combination of disruptive innovation in network architectures (e.g. BlockChain), new sensor and wireless communication technologies (e.g. 5G), nanotechnologies, robotics, and artificial intelligence is likely to create unprecedented possibilities for innovation, most often based on predominantly open standards and free/open source software, low entry barriers, and completely innovative funding and management arrangements. Section 2.3 below deals with ICT innovation also from this perspective.

2.3 Innovation in the ICT ecosystem

In this section we explore the consequences of the four main features of the ICT ecosystem, and the six trends identified in Section 2.2, for innovation and entrepreneurship. Accordingly, the next pages explore the various elements of the innovation ecosystem as identified in Section 1 of this report with specific reference to

43 http://www.finextra.com/finextra-downloads/newsdocs/The%20Fintech%202%200%20Paper.PDF

ICT. This section also explores the role of key innovation drivers and policies such as competition, intellectual property, and sector-specific regulation.

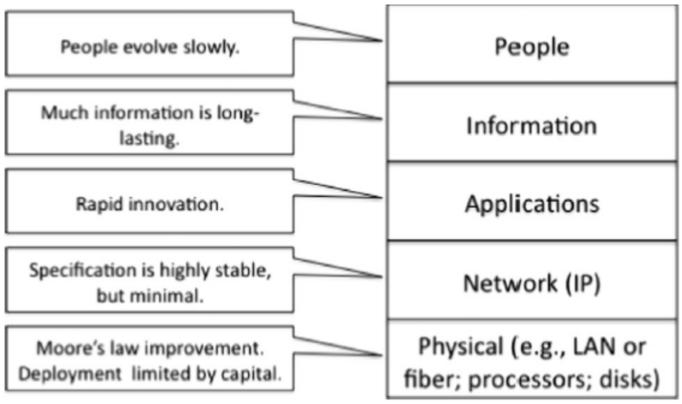
2.3.1 Layers: co-evolution, co-dependency, expansion

A clear understanding of the evolution of the Internet architecture is essential to define the peculiarities of innovation in the ICT ecosystem. The latter can be seen as the result of the simultaneous evolution of various layers and platforms, which retain their peculiarities in terms of the pace of evolution, the actors involved, the modes of interaction between players, and the mode of innovation that emerges. More specifically, Claffy and Clarke (2014, 2015) define the ICT ecosystem as a perfect setting for co-evolution, and explore the natural rate of change of various components of the ICT ecosystem, where some interdependent actors have a natural tendency to evolve faster than others. In particular, they observe that "the rapid pace of Moore's Law drives rapid innovation in the private sector, lending advantage to those who invent, discover, or adapt to new technologies sooner than others. But as technology is integrated into industry and society, different parts of the ecosystem exhibit different dynamics, subjecting each part of the ecosystem to evolutionary constraints".

Figure 8 below provides a possible representation of the ICT ecosystem, developed by Clarke and Claffy (2015). This picture is almost identical to the one offered by Fransman and described in Figure 4 above: it is and based on the OSI layers, but including also end users (people). There, the physical (lowest) layer experiences a rate of change gated by labour and sources of capital, neither of which follow a Moore's Law cost function. The ongoing transition to optical fibre networks (still too slow in Europe) is expected to bring a quantum leap in capacity, which will pay returns for several decades. Cloud computing is another example of the interplay of Moore's law and capital investment. The large data centre infrastructures supporting cloud computing benefit from both rapidly advancing technology and ever increasing massive arrays of computers. The limit to the capacity of a data centre is not primarily Moore's Law, but construction and operational costs.

At the Network layer (based on the Internet Protocol, or IP), the durability of the specifications of the core protocols provides a stable foundation for rapid innovation at other layers. At the application layer, the process of innovation is driven at almost frantic rates that Clarke and Claffy estimate as holding a potential of 10 improvements in underlying technology every 5 years. At the information layer, the creation, storage, search and retrieval of essentially all forms of data – information, content, knowledge – is moving on line (see Section 2.2.2 above). Finally, the people level displays a transformative empowerment from the deployment of technology in the hands of humans. But human capabilities in no way grow on a Moore's Law curve. As observed by Clarke and Claffy (2015), "we do not get twice as smart, or twice as capable of processing information, every 18 months. So we drown in information overload, and call for even more technology to control the flood, which makes us even more dependent on the technology".

Figure 9 – Layered ICT ecosystem, and pace of evolution



Source: Clarke and Claffy (2015).

These different paces of technology integration across the ecosystem also influence the stability and agility of firms. Companies that have invested in physical assets like fibre to the home, towers or data centres can sometimes earn a stable place in the ecosystem through that investment, although a bad technology bet can leave them disadvantaged by a stranded investment. Firms with extensive physical infrastructure investments also cannot easily move, and typically remain domestic except by merger and acquisition of firms in other countries. In contrast, firms at higher layers are more likely based on an idea (like Facebook) than on heavy capital investment. The commercial ecosystem experiences constant pressure from application innovators to seek new capabilities from the physical layer (e.g., more capacity to the home), while the investment in those capabilities must be made by a different set of firms. According to Clarke and Claffy (2015), "this tension is a classic example of co-dependency and co-evolution within the industrial part of the ecosystem, where applications are limited in their ability to evolve by the rate at which the physical layer can evolve. Because the application layer depends on the physical layer, the application layer cannot simply out-evolve the physical layer, but is gated by it"[44].

Based on the above, it is reasonable to expect what follows:

- *Innovation takes place in different ways across layers*. More traditional, R&D based innovation characterises hardware layers, even if open, distributed innovation models are becoming more commonplace also in those layers. To the contrary, the application layer is typically characterised by new business models and organisational innovation, rather than by new technological improvements. And while openness seems to be an increasingly defining feature of all layers of the ICT ecosystem, the degree of granularity reached by more virtualized layers such as cloud-based platforms and application is unrivalled in the "physical layer".
- *Co-evolution: the pace of innovation differs across layers.* The higher the layer, the more intangible the investment behind new products and services, the faster the pace of innovation. This applies also to the competitive race for each layer: while the physical layer has shown a relative degree of stability over time, the higher layers feature a constant rise and fall of dominant players, and even when players manage to remain prominent for a significant period of time, they do so at the cost of massive investment in new products and services, new markets, and in the acquisition of smaller players.
- *Co-dependency: the pace of innovation at each layer is dependent on the evolution of other layers.* The existence of a robust, high capacity network and the

[44] See Clarke and Claffy (2015).

development of facilities such as Internet exchanges and data storage networks determine the evolution of the higher layers. For example, the App economy could develop only when the underlying mobile infrastructure and cloud platforms became well developed. And countries in which the infrastructure has greater capacity experience more developed and dynamic application and content layers. The video streaming market, for example, could develop earlier in the United States also thanks to the existence of high-speed broadband networks such as Cable operators using DOCSIS 3.0 and optical fibre networks built by ISPs.

- *Expansion*. The ICT ecosystem is not static: the Internet is in constant expansion. This has to be fully taken into account before an ICT-specific innovation policy is conceived: the peculiarities of the ICT ecosystem are gradually permeating the dynamics of innovation and the re-intermediation of many other sectors, and they are also creating entirely new sectors. This is one of the aspects that make the ICT ecosystem most intractable for policymakers: as its peculiarities evolve, its specificity is declining, and its pervasiveness and sheer magnitude are rising.

Box 5 - Models of ICT innovation – the findings of two EURIPIDIS papers

Gabison (2015) addresses the issue of how relevant is the ICT sector in Europe, and offers a macroeconomic perspective of the birth and death of firms in the manufacturing and service sub-sectors of ICT. He finds that ICT companies constituted only 4.6% of all companies in 2011 and a similarly tiny fraction of employment. However, the number of ICT service companies was growing steadily, and the ICT service sector was growing much faster than the ICT manufacturing sector (which actually, appears to be shrinking in terms of number of firms, with deaths outpacing births). ICT service companies represented three out of every four ICT companies; and almost nine in every ten new ICT companies were ICT service companies. Consistently, the ratio of high-growth ICT service companies is larger than that of ICT manufacturing and ICT wholesale companies. Other important findings are that jobs created by new manufacturing and by ICT manufacturing companies do not compensate for jobs destroyed by exiting companies; and that new ICT companies tend to survive more often and grow faster than new non-ICT companies. While this is certainly useful information, the unavailability of data for a breakdown per layer of the ICT ecosystem prevents a full appraisal of modes of innovation prevailing for each layer, in line with what observed above and predicted, although qualitatively, by Fransman (2014) and also by Claffy and Clarke (2015).

Biagi *et al.* (2015) can be usefully complemented by a reading of Puissochet (2015), as the former study provides a structured and solid empirical study that offers evidence on simple and complex indicators of innovative activity of the ICT sector, compared to the overall economy, using CIS data for the period 2004-2012 for 20 EU countries; whereas the latter offers an observation of 10 French SMEs mostly active as Specialised Technology Suppliers, and chosen by the author as examples of innovative SMEs in the ICT sector. The results confirm that:

- *The ICT sector is especially innovative*, both in terms of share of firms (among ICT firms) performing R&D and in terms of firms producing technological (product or process innovation) or generic (product or process or organizational or marketing) innovation. In particular, ICT firms tend to have in-house R&D capability and introduce new-to-the-market product or process innovations. This finding is mirrored by the empirical observation of R&D intensity in ICT (Comino and Manenti, 2015), as well by anecdotal evidence offered by Puissochet.
- *Geographical proximity is still important.* Biagi et al (2015) find that cooperation with entities within the home country is more likely than cooperation with entities within the EU, which is more likely than cooperation with entities external to the EU.

- *Innovation systems appear incomplete, or only partly working.* For example, interaction with universities and research centres appears very limited both in Biagi et al (2015) and in Puissochet (2015). Both papers observe that internal and market sources of knowledge are more relevant than education and research centres.
- *IPRs appear to play a limited role.* Both Biagi et al (2015) and Puissochet (2015) conclude that IPRs are not perceived as important drivers of competitive advantage, whereas secrecy and lead time advantage seem to matter more. This is likely to be due to the fact that the current institutional setting governing IPR reduces their relevance as a competitiveness driver for ICT firms.
- *Key barriers to innovation include lack of finance, lack of qualified personnel and uncertainty over demand*. Here too, both studies reach the same conclusion. Puissochet (2015) observes that public funding - largely focused on R&D - seems efficient for the support of start-ups and new companies. It can be said that generally, in France, companies see public funding of R&D as satisfying. Research tax credit and zero rate lending for R&D are widely used and much appreciated. Raising private funds is more difficult, especially raising funds for commercial and international development. Most of the private funding observed happened during the initial stages of the company, but getting funding thereafter for more ambitious growth seems almost impossible.

2.3.2 The entrepreneurial function

In the ICT ecosystem, entrepreneurs can be defined in different ways, and no unique definition has arisen to date (Bogdanowicz, 2015). A definition of "Web entrepreneur" adopted in a recent study for the European Commission refers to "an umbrella term that covers start-up founders who build innovative and often disruptive businesses on top of the Internet, mobile and various cloud-based technologies, programming interfaces and platforms"[45]. However, an entrepreneur is not necessarily the inventor of a new product or service, but rather the actor that ensures the diffusion of new ideas by providing means and audience to it. In this respect, the entrepreneurial function in the ICT ecosystem seems to be split between different types of players, all of which are essential for the ecosystem to thrive.

Box 6 – Measuring digital entrepreneurship: a EURIPIDIS paper by Marc Bogdanowicz

The EURIPIDIS Report authored by Marc Bogdanowicz explores the concept of digital entrepreneurship and the current measurement frameworks that support the empirical analysis of entrepreneurship, its determinants, performance and impacts. The report shows that a robust theoretical economic foundation for entrepreneurship has developed within the Schumpeterian perspective. This theoretical foundation justifies the interest of policy makers in entrepreneurship in advanced economies - an interest that is currently rooted in policies for SMEs and business conditions. To capture the digital aspect of entrepreneurship, the report proposes the following definitions: (i) Digital entrepreneurs are those persons who seek to generate value, through the creation or expansion of economic activity, by identifying and exploiting new ICT or ICT-enabled products, processes and corresponding markets. (ii) Digital entrepreneurial activity is the enterprising human action in pursuit of the generation of value, through the creation or expansion of economic activity, by identifying and exploiting new ICT or ICT-enabled products, processes and corresponding markets. (iii) Digital entrepreneurship is the phenomenon associated with digital entrepreneurial activity.

45 See: file:///Users/ar376/Downloads/Open%20platforms%20for%20web%E2%80%90based%20applications.pdf

The report states that today data availability and the emergence of the Internet make it possible and worthwhile to investigate the peculiarities of entrepreneurship in the digital sphere. The report investigates 12 existing measurement frameworks, and 6 additional recent mapping frameworks .This investigation leads to the following main observations:

- the large majority of the above frameworks have no or weak links with innovation, the central concept of entrepreneurship in the Schumpeterian perspective.
- most of these frameworks focus on the creation of new firms and neglect the entrepreneurial activity within existing firms.
- finally, the ICT dimension is usually absent.

These three missing aspects – innovation, 'intrapreneurship', and ICT – mean that there is little support for digital entrepreneurship policy making in the current empirical frameworks and their results.

The report recommends that existing measurement frameworks be used to create a new tool targeted at data collection and analysis of digital entrepreneurship in support of policy making for the long-term conception, monitoring and evaluation of European digital entrepreneurship policies. Three operational options are proposed:

1. The large body of surveys, analysis and research on the Global Entrepreneurship Monitor (GEM) and the Global Entrepreneurship Index (GEDI) testify of two decades of academic work and policy support. Adapting their existing theoretical and empirical frameworks to digital entrepreneurship would allow to benefit from past and current analysis capacity.

2. The Community Innovation Survey (CIS) is an iconic European survey which explores innovation at firm level. While it serves different purposes, expanding the range of its questions, adapting some of its structural characteristics (panel) and/or bridging its micro-data with other existing surveys could be envisaged.

3. A range of recent mapping initiatives have been undertaken to investigate the existence and dynamics of digital start-ups and their ecosystems. These initiatives could be specifically nurtured bearing in mind that they were, more than other measurement frameworks, designed ex-ante to focus on ICT.

The report concludes that a renewed political interest in digital entrepreneurship calls for renewed empirical evidence. Current policies still rely on past concepts, tools and analysis that mainly address SMEs and business demographic issues, and usually leave aside innovation, technology and in-house entrepreneurial activity. Contemporary economic and political thinking deserves a better understanding of the nexus entrepreneurship / ICT-enabled innovation / economic growth. The report suggests that empirical tools still need to be developed that would allow us to gather and analyse the evidence about digital entrepreneurship that is necessary for the conception, implementation, monitoring and evaluation of policies.

To be sure, the existence of young, talented and skilled, risk-loving individuals can lead to the flourishing of innovation in the ICT ecosystem, mostly in the higher layers. A relatively more concentrated and stable market structure is required at the physical layer for the testing and development of innovation. This is potentially testified by the fact that large companies are still holding the majority of patents in those layers: in wireless networking, for example, market concentration is increasing significantly with the merger of Nokia and Alcatel-Lucent, and the recently expanded patent cross-licensing agreement between rival companies Ericsson and Huawei[46]. These players,

[46] Under the terms of the agreement, both firms will able to access and implement standard essential patents (SEP) for the likes of GSM, UMTS and LTE. Holders of SEPs are required to offer other companies licenses under fair, reasonable and non-discriminatory (FRAND) terms.

although with varying degree, orchestrate the evolution of technology in this part of the physical layer by coupling open innovation models with a fairly stable market structure. In this respect, they represent the existing platforms through which a smaller technology supplier can reach the market.

While in the physical layer large R&D-based companies seem to be increasingly playing the role of catalysts of external R&D through the development and refinement of open innovation models, higher layers depend on the essential role of platforms as online intermediaries. Not only large platforms such as Google, Amazon or Facebook provide "eyeballs" to new products: their rivalry has led them to gradually shift to open models to gain competitive advantage and exploit it against their rivals through a strategy that chiefly depends on the maximization of applications. This led players like Amazon and Google to develop a wholly new menu of services for entrepreneurs, which range from training on specific computer and management skills to the provision of free storage space, traffic acceleration services, and mentoring services[47].

More generally, the role and intensity of economies of scale and network effects seems to vary across the layers of the ICT ecosystem. On the one hand, the physical layer displays high fixed costs and strong direct network effects, leading to economies of scale. On the other hand, the application layer, even more under the ongoing platformization, is not always characterized by high fixed costs (CAPEX is typically much greater for telecom companies than for online platforms), and even more importantly is pervaded by indirect network externalities and the growing importance of data availability: while the former factor seems to lead to short-term barriers to entry (so-called "competition for the market", rather than "in the market"), the latter does not seem to represent a real barrier to entry as of today, judging from the ongoing proliferation of new companies that base on big data their business model. Even more importantly, the layered architecture of the ICT ecosystem leads to shifting "points of control" (as defined by Robin Mansell[48]): as the ecosystem becomes platformized, lower layers become increasingly commoditized, and the most prominent platforms (i.e. the strongest layer of the architecture, as well as the most concentrated one) shifts upwards. As an example, the strongest layer of the ICT ecosystem has moved from the physical layer (e.g. microprocessors) to operating systems (Windows), Browsers (Exlorer and then Chrome), and now cloud platforms (Android, iOS, Azure, AWS). As the powerful platforms move upwards, previously concentrated (lower) layers become more competitive (e.g. hardware, operating systems) and entry barriers at higher layers collapse (e.g. in the app layer today).

Even higher in the Internet layered architecture, platforms in cloud computing and Web 2.0 applications increasingly depart from the firm-centric appearance described by Fransman, to assume a more shared and open configuration. Examples include the already-mentioned Hadoop, Spark and Blockchain platforms, which largely rely on open source-type cooperation between various types of players and programmers.

In addition, as innovation is defined as a function of its impact on social welfare (see above, Section 1), then also the public sector is to be considered as performing entrepreneurial functions. More specifically, governments play the role of entrepreneurs both in terms of funding high risk-high reward basic research projects (Mazzucato, 2013), but also by making it easier for digital innovators to use the facilities they would need to develop their ideas. Mechanisms such as DARPA's Fast Track Initiatives in the US or the European Commission innovation vouchers provide small contracts to individuals, which diversify the range of ideas for projects that receive funding. Similar

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Read more at http://www.techweekeurope.co.uk/networks/carriers/ericsson-huawei-patent-licence-183829#7ewaFbQ4gRXZHRWL.99

47 See: https://cloud.google.com/files/esg-whitepaper.pdf and https://www.googleforentrepreneurs.com/

48 See Mansell, Robin (2015) Platforms of power. Intermedia, 43 (1). pp. 20-24. ISSN 0309-118X.

approaches are being used to support citizen science and crowdsourcing projects. Here too, as the ICT ecosystem expands to encompass other sectors of the economy, these peculiarities might become common traits shared by several different economic sectors.

2.3.3 Funding ICT start-ups: a multitude of channels

In the ICT ecosystem, not unlike other sectors of the economy, access to finance is one of the key obstacles to innovation and would-be entrepreneurs. Small companies and individual entrepreneurs still find it difficult, especially in Europe, to access sufficient seed funding in order to bridge the so-called "valley of death", which separates the implementation of an innovative business idea from break-even through commercial revenues.

Over the past decades, **Venture Capital** has been considered to be the most appropriate form of financing for innovative firms in high-tech sectors (Koutroumpis et al. 2015). Studies have identified a positive link between VC funding, innovation, and firm performance, while others have shown that innovative firms are more likely to receive funding than imitators. Increases in VC activity in an industry are associated with significantly higher patenting rates too, while in Europe VC has helped innovative firms to reach IPOs in European stock markets. Over the period 1991-2005, VC has accounted for more than 10% of industrial innovation in Europe, and its success was mostly concentrated in countries with lower barriers to entrepreneurship, with a tax and regulatory environment that welcomes venture capital investment, and with lower taxes on capital gains. In spite of these effects there is a growing strand of literature suggesting that causality runs from patents to VC, or put another way, that innovation creates a demand for VC and not VC a supply of innovation[49]. Even more importantly, part of the literature has highlighted that high technology firms backed by VC are likely to outperform their non-VC-backed counterparts due to the active monitoring and coaching that VC firms undertake to their portfolio companies, and the signal of quality that VC investment conveys.

Box 7 – Venture capital principles in the ICT ecosystem – a EURIPIDIS paper by Garry Gabison

The EURIPIDIS report on venture capital authored by Garry Gabison (2015) addresses important issues such as: How do venture capital funds finance companies? How do they select start-ups? How do they affect ICT companies and innovation? Since venture capital funds invest in young, small, and innovative companies, their fund managers must defeat information asymmetries to invest profitably. They rely on signals about the entrepreneur (education, past experience, etc.) and about the companies (patent filed, turnover, etc.) to invest. This report focuses on the funds and their decisions. Once they invest, fund managers must face up to two problems. First, there is a moral hazard problem: when entrepreneurs receive an investment, they gain control of the funds and may not use them as agreed. Second, fund managers face an agency problem: when they invest, they separate capital from management and this separation means that the entrepreneur's and fund manager's incentives become misaligned. Therefore, fund managers resort to stage financing, monitoring, and exit incentives to ensure that entrepreneurs spend the invested money as agreed and remain motivated to perform. Funds invest in innovative companies because they generally generate higher returns upon exit. Venture capital funds often tend to select innovative companies and make them even more innovative. Patents and patent portfolios have been used by investors to measure the innovation potential of companies and subsequently invest. Patents, though not being a perfect measure of innovation, allow entrepreneurs to signal to

49 See Geronikolaou, G. and G. Papachristou, "Venture Capital and Innovation in Europe," Modern Economy 3 (2012).

venture capital fund managers how ripe their companies are for investment. Because venture capital funds must monitor their investment, the venture capital markets usually remain local. Even within Europe, venture capital funds tend to invest within their national borders: venture capital funds of a given country highly correlate (0.92) to the funds received by companies of a given country. According to 2013 data, the Czech Republic, the Netherlands, and the United Kingdom were the main beneficiaries of the little cross-border investment occurring in Europe. The EU has passed regulations to facilitate cross-border investment. The European Investment Fund has invested in many funds to help catalyse additional funds. The financial returns may seem low at 4.2% in 2013 as compared to the private sector but the social impact could be greater than this number would imply.

Venture capital is, however, not the only source of financing available to ICT firms. One peculiarity of the ICT ecosystem is the greater importance of distributed platforms for the funding of innovative products. The relative ease of development of prototypes and beta application versions in the ICT ecosystem, and the fact that innovation in higher layers is most likely featuring very low entry barriers and low start-up costs, is creating new opportunities for funding innovation, in particular through the proliferation of **crowdfunding platforms**. However, crowdfunding is still in its infancy in Europe, whereas in the United States it already led to the success of wearables such as the Pebble Watch[50]; gaming solutions such as Ouya[51] and Oculus Rift[52]; Robots like Jibo[53]; connected-home systems such as Canary[54]; and many more. A recent report by Massolutions shows the dramatic rise of crowdfunding volumes, poised to overtake Venture Capital in 2016[55].

Public support schemes for ICT start-ups and scale-ups are another channel available to entrepreneurs. Schemes such as the US SBIR, the UK SBRI and the Horizon 2020 SME Instrument, as well as the Start-up Europe initiative and the innovation vouchers at the EU level, all aim at providing entrepreneurs with funding to test and commercialise their innovative business ideas. In addition, the use of prizes, pay-per-success schemes and challenges is on the increase, particularly in the United States and in the United Kingdom.

Finally, and importantly, funding and support for start-ups is provided by **large ICT companies that adopt an open innovation model, and by platforms** seeking to maximise the number of their applications to beat competition and establish themselves as *de facto* industry standards. For example, Google for Entrepreneurs provides financial support, mentoring, training to thousands of entrepreneurs at the global level[56]; through FbStart, Facebook provides start-ups with an exclusive community, worldwide events, mentorship, and up to $80,000 in free tools and services[57]; Amazon Launchpad makes it easy for start-ups to launch, market, and distribute their products to hundreds of millions of Amazon customers across the globe, with benefits including a streamlined onboarding experience, custom product pages, a comprehensive marketing package, and access to Amazon's global fulfilment network; Microsoft helps companies in their start-up and subsequent phases through its BizSpark and Ventures programmes[58]. In

50 https://getpebble.com/
51 http://www.ouya.tv/
52 www.oculus.com/en-us
53 http://www.jibo.com/
54 http://www.canary.is/
55 http://www.forbes.com/sites/chancebarnett/2015/06/09/trends-show-crowdfunding-to-surpass-vc-in-2016/2/
56 https://www.googleforentrepreneurs.com/startup-communities/
57 https://fbstart.com/
58 https://www.microsoft.com/bizspark/about/. https://www.microsoftventures.com/programs

addition, companies like Huawei, Ericsson, Nokia, AT&T, Verizon, Orange, Deutsche Telekom all have programs for start-ups[59].

As will be explained in Section 3 below, there are significant differences in the availability of these channels for start-up funding in different countries, both within the EU and between the EU and other parts of the world. In particular, the relative availability of venture capital and crowdfunding, as well as the design of public support schemes, places the US and a number of EU countries (the UK, Scandinavian countries, the Netherlands) in a more advantageous position compared to most Southern and Eastern European countries. Likewise, specific regions have specialised in the development of hardware and software products despite the inherently global nature of the ICT ecosystem: for example, the software cluster in Bangalore, the Silicon Valley, European ICT poles of excellence such as Munich, London and Paris, emerging accelerators such as Berlin's The Factory and Tech City in London display the combination of infrastructure, knowledge and intermediaries that is needed for start-ups to flourish[60]. To the contrary, ambitious attempts such as Russia's Skolkovo campus have failed to create fertile ground for start-ups to blossom[61].

Box 8 – Understanding Crowdfunding – a EURIPIDIS paper by Garry Gabison

Another EURIPIDIS paper is "Understanding Crowdfunding and Its Regulations", authored by Garry Gabison (2015). This paper provides an interesting analysis of a phenomenon that was enabled by the diffusion of Internet connectivity, and the analysis focuses on crowdfunding as a potential way to overcome the often-declared problems in access to finance that affect most sectors, including the ICT sector in Europe. Crowdfunding is seen as a potential way to go beyond the traditional methods of financing businesses and innovation and as a potential way to address this barrier to innovation, and its potential appears significant in ICT. The report contains an explanation of how crowdfunding campaigns and platforms function and identifies four declinations of crowdfunding: donation, reward, lending, and equity crowdfunding. The report also explains that crowdfunding does not come without its drawbacks, since entrepreneurs must disclose information; the crowd is also exposed to potential fraudulent schemes, since most transactions are conducted over the Internet and are often far from transparent. The report focuses on equity crowdfunding because they involve higher funds, and surveys existing regulations in Italy, the United Kingdom, and France and proposed legislation in the United States, where crowdfunding has already emerged even in the absence of a fully defined legal framework.

2.3.4 Users and skills

Another key peculiarity of the ICT ecosystem, at least for the time being, is the growing importance of the human factor, considered as an increasingly scarce resource. The European Commission has long denounced the emerging skills mismatch in Europe, looking at the slower pace of skills update compared to technology update: "skills development does not come about as fast as technological development, which is why we are faced with a paradoxical situation: although millions of Europeans are currently without a job, while companies have a hard time finding skilled digital technology experts. As a result, there could be up to 825,000 unfilled vacancies for ICT … professionals by 2020". Notably, missing skills do not include only **ICT-related**

59 http://techcrunch.com/2014/11/11/deutsche-telekom-launches-620m-fund-will-focus-on-german-startups-and-pe-deals/; Orange Fab.

60 http://www3.weforum.org/docs/WEF_Global_IT_Report_2015.pdf; http://publications.jrc.ec.europa.eu/repository/bitstream/JRC85408/eipe_summary_final_jrc85408.pdf

61 http://foreignpolicy.com/2015/05/06/the-short-life-and-speedy-death-of-russias-silicon-valley-medvedev-go-russia-skolkovo/

technical skills, but also, and importantly, **managerial skills**, which themselves explain a portion of the productivity gap between the United States and Europe in ICT: both these skills are part of the core entrepreneurial skills[62].

In many parts of the world, the emergence of ICT as an enabling technology and the gradual expansion of the ICT ecosystem into other sectors, not just as ICT-using but as fundamentally ICT-powered, has led policymakers to develop specific policies to promote so-called STEM (Science, Technology, Engineering and Mathematics) education even in early school years. Recently, in the United States the Obama administration launched a $4 billion programme dedicated to Computer Science, with the aim to increase access to K-12 CS by training teachers, expanding access to high-quality instructional materials, and building effective regional partnerships. In the EU a recent report for the European Parliament highlighted "persisting skills shortages in STEM fields in spite of high unemployment levels in many Member States"[63].

Needless to say, skills and computer literacy are needed also from a user's perspective, in order to ensure the uptake of new technologies. And these skills are increasingly subject to obsolescence in the ICT sector, as a consequence of shorter product life cycles and fast innovation rates. A high quality secondary and tertiary education constitutes a fundamental ingredient of the so-called "knowledge triangle": as a matter of fact, when universities produce skilled graduates and high quality basic (ICT) research, and the legal and business environment offers the chance to translate such research in applied research and then innovative products, then the whole sector can profit from a more dynamic flow of ideas and cross-fertilization in innovation. In a recent study, Osborne and Frey (2013) showed that as much as 47% of existing jobs are at risk of computerisation in the coming years (see figure below). A recent report for DG Employment also highlights the challenges that this trend will create for the labour market in Europe[64]; and researchers from Bruegel have applied the framework created by Osborne and Frey to European data, showing results that are even more worrying, with 54% of jobs on average being at risk of computerisation. Even more recent work by James Bessen (2015) shows that the ongoing technological revolution is more likely to create a skills shortage than a job shortage: a finding that points at the education system as responsible for creating the skills needed, with the speed required[65].

In this respect, it is clear that the challenges that are already perceived today will only become more pressing in the coming years. Evidence from global markets suggests that many industrialized countries do not compete anymore on low salaries, but rather on the availability of reliable authorities, world-class infrastructure and, most importantly, a highly educated and skilled workforce. This is why re-launching Europe's objectives in higher education is key to Europe's future innovation and employment policies. As shown in recent research performed at the JRC, this may require fundamental changes in the way learning occurs both at school and university, and over the course of individual life (see i.a. Redecker et al. 2011; Kampylis et al. 2015), and this in turn requires a new framework for entrepreneurial competences (Komarkova et al. 2015). Figure 9 below shows the mix of entrepreneurial competences as developed by Komarkova et al. 2015.

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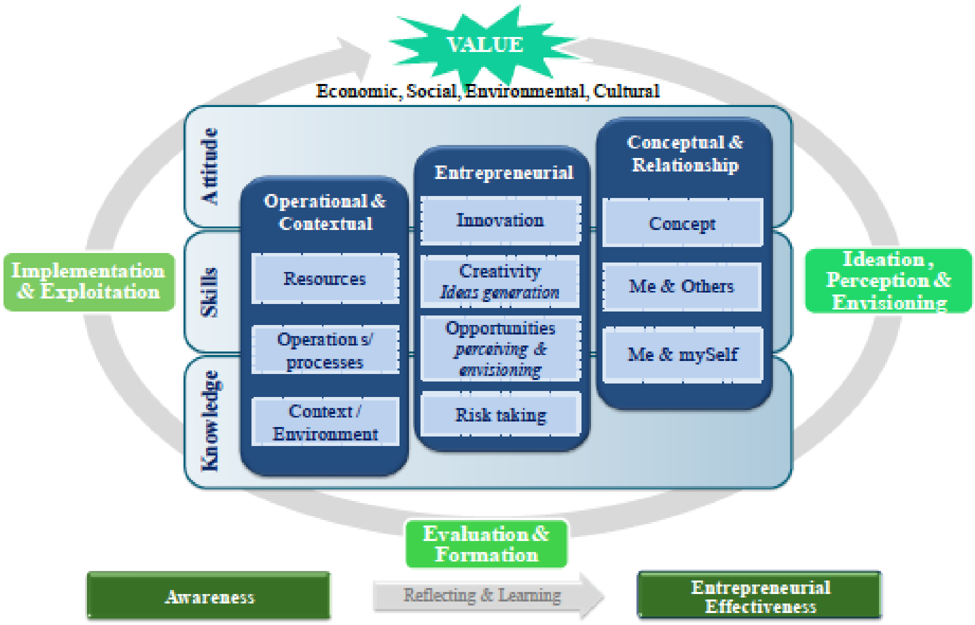
[62] http://eskills4jobs.ec.europa.eu/c/document_library/get_file?uuid=b69ba1d7-6db4-415d-82e4-ac4d700a38b8&groupId=2293353

[63] See: http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL_STU(2015)542199_EN.pdf

[64] For a literature review, se http://epthinktank.eu/2015/05/11/tackling-long-term-unemployment-in-the-eu/

[65] Bessen, James E., How Computer Automation Affects Occupations: Technology, Jobs, and Skills (November 13, 2015). Boston Univ. School of Law, Law and Economics Research Paper No. 15-49. Available at SSRN: http://ssrn.com/abstract=2690435 or http://dx.doi.org/10.2139/ssrn.2690435

Figure 10 – Summary of entrepreneurial competences



Source: Komarkova et al. (2015), Figure 23.

2.4 Consequences of the ICT ecosystem for policymaking: sectoral and horizontal policies

After identifying the main features of the ICT ecosystem, its current evolution and the consequences for the nature and pace of innovation in various parts of the ecosystem, this section reflects on the consequences for innovation policy and "horizontal policies" (i.e. policies not directly related to innovation, but anyway relevant for innovation) in the ICT ecosystem. Section 2.4.1 below deals with innovation policies such as intellectual property protection and direct support for entrepreneurship. Section 2.4.2 reflects on the role of horizontal policies such as competition policy, sector-specific regulation and data protection regulation. Section 2.4.3 takes an even broader approach and reflects on the role of better regulation and flexible regulatory approaches in the ICT ecosystem.

2.4.1 Innovation policy instruments: Intellectual Property Rights

When it comes to policies for ICT innovation, the peculiarities identified in Sections 2.1, the trends highlighted in Section 2.2 and the features of innovation as described in Section 2.3 lead to the definition of specific approaches to the choice and design of policy instruments. In particular, it is useful to reflect on the role of intellectual property rights in the context of ICT markets.

First, there is no doubt that **the patent system** still plays a fundamental role in spurring incentives to invest in R&D at the lower layers of the ICT ecosystem, and in particular at the physical layer. Recent research confirmed that even smaller firms such as specialised technology suppliers can rely on the patent system to signal their value and to exploit their patent portfolio as a "bargaining chip" in negotiations with larger firms (see box on JRC research on IPRs). For example, Comino and Manenti (2015) report several studies that show that possessing a large stock of patents increases the chances of start-ups and SMEs of being financed by venture capitalists (Cockburn and MacGarvie, 2009).

However, especially at higher layers of the ICT ecosystem where innovation seems to be less dependent on R&D, it is important to avoid excessive rigidity in the patent system in order not to hamper the needs of new business models by creating incentives to accumulate patents and use them "as a sword" against innovative products and services.

In particular, technological fragmentation and the rise of system goods have led to the emergence of **patent "thickets"**. As widely acknowledged in the literature, stronger IPRs can incentivise disruptive innovation, but can also raise the cost of follow-on, incremental innovation (Landes and Posner 2003). Recently, some scholars have stressed how the IPR system in the United States has become "sand rather than lubricant in the wheels of American progress" and needs a deep reform (Jaffe and Learner, 2004), while others go even further by arguing its gradual abolition (Boldrin and Levine, 2012). Possible solutions rely on the ability of platform operators to "contract into liability rules" either by avoiding the clear definition of IPRs, or by creating patent pools or other complex forms of IPR governance.[66] In these settings, **forms of abusive exploitation of IPRs** have emerged, including strategic behaviour during standardization and patent pooling processes, collective action and multiple marginalization problems (royalty stacking), patent trolling behaviour and others. While this evidence appears much clearer in the United States (where a revision of patent legislation is currently under-way exactly to avoid these types of phenomena), also Europe potentially displays these problems. The flip of the coin is that in the United States large IPR intermediaries are much more developed than in Europe, and range from patent exchanges (e.g. Ocean Tomo) to large-scale managers of patent portfolios (e.g. MPEG LA). At the same time, the new unitary patent system that EU countries are about to adopt is expected to have a strong impact, but could also lead to enhanced forms of "trolling" (or what authors call activities by Patent Assertion Entities), which can have both positive and negative effects, particularly in the ICT sector, where they are most likely to emerge[67].

Given the different pace and modes of innovation at different layers of the ICT ecosystem, a reflection on the possible differentiation of IPR policy seems appropriate. In the co-evolutionary, co-dependent setting that we described in Section 2.2 above, should policymakers significantly modify IP legislation to avoid stifling innovation? Currently, the evidence is still too thin to advocate change: however, the following observations suggest that the debate might become important in the future:

- *Especially in the ICT ecosystem, some companies reportedly prefer to rely on trade secret rather than patent law* (McGurk and Lu, 2015; Biagi, Pesole and Stancic 2015)[68]. This is particularly important in the ICT ecosystem, since the predominance of information goods exposes the sector to an enhanced risk of appropriation and free riding, both at the domestic and at the international level. A recent OECD study surveys the economic importance of trade secret, and related importance of its protection[69].
- *Some of the layers of the ICT ecosystem display a nascent, rather different combination of business models and IP management practices.* As illustrated above, some of the leading IT companies (platforms) are taking a clear stance in favour of

[66] Robert P. Merges, Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations, 84 Cal. L. Rev. 1293.

[67] As Comino and Manenti (2015) define them, "PAEs are certainly the most controversial type of intermediary: they are responsible for an increasing number of patent lawsuits, but they may also significantly improve market liquidity and help SMEs to monetise the value of their IPRs. The available evidence on patent intermediaries and PAEs is US-based while little is known for Europe".

[68] file:///Users/ar376/Downloads/IP%20Research%20Trade%20Secrets_web.pdf; http://hstlj.org/wp-content/uploads/2015/06/The-Intersection-of-Patents-and-Trade-Secrets.pdf

[69] OECD (2013), Approaches To Protection of Undisclosed Information (Trade Secrets) - Background Paper OECD Trade Policy Paper No. 162, by Mark F. Schultz and Douglas C. Lippoldt. TAD/TC/WP(2013)21/FINAL.

open business models, and have publicly announced that they will not claim exclusivity nor licensing fees on their intellectual property[70].

- *In the already mentioned case of BlockChain, previous attempts to create a viable, open, permissionless distributed database were reportedly hampered by the existence of patents on a number of key technological features* (then expired in 1996). BitCoin was initially not patented, and use of the patent system, if anything, has been sought to contain their diffusion (by JP Morgan, but the patent application was rejected as not novel). The reaction to these attempts has been the decision, by Coinbase, to file nine patent applications to be used as a "shield" against similar attempts[71]. Previous architecture innovation and open source threads such as Gnutella have reportedly been key in the development of the BlockChain model[72]. All of this creates, today, a viable alternative to the IP-based model of innovation: that of so called "permissionless innovation", mostly based on open source software and open standards. However, it must be recalled that permissionless innovation is happening in specific provinces of the ICT ecosystem, not in all, and it can also happen through a combination of patents and open standards, not necessarily only through open standards (Chien, 2015)[73].

In other words, *at least in some sectors of the ICT ecosystem the original "innovation by exclusion" paradigm of patents is being replaced by a rather different context, in which patents are either no claimed at all; they are used only as shields to avoid strategic behaviour and free riding by rivals; or they are used to consolidate and then share system goods based on a multitude of technologies.* The recently updated guide to alternative patent licensing produced by the Juelsgaard Intellectual Property & Innovation Clinic at Stanford Law School in partnership with EFF and Engine provides a high-level overview of several tools that inventors and innovators could use today to avert unnecessary and costly patent litigation (or at least to avoid "trollish behaviour" themselves). The tools fall roughly into three categories[74]:

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70 Most notably, Google's "non-assertion pledge" on cloud-related technology offers a clear example of how openness stances can prevail over those of closed business models in some of the layers of the ICT ecosystem. Likewise, Tesla's decision to open up its patents on core technologies related to electric vehicles was received by commentators as a sign that the patent system can, under some circumstances, act as an obstacle to innovative, disruptive business models. Following this announcement, Toyota and Ford made similar announcements. In February 2015, LG promised to open its 29,000 patents to SMEs, and an even bigger number to start-ups. Also companies like Panasonic (for the Internet of Things), Facebook and Blockstream (in 3D printing, Bitcoin, and drones) and Daewoo, Samsung, Hyundai Motors, and Lotte (in a variety of sectors) are following similar strategies.

71 But the system itself was born with very limited intellectual property protection: the CEO of one company active in the BitCoin sphere, BitPay, reports that: "in the early days (2011) of BitPay we spent some time filing provisional patents (one on decentralized bitcoin exchanges and the other related to clearing and settlement): I felt like it was a complete waste of time and money … Why spend money on patents and copyrights when I could simply make these inventions available to anyone and profit from the increased utility of bitcoin?" Coinbase CEO explained that the intent of the patents were not to drive smaller companies out of business, but to protect themselves from services "engaging in patent warfare." Still many in the community were not pleased by this response calling Coinbase "evil" and asking how they can patent ideas they did not invent. http://cointelegraph.com/news/115337/coinbase-on-bitcoin-patents-dont-hate-the-player-hate-the-game

72 http://www.ofnumbers.com/2015/07/09/a-blockchain-with-emphasis-on-the-a/

73 Chien, Colleen V., Exclusionary and Diffusionary Levers in Patent Law (June 29, 2015). Southern California Law Review, Forthcoming; Santa Clara Univ. Legal Studies Research Paper No. 18-15. Available at SSRN: http://ssrn.com/abstract=2624692.

74 See: https://www.eff.org/files/2016/01/26/hacking_the_patent_system_belcher_and_casey_updated_january_2016.pdf

(i) *Defensive patent aggregators* such as Allied Security Trust, RPX, and Unified Patents, which use the pooled resources of member companies to purchase patents that may otherwise be purchased by trolls.

(ii) *Defensive patent pledges*, which involve commitments to only use patents defensively or to assert one's patents only under certain circumstances. Some pledges create a sort of demilitarized zone for patents: for example, when a company signs onto the Defensive Patent License (DPL), it promises not to offensively assert its patents against another company that has also agreed to the DPL. Other pledges place limits on the patent owner's ability to sue anyone for infringement. For example, Twitter's Innovator's Patent Agreement involves a guarantee to employees that if they assign an invention to Twitter, the patent on that invention will not be used to sue anyone offensively without the inventor's permission.

(iii) *Patent litigation insurance*, in which customers pay a fee in order to receive legal assistance if and when they are threatened or sued by a patent owner (so-called "before-the-event" insurance). Although patent litigation insurance has existed in some form for several years, it has become increasingly popular in the past few years. In October 2015, defensive patent aggregator Unified Patents launched an optional insurance plan for its members at a much lower premium than other insurance offerings, making it a viable option for start-ups.

Interestingly, the EFF-Stanford-Engine guide claims that the patent system "is broken", and that "in many high-technology industries today, the patent system is a scourge on innovation. Patent trolls buy overbroad patents, often from bankrupt companies, for the sole purpose of extorting licensing revenues from companies that are actually innovating and creating new products. Overworked patent examiners increasingly grant overbroad, obvious, and non-novel patents—particularly on software. Some companies aggressively assert their patent portfolios to keep legitimate competitors out of the market entirely. Small companies are particularly vulnerable, since the cost of fighting a lawsuit (even a flagrantly frivolous one) could easily put a start-up out of business. Faced with the constant threat of crippling litigation, small companies often perceive their best—or only—option to be laying low and hoping to stay off patent holders' radar". Accordingly, the guide claims that innovators are *de facto* hacking the patent system to continue to innovate. However, patent hacking isn't a substitute for patent reform. These hacks help keep some patents out of the hands of trolls but they don't come close to preventing all the harms caused by software patents.

The Intellectual Property Rights debate does not end with patent reform and trade secrets. Perhaps even more importantly, *with the rise of the data-driven economy, copyright legislation is becoming increasingly unfit for purpose both for what concerns its overall design, and even more importantly its enforcement*. This is particularly important for the higher layers of the ICT ecosystem, i.e. the application and content layer, and the user layer. Renda et al. (2015) highlight that digital technologies make it extremely easy to combine existing content in order to develop new artistic works and services, and that in Europe it is still uncertain whether the unauthorised scanning and digitisation of literary works which are not displayed to users but are merely used for purposes of data[75] and text mining[76] infringe copyright or not.[77] Considering that text and data

[75] 'Data mining' is normally referred to as the extraction of implicit, previously unknown, and potentially useful information from data. Data mining is in many ways conceptually similar to 'reading' and 'research'. It is a way for software to perform tasks such as reading, comparing and analysing large quantities of data in order to draw conclusions. It has become a 'copyright suspect' since the above-mentioned tasks are achieved through technology.

[76] 'Text mining' indicates finding structural patterns in texts, extracting information out of these patterns and combining them with data on the use of works such as data on searching and accessing works.

mining entails a temporary reproduction of copyright works, as a technical necessity, the issue is whether or not such a reproduction should be regarded as transient or incidental under the mandatory exception of Article 5(1) of the InfoSoc Directive. The issue is so urgent that the UK started developing a comprehensive reform plan that resulted, in 2014, in the enactment of new copyright exceptions that included an exception covering text and data mining for non-commercial research, which was not contemplated in the list of exceptions originally included in the 2001 Information Society Directive.[78] UK law now allows researchers to make copies of any copyright works for the purpose of computational analysis if they already have lawful access to the copyright work, without having to obtain additional permission from the copyright-holder to make the necessary copies.

The OECD recently observed that "the potential for productivity gains in the creation of scientific knowledge are ... huge. However, questions have emerged about whether current copyright regimes are appropriately calibrated with regard to 'automatic' scientific knowledge creation". The OECD quotes the JISC (2012) analysis of the value and benefits of text mining, which concluded that "the barriers limiting uptake of text mining appeared sufficiently significant to restrict seriously current and future text mining in UKFHE [UK further and higher education], irrespective of the degree of potential economic and innovation gains for society." Copyright has been identified as one these barriers, which has led to debates between the scientific community and the publishers of scientific journals.

Research on TDM techniques has advanced considerably in recent years. The OECD reports that the number of academic articles published on the subject of TDM since the beginning of the 1990s reveals that the United States has so far produced 46.6% of the publications dealing with TDM, followed by the United Kingdom (11.1%), Taiwan (8.8%), Canada (5.7%) and China (4.6%). The OECD argues that "Whether current copyright regimes are promoting or hindering TDM is an open question". According to a recent JISC report on the value and benefit of text mining (JISC, 2012), licensing agreements represent a key barrier to the use of text mining techniques in the higher education and research communities in the UK. Recent OECD analysis has highlighted how the context in which IP frameworks operate has been changing substantially. In this evolving context, the way copyright laws address TDM is not always clear in all jurisdictions (OECD, 2015). According to the same report, there is some (disputed) evidence that researchers in certain jurisdictions (such as the European Union and Brazil) are inhibited from engaging in TDM due to fears of infringing copyright in the process.

One step further, the blossoming data analytics sector seems to be increasingly reliant on open source software rather than on traditional copyright protection, possibly as a consequence of the difficulties connected with the copyright regime[79]. Many data

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77 On automated text processing and data mining Borghi & Karapapa point out that automated data processing can pursue commercially valuable objectives such as data analysis, sophisticated text analysis (e.g. the content of a book or the whole production of a specific author), analysis of metadata on patterns of use of digital copies (e.g. to create databases of user profiles) and computational analysis (which includes image analysis and text extraction, linguistic analysis and automatic translation and indexing and search) (Borghi & Karapapa, 2013).

78 See UK Intellectual Property Office (2012), *Modernising Copyright: A modern, robust and flexible framework*, 20 December, p. 16. Other areas in which the document announced legislative intervention are educational uses, quotation, parody, research and private study, disabilities, preservation, public administration and reporting.

79 Clark, J. (2013), *Text Mining and Scholarly Publishing*, Publishing Research Consortium; European Commission (2014), "Standardisation in the area of innovation and technological development, notably in the field of text and data mining", Report from the Expert Group; Filippov, S. (2014), "Mapping tech and data mining in academic and research communities in Europe", Lisbon Council, 16/2014; OECD (2015a), *Inquiries into Intellectual Property's*

processing and analytic tools that are now spreading across the economy as enablers of new data-driven goods and services were initially developed by Internet firms. Apart from the already-mentioned Hadoop, a well-known example is R, a GPL-licensed open source environment for statistical analysis, which is increasingly used as an alternative to commercial packages such as SPSS and SAS[80]. Today R is also an important part of the product portfolio of many traditional providers of commercial database and enterprise servers such as IBM, Oracle, Microsoft and SAP, which have started integrating R together with Hadoop into their product lines. The OECD report also mentions a study by Muenchen (2014), which suggests that the most popular statistics software (SPSS, SAS) is declining in popularity, while R is becoming more and more popular; and a survey by the data mining website KDnuggets (2013) confirms the trend that a large number of data analysts are using open source or free software for data analysis[81]. More specifically, RapidAnalytics (free edition), R, Excel, Weka/Pentaho, and Python were the top five data analytics tools used in 2013. All but Excel are free or open source tools.

EURIPIDIS papers on intellectual property and ICT innovation

The role of IPRs in the ICT ecosystem has been subject to significant analysis, in particular for what concerns patents, but also, increasingly, copyright. The most encompassing of the EURIPIDIS papers on this topic, authored by Comino and Manenti, provides a comprehensive and unitary analysis on the use of patents, copyright and trademarks in ICT industries, defined as "among the most dynamic and innovative segments of modern economies and … very intensive in the use of IPRs". Important contributions are also found in the papers authored by Pentheroudakis (2015), dedicated to patent; and in another EURIPIDIS paper authored by Meniere (2015) on FRAND licensing.

More specifically, Comino and Manenti (2015) observe that ICT industries feature an intensive use of IPRs, and that in ICT, technological complexity combined with the cumulativeness of the innovation process leads to fragmentation of IP rights and to the emergence of patent thickets (which they characterize as essentially an ICT phenomenon). Complexity is exacerbated by the fact that digital technologies make it easy to combine existing products to develop derived works, which calls for interoperability among different standards as a crucial factor for the success of a given technology. In this context, the authors explicitly discuss the challenges of managing patent pools and standard setting organisations (SSOs), in particular for what concerns the so-called "thicket" problem, for which the authors invoke a strong role of IPR intermediaries, including controversial ones such as Patent Assertion Entities. Another important issue is the need to increase the transparency of the IP system, and take action to preserve the quality of patents. Finally, the authors invoke the need for further analysis on the possible effect of an increase in European software patents, and observe that the new unitary patent system and unified patent court that European countries is expected to have a major impact on firms IP strategies and on the harmonisation process taking place in Europe. For what concerns more specifically ICT, the authors emphasize the possibilities offered by IPRs to create hybrid models that patent protected software and open source in composite IP bundles: however, further research is therefore needed to shed light on how firms mix different IPRs, as well as of the interplay of the various property rights.

Economic Impact, OECD Publishing, Paris; JISC (2012), *The Value and Benefits of Text Mining*, JISC, www.jisc.ac.uk/sites/default/files/value-text-mining.pdf.

80 GPL stands for "General Public License, perhaps the most well-known and established licensing system for open source software.

81 OECD (2015), Data-Driven Innovation: Big Data for Growth and Well-Being, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264229358-en

Much in the same vein, Pentheroudakis (2015) analyses and denounces the absence of empirical evidence on royalty stacking and patent hold-up practices, and argues that in its absence the debate on FRAND licensing is doomed to remain essentially theoretical. Theoretical arguments are usually derived from simplistic assumptions about the mechanisms of royalty determination such as the existence of a unique public royalty price for all implementers, or the absence of delay between the adoption of a standard and the licensing of the related standard-essential patents (SEPs). This observation seems to have more research implications than policy ones. Ménière (2015) observes once more the impossibility or defining a one-size-fits-all solution, but adds that given the absence of strong empirical evidence of strategic behaviour, the current focus of the debate should mostly fall on how to better frame the process of FRAND bargaining in order to prevent biases in favour of one or the other negotiating party, as well as on a broader set of issues, such as the governance of SSOs and patent pools, or on the transparency of patent licensing conditions.

Furthermore, all authors focus their attention specifically on software, given the fact that the availability of patents for software has traditionally been limited and controversial in Europe, as opposed to the United States. The interplay between open source software and patent law is mentioned both by Comino and Manenti (2015) and by Pentheroudakis (2015) as a potential issue for policy, but especially with the emergence of non-viral types of open sources licenses and of giant IT companies that manage at once open source and patent projects (e.g. IBM, Google), the issue seems more complex[82]. Comino and Manenti (2015) provide a comprehensive analysis of various market strategies, which potentially create problems of co-existence between proprietary and open source software models; at the same time, they quote literature that questions the viability of software patents (Bessen 2014) and show the emergence of both offensive and defensive strategies that use patents to either raise rivals' costs, extract undue revenues (especially in case of non-practising entities), or defend the company from strategic attacks (Blind 2007)[83].

With the rise of the data-driven economy, copyright legislation is becoming increasingly unfit for purpose both for what concerns its overall design, and even more importantly its enforcement. Only Comino and Manenti (2015) discuss copyright, reporting literature focused mostly on the music industry. They find that file-sharing technologies undoubtedly hamper copyright protection; however, the available evidence does not indicate that these technologies have lowered the incentives to create artistic works. To the contrary, digital technologies make it extremely easy to combine existing content in order to develop new artistic works and services. The authors call for the creation of an efficient market for copyright licensing and the simplification of pan-European licensing for copyrighted works.

Finally, Comino and Manenti (2015) report that the literature on trademarks and IP bundles is relatively scarce and typically not specific to ICT industries, and argue that more research is needed for what concerns the joint use of IPRs (bundles) and a better understanding of the interplay of the various IPRs.

These papers contribute to the understanding of current problems and trends in IPR use and protection in the ICT sector and beyond. However, they also leave some uncovered areas on the following issues, which are of key importance for the development of a suitable ICT innovation policy:

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82 There is probably a misuse of the term open innovation in that paper, at page 48. Open source and open innovation are two fundamentally different concepts.

83 A series of legal controversies against Linux vendors and users has raised concerns about the compatibility and coexistence of patent protected software and open source. For these reasons, open source developers started adopting defensive strategies as the creation of patent pools aimed at protecting Linux. But IBM is also doing the same.

- Various patterns of IPR protection at different layers of the ICT ecosystem. In particular, trade secrets seem to have become an increasingly dominant way of protecting intellectual property at the higher layers of the ecosystem (McGurk and Lu, 2015)[84.] A recent OECD study surveys the economic importance of trade secret, and related importance of its protection.
- An analysis of IPRs as obstacles to innovation, especially in the field of content and media, but increasingly in many other sectors. This should include the analysis of both barriers to IPRs (in particular, patent) for smaller companies (see WIPO 2015), as well as IPRs as per se obstacles to innovation.
- An analysis of whether and how large platforms govern IPRs contractually in an efficient way in the definition of their system goods; in other words, whether large platform operators can act as transaction-cost reducers in what is otherwise widely recognised as a mounting patent and copyright thicket.
- The potential and role of IP-backed financing for entrepreneurship in Europe. In this respect, Comino and Manenti (2015) report that several studies show that possessing a large stock of patents increases the chances of start-ups and SMEs of being financed by venture capitalists (Cockburn and MacGarvie, 2009).

2.4.2 Competition policy and the role of platforms

Another policy that is often considered to be in need of adjustment in the ICT ecosystem is competition policy, and in particular antitrust law. Even if a comprehensive treatment of this policy area would fall outside the scope of the report and would require a lot more space, it is important to highlight a number of issues that would deserve analysis and reflection in the coming years.

At the lower levels of the ICT ecosystem attention has been devoted to the consequences of anticompetitive behaviour in the management of IPRs. In this respect, possible anticompetitive conduct has been already subject to investigation within the context of patent pools and so-called standard essential patents (SEPs, *i.e.* patents that are essential to produce products in compliance with a particular standard). Some of the grey areas that remain even after the recent CJEU decision in *Huawei* include: under what circumstances license terms can be considered "FRAND"; whether holding a SEP implies, *per se*, a dominant position on the market[85]. Clarifications on these issues would greatly improve the level of legal certainty for companies operating at the physical layers of the ecosystem.

But it is at the higher layers that antitrust law seems to be most in need of a rethink. There, competition for the market, direct and indirect network externalities, rapid pace of innovation and high contestability of dominant positions create enormous problems to competition authorities, potentially creating significant uncertainty in the market. Renda (2015), in presenting the challenges the European Commission has to face in the ongoing antitrust investigation against Google, discusses in detail a number of issues related to abuse of dominance cases in the higher layers of the ICT ecosystem. These include[86]:

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84 file:///Users/ar376/Downloads/IP%20Research%20Trade%20Secrets_web.pdf; http://hstlj.org/wp-content/uploads/2015/06/The-Intersection-of-Patents-and-Trade-Secrets.pdf

85 CJEU, 16 July 2015, case C-170/2013, Huawei Technologies Co. Ltd. v. ZTE Deutschland GmbH.

86 A good example in this respect is provided by the standard adopted in different jurisdictions on refusal to deal, a form of abuse of dominance that can trigger compulsory access remedies, or mandatory licensing of intellectual property in knowledge-based markets. This rule, besides inspiring competition law enforcement had a profound impact on *ex ante* regulatory regimes such as the one for electronic communications in force in Europe since 2003 (Renda, 2010, 2013; Pelkmans and Renda, 2011; Pelkmans and Renda 2014).

- Whether market definition should be reconsidered in light of the platformization of the Internet, and the emergence of competition between platforms that, by definitions, belong to different relevant markets.
- Whether the concept of dominance should be reconsidered, to reflect the competitive pressure exerted by players that are located outside the "relevant market", and thus to reflect the original interpretation of the CJEU, according to which dominance is chiefly related to appreciable independence of behaviour.
- Whether abuse of dominance should be redefined to mirror the peculiar dynamics of competition "for" the market, and thus by abandoning, at least in part, a "structuralist" view of antitrust to reflect the current landscape of competition, in which players are subject to competitive pressure from future products, rather than by current rivals.
- What the "special responsibility" attributed by EU competition law to dominant firms entails for firm behaviour in digital markets.
- Whether remedies should be carefully gauged to avoid distorting market behaviour, and how can such remedies be monitored and verified over time in a way that incorporates fast technological progress.

Several sources of uncertainty exist with respect to these questions, especially in Europe, as will be clarified below. At this stage, it suffices to clarify that the solution to these questions appears to diverge significantly in the United Stated and in Europe; and that this divergence is often considered as a factor that contributes to making the U.S. system more conducive to entrepreneurship and innovation than the European one. This is even more important as the criteria adopted in antitrust law for refusal to deal are also the main basis for the sector-specific regulation of network industries (and notably, electronic communications) in major economies. This led for example the United States to adopt a more investment-friendly regulatory framework in broadband regulation since 2003, whereas the EU remained faithful to a compulsory access model inspired by the so-called "essential facilities" doctrine (Renda, 2010; 2015). The same criteria affect the current debate on platform regulation, which at the EU level might lead to creating a specific set of rules for digital platforms.

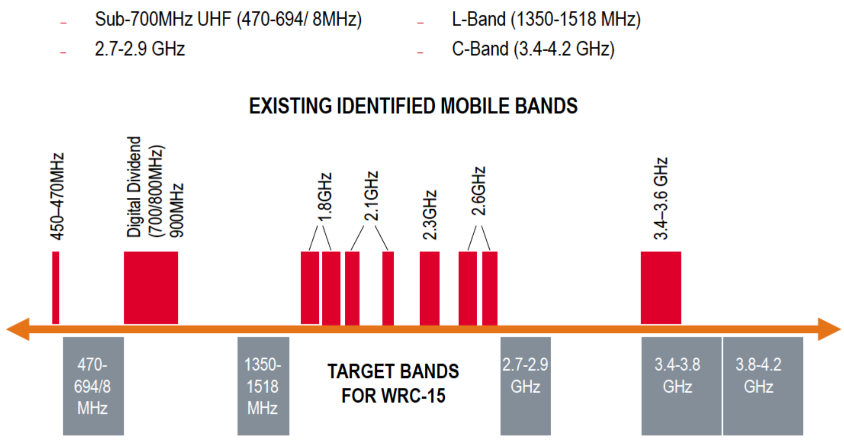
2.4.3 Sector-specific regulation: from infrastructure to platforms and media pluralism

Needless to say, sector-specific policies can have a remarkable impact on innovation. Different layers of the ICT ecosystem are of course affected by different policies, and the trends highlighted in Section 2.2 above should be taken into account in shaping the overall environment for innovation and entrepreneurship. Even if a full account of all these policies would fall outside the remit of this report, it is important to highlight the following:

- *At the physical layer*, traditional access-based regulation has been for a long time reliant on the definition of relevant markets and the identification of dominant positions. However, convergence between fixed and mobile operators caused by the advancement of wireless broadband technologies is increasingly requiring a different definition of relevant markets. At the same time, competitive pressure exerted by so-called "over-the-top" players is leading to a blurring of the boundaries between the physical and the application layer, with products like Skype, Whatsapp and others being perceived as substitutes of traditional voice and SMS services. This requires a reassessment of the current approach to regulation in the interest of consumers. In addition, public support for broadband connectivity (fixed or wireless) in rural areas is being perceived as increasingly needed by countries that wish to harness the potential of the higher layers of the ICT ecosystem: this is leading to an expansion of the menu of possible interventions for policymakers and regulators, including i.a. public funding of broadband networks; the revision of universal service and coverage obligations; the launch of public-private partnerships for broadband deployment; allowing co-investment and risk-sharing plans between competitors; etc.

- Similarly, *spectrum policy* is being adapted to ensure that wireless broadband (including the upcoming 5G standard) is given as much spectrum as possible, both at low frequencies (600-900Mhz) and at higher frequencies. Availability of the 700 MHz band today appears as an essential, but by no means sufficient condition to fully embrace the mobile broadband revolution, as testified by the fact that countries that traditionally have assigned a much larger amount of spectrum to mobile broadband, like the United States, the United Kingdom and Germany are currently feeling the urge to further expand spectrum availability in order to enable emerging, highly welfare-enhancing technological revolutions[87]. GSMA (2015) currently proposes four new allocations to mobile broadband in WRC2015: one allocation in the UHF band below the 700MHz; the L-bank (1350-1518 MHz); the 2.7-2.9 MHz band; and the C-band (3.4-4.2 GHz). The latter band is now being used more intensively for mobile broadband in some European countries (see Plum, 2015)[88] and is subject to study also by the FCC, where there seems to be increasing awareness that this frequency range is particularly suitable for the evolution of 4G and future 5G innovation. The C-Band, used in various ways in different countries, potentially offers those large contiguous blocks that are required for mobile broadband use as mobile data traffic grows.

Figure 11 - New allocations identified by GSMA for mobile broadband



Source: GSMA (2015).

The availability of new technologies such as cognitive radio, able to navigate through the spectrum to avoid interference and to optimize techniques such as spectrum sharing, can usefully be coupled with the need for ultra-high-speed connectivity especially in densely populated areas. This is why device manufacturers and mobile operators are seeking the allocation of spectrum bands not only in UHF spectrum, but also in higher frequency ranges. In this ranges, capacity increases, though they require adequate network density, which can be reached only in densely populated (urban and suburban)

87 Five years ago the U.S. Federal Communications Commission projected a licensed spectrum deficit of almost 300 MHz by 2014. Bazelon and McHenry (2015) find that by 2019, the U.S. will need more than 350 additional MHz of licensed spectrum to support projected commercial mobile wireless demand. Accordingly, over the next five years the United States (U.S.) must increase its existing supply of licensed broadband spectrum by over 50%.

88 See: http://www.plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_C-Band_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf

areas[89]. Recently, the so-called millimetre spectrum (between 30GHz and 300Ghz) has become subject to enhanced attention as well, especially in light of 5G applications (See section 3.4 below): For example, the FCC published a Notice of Proposed Rulemaking that seeks to provide "flexible spectrum use rules for bands above 24 GHz, including for mobile broadband use," and including millimetre wave spectrum, with the idea that promoting flexible use of those spectrum bands would help support the continued development of high-speed mobile broadband services[90].

- At the *logical layer*, after more than a decade in which the ICT ecosystem was largely left to self-regulation by engineers and industry players (in the W3C, IETF, ICANN), since the early 2000s there have been increasing calls for public regulation mandating that Internet Service Providers (ISPs) respect the "network neutrality" principle. What is quite surprising is that, as the ICT ecosystem evolves, it becomes increasingly clear that regulation imposing network neutrality would be unlikely to achieve any of its stated objectives and goals (Renda 2015). This is essentially due to the fact that, in the upper layers of the Internet, traffic flows are already largely "managed", and traffic is being prioritized in a way that many consider to be absolutely welfare-enhancing (Renda 2010; 2012; 2015). In addition, and relatedly, the Internet and its underlying technology are evolving in a way that makes the inspection of content that flows through servers both possible, and in some cases even desirable, e.g. for spam-filtering and overall security purposes (to the extent that users' privacy is duly respected). Growing emphasis on the need to monitor Internet activity, e.g. for counter-terrorism and copyright enforcement purposes, has led to the definitive sunset of the "neutrality as anonymity" stances: today, it is clear that the current debate on Internet policy does not look at the right to surf anonymously as a policy goal *per se*, with some isolated exceptions. In other words, the breath-taking pace of evolution of the Internet ecosystem has made the hectic network neutrality debate less important for end users than it appeared in the mid-2000s. Today, what remains valid about the network neutrality *querelle* are essentially two issues: (i) the extent to which existing rules of network neutrality create sufficient incentives for ISPs to upgrade their networks; and (ii) the distributional impacts of network neutrality legislation, in particular for what concerns the telecommunications operators and so-called over-the-top (OTT) players such as Google or Skype. The key priority today is to provide legal certainty on the types of specialized service that will be allowed under the EU future regulatory framework; as well as on the traffic management practices that can be considered "reasonable". This will stimulate in particular ISPs in entering competition with higher-layer Content Delivery Networks (e.g. Akamai, Limelight, Level3): this competition is likely to spur innovation, given the growing importance of traffic management and acceleration in the current Internet.
- The neutrality debate has extended over time to so-called "Internet platforms" that are so paramount in the *application layer* of the ICT ecosystem. Online intermediaries such as Google, Facebook, Amazon today play an important role in the selection of information that is made available to end users, as well as in the promotion of entrepreneurship. Their role is today important and potentially welfare-enhancing, but also very delicate from a public policy standpoint. This has led them to be subject to different regulatory debates, which bear important consequences for end users. First, particularly in Europe, Internet platforms are subject to a heated debate on possible "platform neutrality" regulation.[91] However, the platform

[89] The density of a network can be defined by referring to the number of cell sites for a given geographical unit (e.g. square km).

[90] Flexibility in spectrum use implies the possibility of trading the usage right, as well as the possibility to change the technology used and/or the service provided by the operator that holds the right to use the portion of spectrum.

[91] One of the first to use the expression 'platform neutrality' was the French National Digital Council (*Conseil National du Numérique*), which published a detailed report on this same

neutrality debate evidently clashes with a simultaneous trend, i.e. the repeated calls for attributing greater responsibilities to digital platforms for the conduct of their users.[92] Such trend is visible in several initiatives (especially in the EU), including plans to review and partly abandon the 'mere conduit' principle; proposals to strengthen intermediary liability and call on online intermediaries to cooperate in the enforcement of copyright and privacy laws (including the 'right to be forgotten'), as well as in curbing defamation, enhancing spam filtering, notifying of security breaches, cooperate in the fight against terrorism and provide other monitoring activities. The contradiction lies in the fact that some parts of EU law seem headed in the direction of imposing neutrality obligations on online intermediaries; whereas on the other hand, other legislation is requiring intermediaries to be more proactive in managing, prioritising and editing the content they pass on to the end users.

- Importantly, the debate on the role of platforms is essential also with respect to *media pluralism* stances at the content layer. However, the platform neutrality principle is in stark contradiction with the objective of media pluralism. The problem is similar to the one already outlined for net neutrality, but exacerbated by the scarcity of attention and trust that characterises the provision and consumption of media content. In short, platforms need to select content, and in selecting content polarise the attention of end users on a subset of available information. Several scholars, including Gillespie (2010), Helberger (2012), Crawford (2013), Latzer et al. (2014), Sunstein (2009), Zittrain (2014) and Goodman (2014) have fuelled the debate [93] on how to design a proactive media policy in the age of online intermediaries: this debate is inspired by an understandable sense of urgency as regards the need to address the prominent role played today by platforms in conveying news and content to end users.

All in all, the economic regulation related to the various layers of the Internet (which largely overlap with the ICT ecosystem) is in need of careful reassessment in many countries. Recently, Renda (2016) provided a summary table related to the myths and challenges of Internet regulation, reported below as table 2.

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concept in June 2014, following a 2013 request from the Ministry of the Economy and Digital Affairs as well as the Secretary of State on Digital Affairs. See Conseil National du Numérique (2014), "Platform Neutrality: Building an open and sustainable digital environment", Opinion No. 2014-2, of the French Digital Council, Paris (www.cnnumerique.fr/wp-content/uploads/2014/06/PlatformNeutrality_VA.pdf).

92 "Europe enlists Internet giants in fight against online extremism", by C. Spillman, 9 October 2014 (http://phys.org/news/2014-10-eu-internet-giants-online-extremism_1.html#inlRlv).

93 See Tarleton L. Gillespie (2010), "The Politics of 'Platforms'", *New Media and Society*, Vol. 12, No. 3 (available at SSRN: http://ssrn.com/abstract=1601487); N. Helberger (2012), "Exposure diversity as a policy goal", *Journal of Media Law*, 4 (1), 65-92. doi: 10.5235/175776312802483880; Latzer et al. (2015), "The Economics of Algorithmic Selection on the Internet", forthcoming in Johannes Bauer and Michael Latzer (eds), *Handbook on the Economics of the Internet*, Cheltenham: Edward Elgar; Sunstein (2009), *On Rumors*, op. cit.; Jonathan Zittrain (2014), "Engineering an Election", *Harvard Law Review Forum*, Vol. 127, and Harvard Public Law Working Paper No. 14-28 (available at SSRN: http://ssrn.com/abstract=2457502); and E.P. Goodman (2014), "Informational justice as the new media pluralism", LSE blog, 19 November (http://blogs.lse.ac.uk/mediapolicyproject/2014/11/19/informational-justice-as-the-new-media-pluralism/).

Table 3 – Problems and myths of Internet regulation

Layer	Emerging problems	Myths
Infrastructure	- Access policy is insufficient to stimulate investment in ultra-fast broadband - Public and private investment needed to sustain the growth of upper layers - The regulatory framework can have distortionary effects, e.g. incentivising less future-proof investment (ex. vectoring) - Structural remedies are proving too rigid and hard to manage over time (UK, Canada)	- Concentrated markets always harm end users
Logical	- Network neutrality regulation unlikely to achieve any of its objectives - However, alternatives so far have not been sufficiently market-tested - Desirability of network neutrality ultimately depends on a careful appraisal of costs and benefits for society, not on ideological stances	- The more neutral the network, the better for end users - Network neutrality promotes media pluralism
Platforms	- Platform neutrality debate appears as a "dead end" - Impossible to apply at once strict platform neutrality and enhanced platform responsibility - Responsible cooperation by platforms appears to have more legs as a future regulatory approach - Competition law must be carefully adapted to the economics of digital platforms	- Online platforms would disregard "niche" content and as such reduce content variety - Online platforms are stifling innovation and preventing market entry
Applications and content	- More rigid copyright protection does not help content production and dissemination in the Internet - Copyright legislation is becoming increasingly important for the development of the data-driven economy: getting it right is essential, and requires courage - A "fair use" approach seems to fit the peculiarities of cyberspace more than a closed list of exceptions and limitations - Enforcement of copyright law is still puzzling: co-regulation seems more promising than cyber-police	- Strict privacy legislation protects and empowers end users. - Strengthening copyright means increasing the availability of content. - Early-on standardization and interoperability is always good for end users.

▪ Users	- The end-to-end architecture of the Internet is what preserves its richness and promotes user freedom, rather than neutrality - End users benefit from a balanced regulatory framework: all layers have to be well nurtured to provide for a unique end user experience - The future will require end users to be more aware of their privacy and to accept possible disclosure of information only in exchange for a better, more customised service	- End users want a neutral network, and desire interoperability and standardization

Source: Renda (2016).

2.4.4 Towards more flexible, adaptive innovation-friendly policy approaches?

This section takes a broader approach to ICT innovation, and explored possible new ways to approach policymaking that leaves more space to innovation. As a matter of fact, one of the key challenges created by the ICT ecosystem for regulators and policymakers is that the pace of innovation is typically much faster than the time needed to review and design policies. As a consequence, sometimes policymakers feel the urge to regulate technologies too soon (sensing that it will take time to finalise the rules); and most often, they produce rules that enter into force too late, when technology has already advanced. In other circumstances, innovation can be hampered by the adoption of rules that reflect specific market conditions and are tailored to incumbent industry players: this might place new entrants and disruptive innovators at a disadvantage, even unintentionally.

Several of the policies mentioned above, from competition law to IPRs to sector-specific regulation, have been subject to critiques in this same vein. Emerging new sectors such as FinTech, the collaborative economy, crowdfunding platforms and business models based on big data have already been at the centre of hectic debates on the need for a more innovation-friendly regulatory approach. Innovation policy, in most of the application layer of the ICT ecosystem, chiefly depends on the ability of regulators to eliminate incumbency advantages and other implicit biases in the regulatory framework to accommodate new, welfare-enhancing technologies, at the same time maintaining a sufficient level of protection for end users.

Examples of new initiatives that aim at increasing the flexibility and future-proof nature of policies that affect the ICT ecosystem include the following:

- The *Regulatory Sandbox report* issued by the UK Financial Conduct Authority in 2015 within its "Project Innovate". The regulatory sandbox aims at allowing new and existing financial services providers to experiment with innovative products with selected samples of consumers for a limited amount of time, and even encouraged the industry to create a virtual sandbox to pre-test with virtual customers new products. For example, the FCA recently hosted a forum to discuss automatic advice business models ("robo-advice"), where attendees noted that it would be very helpful if they could test their algorithms in a regulatory sandbox. A sandbox could allow a firm to make their advice platform available to a limited number of consumers. As a safeguard, once the advice is issued, but before transactions are executed, financial advisers would review the advice. This would allow firms to learn how consumers interact with their advice platform and how their algorithm performs compared to human assessment. The effect of the regulatory sandbox would be to allow for experimentation and monitoring of new products and services, under an extremely simplified authorization regime. Potential benefits include more effective competition; reducing the time and, potentially, the cost of getting innovative ideas to market; enabling greater access to finance for innovators; enabling more products to be tested and, thus, potentially introduced to the market; and allowing the FCA to work with innovators to ensure that appropriate consumer protection safeguards are built in to their new products and services.

- The *regulatory humility* approach of the Federal Trade Commission in the U.S. Motivated by the observation that prescriptive *ex ante* regulations can hinder innovation, the FTC has decided to award priority to ex post case-by-case enforcement of specific rules. This reveals a so-called "incrementalist" approach to regulation, which entails market monitoring and prudent vigilance, coupled with relatively easy market access of new products. Recently an FTC Commissioner argued that "incremental approaches are particularly well-suited to dealing with fast-developing areas of technology", and added that "another nimble, transparent and incremental tool that is well-suited to regulation in fast changing industries is industry self-regulation, with agency enforcement as a backstop", since "compared to traditional government regulation, self-regulation has the potential to be more prompt, flexible, and responsive when business models or technologies change"[94].

More generally, the future of ICT regulation seems to be chiefly dependent on principles-based regulation, rather than on prescriptive, command and control regulation. The use of co-regulatory schemes and adaptive regulation seems to be increasingly needed, together with specific screens that lead policymakers to focus on possible innovation impacts when crafting new legal rules (so-called "innovation principle"). Respect for flexibility and innovation in policymaking requires a degree of oversight: and indeed, in the United States Stuart Benjamin and Arti Rai (2009) have advocated the creation of an Office of Innovation Policy (OIP), which would opine on regulatory issues having a major effect on the competitiveness of U.S. companies, and would have the power to comment on the competitiveness effects of major regulatory actions.[95] Similarly, the European Commission has recently opened a consultation for the creation of a European Innovation Council, although it is not yet clear if the new body will have similar powers.

Very few commentators have directly addressed the issue of flexible, adaptive policymaking in the layered ICT ecosystem. In their attempt to propose an adaptive framework for the Internet, Clark and Claffy (2015) argue that the following requirements are essential:

- Agreeing on policy goals;
- Measuring progress towards those goals;
- Designing regulatory options intended to move towards those goals;
- Being able to determine that policy changes indeed caused observed outcomes; and
- Dealing with potential destabilization of ecosystem, due to rapid policy adjustments.

Likewise, according to Richard Whitt, policymakers should possess the flexibility to revise and adapt the structure of policies and programs to changing circumstances. This leads Whitt to look at better regulation tools, such as the use of sunset clauses and forms of

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94 See FTC Commissioner Maureen K. Ohlhausen, The Procrustean Problem of Prescriptive Regulation: Three Principles to Promote Innovation, Engage Volume 16, Issue 3, October 29, 2015.

95 Stuart Minor Benjamin and Arti K. Rai, "Structuring U.S. Innovation Policy: Creating a White House Office of Innovation Policy" (ITIF, June 2009), www.itif.org/files/WhiteHouse_Innovation.pdf

experimental policymaking, to trigger learning on the side of government[96]. The "adaptive regulator" would be guided by a number of principles, including:

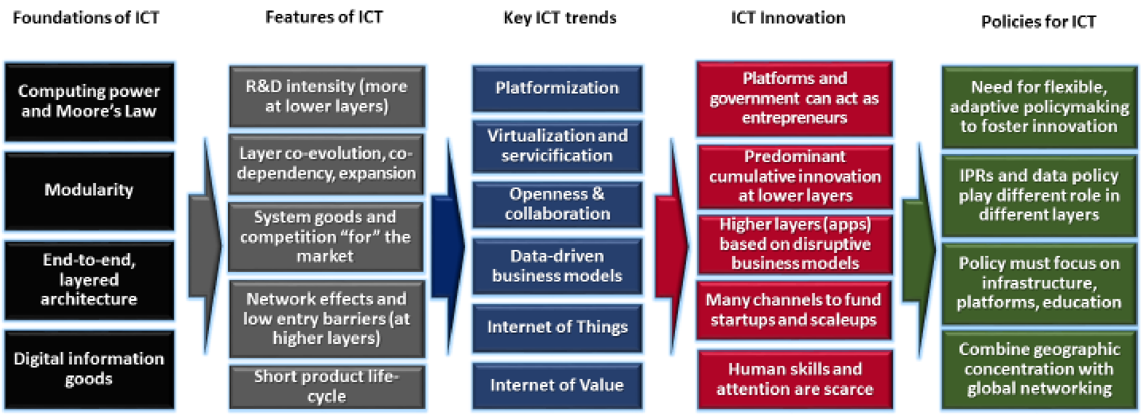
- An *incremental* approach, meaning that small steps should be taken and social change should be based on experience;
- An *experimental* approach, justified by the "combination of uncertainty and constraints on predictability [which] create … the necessity for policymakers to experiment;" and
- A *flexible* approach, required by the existence of deep uncertainty.

This is where this literature stops, and where new insights would be urgently needed. Besides the already mentioned papers by David Clark and K.C. Claffy, and the original insights by Richard Whitt, key contributions were provided by authors such as Christopher Marsden and Jonathan Cave, who look at various forms of co-regulatory schemes that have emerged on the Internet[97]. But by and large, an elaboration of hybrid, dynamic and adaptive regulatory governance arrangements that can enable learning through experimentation in ICT policy is missing.

2.5 Taking stock, and looking forward

This section has surveyed the main foundational features of the ICT ecosystem (Section 2.1) and a number current trends that are affecting the pace and direction of innovation in ICT (Section 2.2). A number of consequences can be identified both for innovation (Section 2.3) and related policy approaches and solutions (Section 2.4). Figure 12 below provides a graphical illustration of the logical relation between the main foundational elements of the ICT ecosystem, its features, its ongoing trends, the resulting consequences for innovation, and related policy implications. Below, we describe the various elements shown in the figure (all of which have been described earlier in Section 2) and discuss the causal links and interrelations between them.

Figure 12 – Logical mapping of Section 2 of this report



Source: Author's elaboration.

[96] Listokin, Y. (2008) Learning through Policy Variation, 118 YALE L.J. 480, 484 (2008) ("[O]ptimal search theory favours high-variance policies, because variance increase the probability of finding excellent policies."). See also Ranchordás, S. (2013), Experimental Legislation: The Whys and the Woes, 1 Theory & Prac. Legis. 415.

[97] Brown, I. and C. Marsden (2013), Regulating Code: Good Governance and Better Regulation in the Information Age, MIT Press.

As shown in Figure 12, the foundational elements of the ICT ecosystem (to the left of the figure) must be coupled with their resulting features and existing trends (and their overall combined effect, as mentioned in Section 2.2.7 above) to draw conclusions on the resulting impacts in terms of innovation and policy. More specifically:

- The fast pace dictated by **Moore's law** affects the overall direction, pace and **expansion** of innovation at all layers of the ICT ecosystem. Vice versa, new business models and emerging successful platforms at higher layers generate demand for more efficient hardware, network equipment, data storage and traffic acceleration, thus affecting the pace of innovation at lower layers. Moore's law directly affects **virtualization** (given by advanced computing capacity) and the emergence of previously unchartered areas such as the **Internet of Things** and the **Internet of Value**. This fast pace of evolution is also responsible for the relative **scarcity of human skills and attention** (skills evolve much more slowly than technology, and over-abundance of information determines a poverty of attention).
- **Modularity** is the basis of the overall organization of the ICT ecosystem, and it is found both in the IT sectors (e.g. in personal computers, which are designed as **system goods** since the 1980s) and in the higher layers of the ICT ecosystem emerged with the Internet (such as modern smartphones and software stacks such as the LAMP). It chiefly affects the nature of innovation, and explains the predominance of **cumulative innovation.** Modularity is also intimately related to the existence of direct and (even more importantly) indirect **network effects,** which call for maximizing the amount of applications to capture the attention of end users. This, in turn, has led to the prevalence of **openness** as a dominant trait of innovation and business models, and is the basis for the co-evolution between layers, which often host complementors of the same system good. The flip of the coin is the **platformization** of the whole ecosystem: layers that exhibit the strongest indirect network effects tend to catalyse other products and services (complementors, applications) towards a single system good, and this centripetal force leads to cumulative innovation and **co-evolution**.
- The **end to end architecture** is the basis for the breath-taking growth of the application and content layer of the ICT ecosystem, as well as the driver of **direct network externalities**. It provides the ICT ecosystem with prevalent **openness** and is the basis for the emergence of the **collaborative economy**. It also affects **platformization** as many of the most powerful and successful platforms of today's ICT ecosystem are entirely based on interaction between end users (e.g. social media, sharing economy services). The end to end architecture of the Internet is also the basis of innovative **funding channels for start-ups**, such as crowdfunding platforms. And it is the essential precondition for the **Internet of Things** and the **Internet of Value** to emerge as new trends.
- Finally, the **digital** nature of **information goods** leads to unprecedented possibilities for sharing, versioning, re-packaging content and – coupled with the end to end architecture displayed by the ICT ecosystem, has led to the emergence of user generated content. It is also the basis for the **servicification** of the economy, which transforms consumption patterns from property-based transactions to access services (e.g. streaming services for movies and music). The negligible marginal costs that follow digitization open up a number of important possibilities also for innovation (**low entry barriers**) and policy (ease of experimentation in **adaptive policymaking** context such as "virtual sandboxes").

All these interactions create important consequences for ICT innovation, and for policies aimed at its promotion. The prominent role of platforms in the ICT ecosystems places them in a privileged position to act as **entrepreneurs**, i.e. as talent scouts that are best placed to locate talent and market opportunities and thus matching ideas with user demand. At the same time, at the lowest layers of the ecosystem (i.e. physical layer) deviating from **cumulative innovation** is often not a rational strategy for private players: this is why often disruptive innovation comes from high-risk, high-reward projects funded by public institutions, as shown by Mazzucato (2011) for the case of the iPhone. This is why also the state is a necessary entrepreneur in ICT. As recalled by Clarke and Claffy (2015), higher layers are characterized by innovation that is faster, typically more **disruptive**, and linked to an idea (often, a **business model**), rather than a product: this peculiar innovation process, that often is accompanied by high market contestability, leaves **less room for the use of IP instruments** such as patents compared to what occurs in the lower layers.

Finally, the challenges for policymakers are evidently related to all the above. In particular, the need for **more flexible, adaptive policymaking** – as already explained in section 2.4.4 above – stems from the short product lifecycle, the disruptive nature of products and services emerging at higher layers (e.g. FinTech; collaborative economy) and the need to avoid incumbency constraints in all those cases in which rules are too rigid to accommodate innovative business models (e.g. smart grids, again financial services, public transportation). As already highlighted above, **IPR policies** must be tailored to the specifics of different layers to avoid creating a straight-jacket effects for entrepreneurs wishing to obtain adequate protection while operating at higher layers of the ecosystem, and at the same time offer SMEs and larger companies at lower layers the legal certainty and "bargaining chips" they need to signal the value of the innovative products they design. When dealing with higher layers, policies like **data protection and copyright law** must reflect the importance of data-driven innovation as an emerging trend in the ICT ecosystem. The accelerating pace of innovation at higher layers, compared with the slower pace at lower layers, and the slow evolution of human competences and skills determine the emergence of key policy challenges: on the one hand, governments would be less and less able to follow and support innovation efforts at higher layers; at the same time, they would need to engage with platforms to ensure the enforcement of legal rules, and even the channelling of funds towards most promising entrepreneurs; on the other hand, governments are likely to have a much more leading role in fostering the deployment of **infrastructure** (also since broadband generates very important positive externalities, which are hardly internalized by the telecommunications companies that deploy the network); the orchestration of **mission-led platforms** dedicated to grand societal challenges such as de-carbonization (Ashford and Renda 2016; Mazzucato 2016); and the organization and delivery (in cooperation with private players) of new forms of **education**, aimed at generating the mix of skills that is needed in today's ICT ecosystem (see Section 2.3.4 above).

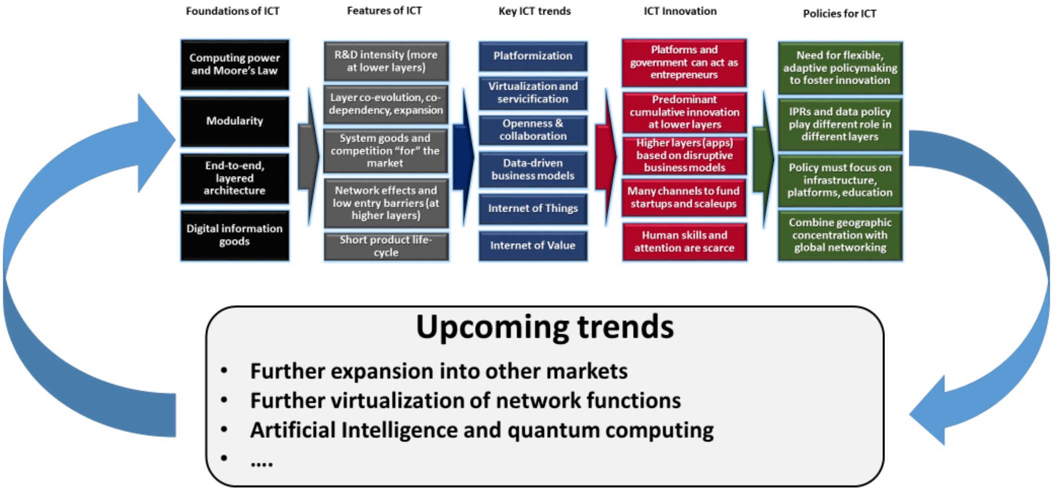
Finally, in terms of platform-building, governments are increasingly required to exploit both the virtues of **geographical proximity** as a driver of entrepreneurship ecosystems (Isenberg 2011); and the **globally interconnected nature** of specific areas of ICT. The combination of the main features of the ICT ecosystem, in this respect, leads to an almost counter-intuitive outcome: while on the one hand infrastructure is normally local, and services are more global, the higher layers of the ICT ecosystem have the ability to generate extremely local services (e.g. apps for specific cities, or even smaller communities); advances in technology and enhanced digitization now allow for "mass customization" (e.g. in Industrie 4.0); and at lower layers many technologies are being developed by globally interconnected poles of excellence, which pool the best competences available on the planet to generate products that are destined to equally global diffusion. This, in turn, leads to the need for an articulate mix of policies, including regional policies for entrepreneurship coupled with incentives for the internationalization of R&D and the interaction of EU ICT firms with digital global value chains and global innovation ecosystems (Fransman).

As a further complication, obviously the mapping of logical relations provided by figure 12 above is by no means final. A number of upcoming trends in the ICT ecosystem promise to change the current policy mix. The most likely trends to be expected are the following:

- *A significant expansion of the ICT ecosystem into other sectors of the economy*. This implies much more than using ICT in existing markets (e.g. banks launch their online apps to provide home banking services); it entails the platformization, dis-intermediation and re-intermediation of entire sectors of the economy, often with the entry of completely new players with disruptive, transformational business models. Sectors such as hotels, public transportation, banking and insurance, retail and food, healthcare, counselling, energy, street lighting and many others are already being permeated by new business models that exploit the potential of ICT, and in particular low barriers to entry, big data analytics, IoT applications and technologies, and artificial intelligence (see below).
- *Further virtualization and cost reductions.* In particular, software defined networks (SDNs) and Network Functions Virtualization (NFV) will lead to the virtualization ("softwarization") of network functions previously performed by hardware, leading to significant cost reductions and improvements in business agility. The cost reduction effect is very visible: WhatsApp was able to build a global messaging system that served 900M users with just 50 engineers, compared to the thousands of engineers that were needed for prior generations of messaging systems. This will further reduce entry barriers even in the physical layer, potentially removing structural constraints towards more pluralistic market structures, and leading to new policy challenges and opportunities. Cost reductions at a massive scale are also being realized by the transition from standalone CPUs to bundles of specialized chips known as systems-on-a-chip (e.g. energy-efficient ARM CPUs plus specialized chips for graphics processing, communications, power management, video processing, and more), which led to a ten-fold drop of the cost of basic computing systems (from about $100 to about $10). Products such as the Raspberry Pi Zero (a 1 GHz Linux computer available on the market for $5) represent the beginning of an era in which sophisticated, high capacity hardware will become ubiquitous and pervasive in our lives.
- *Artificial intelligence and robotics.* Applications of AI are currently focusing on machine learning techniques such as Deep Learning, now improving at unprecedented pace thanks to new algorithms, cheap parallel computation, and the widespread availability of large data sets. Importantly, many of the papers, data sets, and software tools related to deep learning have been open sourced. This has had a democratizing effect, allowing individuals and small organizations to build powerful applications. Software tools like Theano and TensorFlow, combined with cloud data centres for training, and inexpensive GPUs for deployment, allow small teams of engineers to build state-of-the-art AI systems. One of the first applications of deep learning released by a big tech company is the search function in Google Photos, which is shockingly smart. Soon significant upgrades are expected in the AI of all sorts of products, including: voice assistants, search engines, chat bots, 3D scanners, language translators, automobiles, drones, medical imaging systems, and much more. The development of quantum computing promises to further advance AI research and its already outstanding potential.

All these technological revolutions are likely to create authentic tectonic shifts in previously well-drawn boundaries between markets, and it is likely that the next revolution in the ICT ecosystem will be powered by a combination of these technological improvements and quantum leaps. Driverless cars, intelligent drones, automated voice assistants, wearables and human enhancement products are being powered by a combination of all these trends. And there seems to be little room for policy that does not use similar tools to oversee and monitor market developments in the attempt to protect the rights of market players and in particular end users. Figure 13 below shows the ongoing trends that seem likely to affect even the foundations of the ICT ecosystem, thus creating new, difficult to anticipate challenges for policymakers.

Figure 13 – How upcoming trends affect the future of policy in the ICT sector



Source: author's elaboration.

These observations and policy implications are further elaborated, with specific focus on the EU, in Section 3 below.

3 EU policies for ICT innovation: analysis and recommendations for future action

The previous sections have taken stock of existing research on the evolving dynamics of ICT innovation ad entrepreneurship. This section discusses the EU public policies that are most relevant for ICT innovation, identifying existing instruments for each of the layers of the ICT ecosystem, and then discussing more generally the innovation-friendliness of so-called "horizontal policies", as identified in Section 2.4 above. Finally, we propose a framework for future action in the field of ICT innovation. As a preliminary *caveat*, it must be observed that an in-depth analysis of all EU policies that are relevant for ICT innovation, or even an analysis focused only on ICT innovation instruments, would represent a herculean task, and would fall outside the reasonable scope of the present report. As a result, below each policy area is sketched in its essential characteristics and instruments, and proposals for reform are outlined for future discussion.

The chapter is organised as follows. Section 3.1 below discusses specific sectoral policies for each of the layers of the ICT ecosystem and proposes a number of concrete recommendations. Section 3.2 discusses innovation policy instruments at the EU level. Section 3.3 comments on the governance of innovation policy at the EU level. Section 3.4 discusses the people layer and the skills sets that are needed. Section 3.5 discusses the "innovation principle" and its use in support of better regulation policies at the EU level.

3.1 EU Policies for the layered ICT ecosystem

There are a remarkable number of policy initiatives at the EU level, some of which are dedicated to specific layers of the Internet ecosystem. Below, we distinguish between the physical layer (both broadband infrastructure and data networks), the logical layer (network neutrality policy), the application and the content layers, and the people layer (i.e. skills).

- *Existing policies for the physical layer revolve mostly around sector-specific regulation and public investment programmes*, which at the EU level include specific lines of actions contemplated by the Digital Agenda (e.g. the e-communications regulatory framework now reformed by the "Connected Continent" package); the Connecting Europe Facility; the earmarking of investment for broadband infrastructure in the structural funds; and the recently launched "Juncker plan" (EFSI), which mostly looks at infrastructure deployment.
    - *For what concerns sector-specific regulation*, the real issue today is to promote the deployment of ultra-high-speed broadband networks, which would bring Europe in line with current leaders in this field such as the U.S, Japan, and South Korea. Here, the problem is to revisit a regulatory framework that, while promoting the entry of several new players and relatively low prices for consumers, has proven unsuccessful in stimulating investment in new networks. Evidence from global practice in telecommunications regulation suggests that world leaders in ultra-fast networks (such as fibre-to-the-home) have not heavily regulated the deployment of broadband by imposing network sharing obligations on investors (Yoo 2014; Crandall 2014; Wallsten 2014). To the contrary, countries that have applied access regulation to new high-speed networks are suffering from sluggish deployment, which in turns damages end users and the economy as a whole (Yoo 2014). This is the case for most EU member states, and notably in Germany, Sweden and Italy, where the regulatory regime has so far not created the right incentives for incumbents to invest significantly in the deployment of optical fibre networks. Even more importantly, the absence of a timely, coordinated (if not centralized) pan-

European spectrum policy has made Europe a laggard in the deployment of 4G broadband.

  - *Apart from regulation, the EU relies also on additional policy instruments to promote infrastructure deployment, potentially encompassing telecommunications networks and data storage networks*. Part of the deployment of ICT R&I is carried out under the Connecting Europe Facility (CEF): however, the telecommunications part of CEF has a relatively thin budget of 1.14 billion euros, out of which 170 million euros are for Broadband networks, while 970 million euros are dedicated to Digital Service Infrastructures (DSIs) delivering networked cross-border services for citizens, businesses and public administrations[98]. CEF supports basic and re-usable digital services, known as building blocks, as well as more complex digital services. The building blocks can be combined with each other and integrated with the more complex services[99].
  - *More recently, the creation of the new European Fund for Strategic Investment (EFSI)* has led to the emergence of new channels through which ultra-fast broadband can potentially be deployed. It is too early to judge if the Juncker plan will be delivering results in terms of ultra-fast broadband deployment, and a lot seems to depend on the governance of the EFSI, including its dependence on cooperation with national authorities and private investors. There seems, already at this stage, a need to better target the EFSI project selection, as well as regional funds, in a way that enables fibre deployment, rather than less future-proof technologies. So far, the latest dashboard on EFSI shows that 10% of the funds will be dedicated to Digital Infrastructure[100].

- *The key EU policy affecting the logical layer of the ICT ecosystem is the rule on net neutrality* that was approved in 2015 with the so-called "Connected Continent" package. Under the new rule, the principle of net neutrality will for the first time be enshrined into EU law: users will be free to access the content of their choice, they will not be unfairly blocked or slowed down anymore and paid prioritisation will not be allowed. In parallel, Internet access providers will still be able to offer specialised services of higher quality, such as Internet TV and new innovative applications, so long as these services are not supplied at the expense of the quality of the open Internet. These rules will be a reality across all member states as soon as the text officially applies on 30 April 2016. However, the EU position on network neutrality is likely to remain controversial in the coming years, as implementation issues are still far from settled. Meanwhile, a number of member states have taken the initiative to regulate the issue, leading to notable inconsistencies across the EU. While countries like the Netherlands, Finland and Slovenia have enacted very strict neutrality rules, France has explicitly allowed traffic management practices, and the United Kingdom regards the possibility to charge quality of service fees as a much-needed opportunity for ISPs to monetise their investments in broadband networks. In this respect, convergence towards a balanced rule on network neutrality would be

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98 Supported projects are to contribute to improvements in the competitiveness of the European economy; promotion of the interconnection and interoperability of national, regional and local networks; access to such networks, thus supporting the development of a Digital Single Market.

99 Building blocks supported so far include: eIdentification; eSignature; eInvoicing; eDelivery; and Automated Translation. More complex digital services supported so far cover, among others, the areas of safer internet, access to reusable public sector information, cyber security, eHealth, and online dispute resolution. The next calls will open between September and October and will concern digital services in the field of eDelivery, eHealth, eInvoicing, Public Open Data, Safer Internet, eProcurement, eIdentification and eSignature, Online Dispute Resolution.

100 http://www.eib.org/efsi/

desirable, in order not to stifle the incentives to innovate both of ISPs and application developers. Such rule would need to allow at least some degree of reasonable network management and traffic differentiation, not least since the 5G technology is already incorporating traffic differentiation to optimise the performance of the network; but also since the increase in the number of applications that make use of the Internet is leading to a wide variance in the required latency of different services, and network optimisation would increasingly rely on traffic monitoring and management.

- *At the application layer, so-called "Internet platforms" are subject to a heated debate on possible regulatory measures*.[101] The European Commission has run a public consultation on online platforms, and is currently carrying out a sectoral competition inquiry on e-commerce. However, the platform neutrality debate evidently clashes with a simultaneous trend, i.e. the repeated calls for attributing greater responsibilities to digital platforms for the conduct of their users.[102] Such trend is visible in several initiatives especially in the EU, including plans to review and partly abandon the 'mere conduit' principle; proposals to strengthen intermediary liability and call on online intermediaries to cooperate in the enforcement of copyright and privacy laws (including the 'right to be forgotten'), as well as in curbing defamation, enhancing spam filtering, notifying of security breaches, cooperate in the fight against terrorism and provide other monitoring activities. The contradiction lies in the fact that some parts of EU law seem headed in the direction of imposing neutrality obligations on online intermediaries; whereas on the other hand, other legislation is requiring intermediaries to be more proactive in managing, prioritising and editing the content they pass on to the end users.
- *In addition, a multi-faceted category of "Internet services" has emerged over time, which is regulated by various instruments at the EU level.* As recently pointed out by Alexander De Streel and Pierre Larouche in a report for CERRE (2016), convergence and the blurring of boundaries between different layers of the ICT ecosystem has made the distinction between Internet services, e-communications services and audiovisual and media services obsolete. It would be very important for the EU regulatory framework to eliminate this "silo" approach and to establish a level playing field between players providing similar services with different technologies. Likewise, the current distinction between linear and non-linear services established by the Audiovisual Media Services Directive seems obsolete.
- *At the content layer*, the most urgent reform at the EU level is that of *copyright legislation*. There, the original design of legislation aimed at strengthening right-holders' protection as well as legitimising the use of technological protection measures has largely failed, especially in those legal systems that have decided to enact a specified, rigid list of exceptions, and focused their enforcement on judicial redress and injunctions[103]. Even more importantly, the emergence of user-generated content and the data-driven economy has made copyright exceptions such as the one for text and data mining uses a must for all legal systems. The future copyright

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[101] One of the first to use the expression 'platform neutrality' was the French National Digital Council (*Conseil National du Numérique*), which published a detailed report on this same concept in June 2014, following a 2013 request from the Ministry of the Economy and Digital Affairs as well as the Secretary of State on Digital Affairs. See Conseil National du Numérique (2014), "Platform Neutrality: Building an open and sustainable digital environment", Opinion No. 2014-2, of the French Digital Council, Paris (www.cnnumerique.fr/wp-content/uploads/2014/06/PlatformNeutrality_VA.pdf).

[102] "Europe enlists Internet giants in fight against online extremism", by C. Spillman, 9 October 2014 (http://phys.org/news/2014-10-eu-internet-giants-online-extremism_1.html#inlRlv).

[103] See Renda, A. *et al*. (2015), "Study on the implementation, application and effects of Directive 2001/29/EC on the harmonisation of certain aspects of copyright and related rights in the information society (InfoSoc) Directive and of its related instruments", Study for the European Parliamentary Research Service.

regime should primarily look at the free circulation of content and information throughout the Single Market, the single most important precondition for the promotion of innovation in the EU: having to negotiate copyright licenses country per country is not a very attractive perspective for a would-be innovator in the media industry. That said, there should be also room for the promotion of specific content wherever market forces do not generate enough of that content (e.g. for the purposes of promoting local or regional culture).

In summary, **key recommendations on sector-specific regulation include the following**:

- ***Prioritize the deployment of a robust, resilient ultra-fast broadband network throughout the territory of the European Union***, using scalable technologies such as optical fibre networks, rather than upgrading (for the last time) copper networks through vectoring and G-Fast technologies.
- ***Devote more resources (e.g., from regional funds) for the development of the digital infrastructure***, including both fixed and wireless networks and cloud storage facilities.
- ***Strengthen the coordination of spectrum policy throughout the EU28***, and coordinate (or centralize) spectrum award procedures in a way that maximizes benefits for the end users (rather than revenues for government).
- ***Boost international cooperation on the 5G standard development***, an area in which Europe seems to have taken the lead until recently, and in which cooperation with China seems to face important obstacles.
- ***Streamline the regulatory framework for digital services***, by abandoning the current silo approach and implementing symmetric, principles-based regulation, rather than asymmetric access regulation.
- ***Avoid strict regulation of platforms such as platform neutrality*** (subject to sound monitoring by competition authorities), *and* ***engage with online intermediaries*** *by developing principles of responsible cooperation in the monitoring and enforcement of specific legal rules, including counter-terrorism, copyright, privacy.*
- ***Award strongest priority to the achievement of a fully integrated single market for content and applications.*** This does not mean that all forms of territorial discrimination should be abolished (as in some cases they can be welfare enhancing). Rather, it would imply a single pan-European copyright title, and a flexible regime for exceptions that would unleash the power of new uses of data (in particular, text and data mining).

3.2 ICT Innovation policy instruments: a focus on data-driven and demand-side policy instruments

The natural consequence of our analysis in Section 2 above is that ICT innovation policy should, for the time being, depart from innovation policy implemented in other fields due to the existing differences between the ICT ecosystem and the remainder of the economy (so-called "brick and mortar" sectors). This, of course, does not mean that traditional, R&D-focused innovation policy instruments must be abandoned in the ICT sector. Rather, they will be more appropriate for the physical and logical layers of the ICT ecosystem, and their relevance will be increasingly worth a rethink as virtualization and platformization conquer also those layers, leading to a plethora of new, often open, business models and to a drastic reduction of entry barriers and computing and data storage costs. Accordingly, the reader should take the suggestions included in the next pages as not carved in stone, but rather as the expression of a peculiarity that the ICT sector is currently exhibiting with respect to other sectors, and which might become less or more prominent over time (more prominent due to increased virtualization of the ICT ecosystem, less prominent as ICT conquers many other sectors of the economy and leads to a massive re-engineering of business models).

As things stand, **the ICT sector is emerging from the scholarly literature as especially innovative**, both in terms of share of firms (among ICT firms) performing R&D and in terms of firms producing technological (product or process innovation) or generic (product or process or organizational or marketing) innovation. In particular, **ICT firms tend to have in-house R&D capability and introduce new-to-the-market product or process innovations**. In the development of a strategy for ICT innovation at the EU level, this report has adopted a "layered architecture" perspective, by discussing the various peculiarities of different layers of the ICT ecosystem. *Key barriers to ICT innovation in existing European companies covered by the literature include lack of finance, lack of qualified personnel and uncertainty over demand and over the regulatory treatment of data*. Public funding seems efficient for the support of start-ups and new companies, but is too focused on R&D and not enough on the needs of new business models. At higher layers, the relative under-development of venture capital and crowdfunding in comparison to the United States seems likely to hinder the birth and growth of new companies with disruptive, transformational business models.

In this respect, the following recommendations can be formulated:

- ***The role of public policy instruments for the promotion of public and private R&D seems to be most relevant for the physical (and partly the logical) layer*** of the ICT ecosystem, which include ICT equipment and components, the underlying telecommunications infrastructure and also the data storage and transmission architecture, encompassing emerging technologies such as i.a. traffic management, acceleration and content delivery networks. This is the layer in which European Companies seems to be also most specialised, so the added value of additional innovation policy instruments might not be as high as for higher layers.[104] In this layer, instruments such as R&D tax deductions and public support for private R&D investment, university-industry technology transfer and the EU Unitary Patent should be made as effective and accessible as possible.
- ***At higher layers of the ICT ecosystem, more agile instruments and innovative demand-side innovation policy are likely to be particularly effective.*** Existing initiatives on access to risk finance (e.g. InnovFin), the EFSI SME Window, the 'Innovation in SMEs' and actions launched within the Entrepreneurship 2020 Action Plan (e.g. Startup Europe Leaders Club, the Startup Europe Partnership, the Startup Europe Accelerators Assembly, the Startup Europe Crowd-funding Network, the Startup Europe Web Investors Forum, and the Startup Europe Web Talent) are all relevant, and are flanked by a number of dedicated EU programmes and initiatives, such as 'Erasmus for Young Entrepreneurs' and the 'Small Business Act for Europe', which include measures to facilitate young entrepreneurs' access to finance as well as to integrate entrepreneurship into secondary school curricula. Further direct financial support at EU level also comes through the European Progress Microfinance Facility, which enables young entrepreneurs to apply for micro-loans of up to EUR 25,000. These initiatives should be coupled with new instruments that take advantage of the increasingly low startup costs observed at the higher layer of the ICT ecosystem, by specifying the societal challenge that entrepreneurs are called to address. In this respect, the following instruments are potentially suited for the application layer of the ICT ecosystem:

[104] As observed by Fransman (2010) and Veugelers and Cincera (2010) in their research on the so-called relative technological advantage (RTA), Europe is more specialized than the US in what these authors call "Layer I" technologies, i.e. those related to telecommunications networks, where the percentage of young companies is only 20%. Europe's weakness is indeed in so-called Layer III, which counted in 2010 only 14 EU companies against 50 in the US, and an overwhelming majority of "Yollies", i.e. young, innovative companies. Similar findings were also reached more recently in the PREDICT project run by the JRC.

- *Prizes and challenges*. For example, in the US a *Challenges and Prizes Community of Practice* was created, which has over 600 members. Examples of successful prizes are numerous[105]. NASA is seeking teams to [build small spacecraft]() that can carry out operations near the moon and in deep space. Prizes are at most worth only a few million dollars, and the competition energizes non-governmental researchers and entrepreneurs to tackle socially significant problems. The Defense Advanced Research Project Agency (DARPA) launched its first "Grand Challenge" in 2004. Whoever could design a driverless car that completed a desert course fastest would win one million dollars[106]. Since then, there have been more DARPA-sponsored competitions involving humanoid robots and radio communications, among other fields. Several Federal agencies have discovered that prizes allow them to: (i) Pay only for success and establish an ambitious goal without having to predict which team or approach is most likely to succeed; (ii) Reach beyond the "usual suspects" to increase the number of citizen solvers and entrepreneurs tackling a problem; (iii) Bring out-of-discipline perspectives to bear; (iv) Increase cost-effectiveness to maximize the return on taxpayer money; (v) Inspire risk-taking by offering a level playing field through credible rules and robust judging mechanisms.
- ***Public-private demand-side instruments***. Again, the U.S. experience can be useful in this respect. For example, GE, the NFL, Under Armor and NIST are using a challenge to advance the development of technologies that can detect early stage mild traumatic brain injuries and improve brain protection. Foundations can sponsor fellowships for prize designers in the public sector to encourage the development and implementation of ambitious prizes in areas of national importance. Foundations could also sponsor workshops that bring together companies, university researchers, non-profits, and government agencies to identify potential high-impact incentive prizes. Universities could establish courses and online material to help students and mid-career professionals learn to design effective prizes and challenges. Researchers can conduct empirical research on incentive prizes and other market-shaping techniques (e.g. Advance Market Commitments, milestone payments) to increase the understanding of how and under what circumstances these approaches can best be used to accelerate progress on important problems.
- ***Social Impact Bonds.*** These are relatively new funding mechanisms known also as "social innovation financing" or "pay for success". They offer governments a risk-free way of pursuing creative social programs that may take years to yield results. Usually, governments decide what problems they want to address and then enter a contractual agreement with an intermediary (or bond-issuing organization) that is responsible for raising capital from independent investors including banks, foundations, and individuals, and for hiring and managing non-profit service providers. If the project achieves its stated objectives, the government repays the investors with returns based on the savings the government accrues as a result of the program's success.

[105] See i.a. Audretsch, D. and T. Aldridge (2014), The Development of US Policies directed at stimulating Innovation and Entrepreneurship. Editors: Itzhak Goldberg, Federico Biagi, and Paul Desruelle.

[106] No car managed to cross the finish line that day and no one took home the prize money. But the challenge got brilliant minds focused on driverless technology. A decade later, Google is close to mastering the technology and most major automakers are working on their own driverless prototypes. Another well-known example of a demonstration project is the Ansari X Prize, which was awarded in 2004. The Ansari X Prize was awarded to aerospace designer Burt Rutan and financier Paul Allen for being the first private team to "build and launch a spacecraft capable of carrying three people to 100 kilometres above the earth's surface, twice within two weeks."

(Taxpayers also receive a portion of the budget gains in the form of freed-up public resources, though the investors may need to be fully paid first.) A neutral evaluator, agreed on by both parties, is hired to measure the outcomes and resolve any disputes that arise.

- ***Most importantly, ICT innovation needs data***. EU institutions can spur innovation at all layers of the ICT ecosystem by providing access to databases held by government, rather than by offering financial support. Access to datasets cannot be limited to EU-funded research; public administrations at the EU and national level hold an enormous amount of data, which could unleash all sorts of innovative business models. Many governments, from the United States to New Zealand, consider data-driven innovation to be a key source of growth for the future (OECD 2014). For example, in the United States the Obama administration has coupled its efforts towards open access and government with more recent initiatives in the fields of citizen science and crowdsourcing: following a tradition that in some sectors dates back to the 1970s, the United States government has today reached new levels of activism in open science and open data initiatives, which rely on a set of presidential directives and on innovative initiatives such as the "datapaloozas" organized by U.S. presidential innovation fellows[107]. At the EU level, the European Commission recently stressed the importance of openness as a key principle for the European Research Area and for the EU innovation policy: in June 2015, EU Commissioner for research and innovation Carlos Moedas highlighted the importance of open science and open innovation and announced the creation of "a new path for European research and innovation policy", fit for an open, digital and global environment.

There is no lack of awareness at the EU level, at least in the European Commission, of the importance of the data economy and data-driven innovation. The Commission announced a number of initiatives aimed at seizing the related opportunities and compete globally in the data economy, such as "Lighthouse" data initiatives capable of improving competitiveness, quality of public services and citizen's life; Developing enabling technologies, underlying infrastructures and skills, particularly to the benefit of SMEs; Extensively sharing, use and developing public data resources and research data infrastructures; Focusing public R&I on technological, legal and other bottlenecks; Making sure that the relevant legal framework and the policies are data-friendly; Accelerating the digitisation of public administration and services to increase their efficiency; and use of public procurement to bring the results of data technologies to the market. The envisaged actions should result in accelerated innovation, productivity growth, and increased competitiveness in data across the whole economy. Also, it is worth reminding that the Council of the EU adopted in May 2015 conclusions on open, data-intensive and networked research as a driver for faster and wider innovation, which calls i.a. on the Commission to present a detailed action plan to accelerate the transition towards a data-driven economy in Europe by the end of 2015. In June 2015, Commissioner Oettinger also committed to work towards on a European Open Science Agenda with all concerned stakeholders and Member States[108]; and Commissioner Moedas has also made openness its flagship commitment. Against this background, one important obstacle is likely to be represented by the often-denounced rigidity of the EU privacy legislation against the flexibility needed for big data applications (see Renda 2015). What emerged so far is that the EU privacy legislation, while in principle protecting end users' privacy more effectively, might end up proving too rigid to allow for welfare-enhancing cloud offerings. Also the recent political agreement reached on the General Data Protection Regulation in December 2015 has been accompanied by

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[107] See Renda (forthcoming), "Open science, open innovation and better regulation: what lessons can the EU draw from the U.S.?", forthcoming report for the European Commission, DG Research and Innovation.

[108] https://ec.europa.eu/commission/2014-2019/oettinger/blog/open-science-knowledge-and-data-driven-economy_en

complaints from both sides of the Atlantic on the possible rigidity of the rules to be adopted[109].

3.3 Simplifying governance and access to innovation policy instruments

The governance of innovation policy has always been a key problem at the EU level, especially in the past two decades, as innovation has started to play an increasingly central role in the EU agenda (see Granieri and Renda 2011). Today, *there seems to be an excessive level of complexity in the governance of innovation policy at the EU level.* This is not exclusive to ICT innovation, but it can hamper the ICT ecosystem even more due to the latter's fast product cycles, and the prevalence of very small if not individual ventures especially at the higher layers.

A number of initiatives adopted at the EU level look at the creation or promotion of *ad hoc* platforms in specific sectors, or sub-sectors of the economy. In many cases, these are research-oriented platforms, aimed at tackling long-term societal challenges by stimulating and catalysing research towards specific fields of science (e.g. the study of the brain; the future of food). These types of platforms correspond more closely to the ones that Mazzucato (2013) considers to be important sources of innovation through public entrepreneurship, since they end up triggering the development of technical solutions that large IT companies are then able to integrate in their system goods.

At the EU level, however, a number of other platforms have been created, which appear more industry-based, or innovation-oriented. They include the Leadership in Enabling and Industrial Technologies (LEIT), which supports the development of technologies underpinning innovation across a range of sectors, including ICT and space, and pays particular attention to the development and application of KETs, stressing their importance for growth and jobs[110]; contractual public-private-partnerships such as the Factories of the Future (FoF), and which is supposed to attract private investment in the order of 5 to 10 times the level of public funding in addition to the in-kind contribution in the PPP projects under Horizon 2020[111]; and the *Future Internet PPP (FI-PPP),* launched already in 2011, which focuses on developing innovative Future Internet technologies for smart infrastructures, business processes, services and applications. Last but not least, the European Institute of Innovation and Technology (EIT) has launched a number of Knowledge and Innovation Communities (KICs).

The ICT-related platform of the EIT has recently been transformed into EIT Digital, and developed a new innovation and Entrepreneurship strategy driven by eight Innovation Action Lines (see figure 6 below). In each Action Line, the most promising research results, disruptive technologies and business strategies are selected and packaged into innovation activities and startups, with the ambition to drive them to succeed in world markets and become European success stories. Sourcing is through Calls for Activities, whereas Startups are sourced either through the Idea Challenge, the largest European startup contest in information technology, or through a direct application to the Business

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[109] Examples: https://www.datainnovation.org/2014/10/proposed-eu-data-protection-regulations-could-impede-medical-research/. http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=1078&PortalId=0&TabId=353. http://www.usatoday.com/story/life/web-to-watch/tech-gaming/2015/12/14/eu-european-union-privacy-directive-google-facebook/77314554/. http://www.wsj.com/articles/europes-privacy-fortress-1450398921?mod=ST1

[110] With a proposed combined earmarked budget of EUR 6.663 billion, KETs represent a major component of the LEIT strand. Recently, there have been efforts to develop synergies with the ESIF (European Structural and Investment Funds for 2014-2020) to improve funding for the KETs.

[111] In Horizon 2020 the EU is committed for the indicative provision of about 6.7 billion euro to the contractual PPPs (FoF, EeB, EGVI, SPIRE, 5G, HPC, Robotics, Big Data and Photonics).

Development Accelerator (BDA). The BDA has a central role in the success of the Innovation funnel, as it coaches the entire funnel (Innovation Activities & Startups) with a focus on access to market - that is, customer adoption. Access to Finance is a team fully committed to helping BDA startups raise funds via a pan-European investor network.

Figure 14 – EIT Digital: Innovation and entrepreneurship strategy

Source: EIT Digital.

Possible improvements, not exclusive to ICT, would include the following:

- ***Consolidate existing research and innovation platforms*** by offering innovators and entrepreneurs one-stop-shops where to get involved with prizes, challenges and obtain vouchers and other form of financing to generate new ideas.
- ***Empower a limited number of organizations in the management of ICT research and innovation projects*****.** These could be, following Granieri and Renda (2011), the EIT for multi-stakeholder platforms, and the EIB for infrastructure-related projects. They could be coordinated by the European Commission or by the newborn European Innovation Council.
- ***Rely on these new organizations to establish technology roadmaps related to specific societal challenges.*** Such roadmaps could become essential for policymakers in shaping adaptive rules (see below, Section 3.4).
- ***Organize the provision of support around these platforms***, by establishing links between research, innovation, entrepreneurs and societal challenges for each of the platforms identified.
- ***Improve the governance of individual projects*** by strengthening the monitoring and evaluation of results.
- ***Expand the innovation radar*** to follow projects in the commercianlization phase, and establish their overall impact and market success. This is even more important since a recent study found that the EU Framework Programmes have so far not contributed very significantly to radical innovations (JIIP, 2015)***.***
- Finally, **Institutional capacity at the regional and local level seems to be still lacking in many regions**, which creates a major weakness in one of the most crucial actors of the innovation system, i.e. governments. The problem is so heavily felt that some commentators and also the Committee of the Regions have endorsed the proposal to create a new Flagship Initiative dedicated to the strengthening of institutional capacity within the upcoming review of Europe 2020.

3.4 The people layer: eSkills and entrepreneurship

Important efforts must be made to improve the availability of eSkills, but the effectiveness of current policies, including the ones included in the Entrepreneurship 2020 Action Plan and the ones managed under the Digital Agenda, could probably be improved through enhanced coordination with existing initiatives (e.g. EIPs, KICs) and research projects funded under Horizon 2020. To be sure, Europe needs a major reflection on the future of jobs, which capitalises on the first steps made with the "Grand Coalition". Education is a fundamental driver of ICT uptake and competitiveness, and must be broadly intended to include a high-quality university system, widespread e-skills and digital literacy among both firms (in particular, SMEs) and citizens.

Importantly, the skills needed are not a single set, but rather a combination of notions, capabilities and attitudes that can help fill all the gaps currently existing in the EU job market, at various layers of the ICT ecosystem. The recommended skill set includes[112]:

- ***Coding skills***, possibly to be introduced as early as possible in school years;
- ***Creativity skills***, to be stimulated through dedicated programmes during primary, secondary and tertiary education;
- ***Science Technology Engineering and Math (STEM) education,*** in order to enable the application of ICT to a wide variety of sectors, from health care to energy, manufacturing, finance, etc.;
- ***Cross-disciplinary skills***, which require abandoning textbook-style education to forge students with enough basic knowledge and culture and advanced notions to be able to handle more than one discipline at once;
- ***Managerial skills***, which include basic entrepreneurship skills such as the ability to conceive of a business plan, or to define a start-up and scale-up strategy for the first years of a new venture;
- ***Financial and accounting education***, in order to empower individual would-be entrepreneurs in their relationship with financial intermediaries.
- ***Leadership and team-working skills*.** For example, the e-Skills Manifesto 2014 by European Schoolnet introduces the INSEAD skills pyramid to divide e-skills into literacy and basic skills at the bottom, occupational skills in the middle and global knowledge economy talents at the top. The manifesto also states that not only programming skills but e-leadership skills – that is, the combination of ICT skills and leadership skills – will be high in demand in the future.

All these skills must be developed and constantly updated. The acceleration of the pace of technological progress will increasingly require that beyond the work-life balance, also the work-train balance of individuals is adequately taken care of[113]. Lifelong learning then must be rethought to mirror the need for a constant evolution and update of the skills available in the labour force. Possible policy actors to be involved include schools (including, most importantly, re-training and empowering teachers), government administrations, and businesses themselves.

[112] See, for a more detailed description of coding skills, creativity skills, cross disciplinary skills, managerial skills, entrepreneurial skills, https://ec.europa.eu/jrc/en/research-topic/learning-and-skills.

[113] In this spirit, the e-Skills Manifesto 2014 by European Schoolnet argues that the 'educate then work model' is becoming less relevant as the turnover of skills accelerates, markets become more volatile and the linear one-way path from education followed by life-long work will have to be exchanged for an increasingly two-way interaction between learning and working.

3.5 Horizontal policies: towards simpler, adaptive regulation

As already mentioned in this report, what matters for innovation is not exclusively innovation policy, especially at the EU level. Evidence of the need for simplifying existing instruments and funding channels, and of eliminating needlessly complicated and burdensome legislation (especially for SMEs) is widespread in the EU. For example, **regulation that creates "red tape" or administrative burdens for businesses can, under certain circumstances, deprive entrepreneurs of resources and time** that would otherwise be devoted to more productive activities. These tendencies work to the disadvantage of the innovativeness of SMEs, who lack the resources to come up to strict legal requirements. Moreover, several contributions in the literature have analysed the impact of entry requirements and regulatory compliance burdens on entrepreneurship: these include, most notably, the ease of doing business indicators and the ease of entrepreneurship index developed by The Conference Board[114].

Key aspects of regulation that affect innovation are stringency, time, flexibility and certainty (Pelkmans and Renda 2014). *Stringency* relates to how difficult and costly it is for firms to comply with new regulatory requirements using existing ideas, technologies, processes and business models. The amount of *time* that a regulation gives to the targeted stakeholders for compliance with the regulatory requirements is essential to stimulate innovation, but timing is a double-edged sword: too little time might discourage innovation and determine an unsustainable increase of compliance burdens, too much time might crystallize innovation efforts due to the lack of pressure to meet the requirements[115]. Flexible, performance- or outcome-based regulation stimulates innovation more than purely prescriptive regulation, provided that it is coupled with adequate monitoring and enforcement (see *i.a.* Coglianese 2015). And also uncertainty has been found to act as a driver and also as an inhibitor of innovation depending on the circumstances[116].

Against this background, **a debate has emerged at the EU level on the need to incorporate an "innovation principle"** in EU policymaking. Emphasis on this need has been so strong over the past months that the CEOs of some of the largest EU-headquartered companies have decided to send a letter to advocate such a change in the European Commission's approach to policy[117]. The exact content of an innovation principle to policymaking is however not fully defined yet: if anything such a principle

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[114] Contributions in the literature have demonstrated that start-up costs are considerably higher in more regulated economies (Fonseca et al. 2001, 2007), and that regulatory reform results in higher rates of market entry by new firms (Klapper and Love, 2011). A recent paper by Braunerhjelm and Eklund (2013) based on World Bank data from 118 countries for a period of six years finds that the entry rate of new firms is significantly reduced by the tax administrative burden, and that this effect is unrelated to general taxes on corporate profits and is robust to the inclusion of several important control variables.

[115] BERR (2008) and Centre for International Economics (2006) discuss specifically the timing of standardization: here too, the message is that standardization should not occur too early, and also not too late to stimulate and encourage innovation. An early standard can kill alternatives (e.g. the GSM standard for mobile communications), creating more intra-standard competition. If the standard is imposed too early, this can generate an undesirable lock-in effect, which leaves society trapped into a suboptimal standard. Similarly, the selection of a rigid, non-scalable standard can inhibit both incremental and disruptive innovation, and as such is highly damaging to social welfare and progress.

[116] Ashford et al. (1985) claim that "although excessive regulatory uncertainty may cause industry inaction on the part of the industry too much certainty will stimulate only minimum compliance technology. Similarly too frequent change of regulatory requirements may frustrate technological development." More generally, it is fair to state that whenever innovation requires large investment in R&D, the absence of reasonable stability or certainty in the regulatory framework can significantly hinder innovation. Our case study of competition rules applied in the e-communications sector below can contribute to shedding some light on this aspect of uncertainty.

[117] http://www.riskforum.eu/uploads/2/5/7/1/25710097/innovation_principle_letter_4_nov.pdf

would help policymakers focus on innovation when drafting legal rules, although available guidance on how to achieve this result is not sufficient to enable fully enlightened choices.

Based on our findings in the previous sections, the following recommendations on horizontal policies can be formulated:

- **A functioning internal market is the single most important reform for EU ICT innovation**. The fragmentation of innovation performance is also a mirror image of the persisting absence of a complete internal market for many of the most innovative sectors, including, most notably, the services sector. Currently, financial markets are fragmented and the level of regulation (e.g., taxation) varies across countries. While a degree of diversity is required, total lack of harmonisation prevents cross-border venture capital investment and the creation of funds in areas where financing for innovation is needed. Furthermore, the obstacles to individuals' mobility (in terms of taxation, portability of pension benefits, etc.) prevent professionals and business angels from reaching new markets and establishing their business where opportunities are still unexploited. Finally, as already recalled, there is no such thing yet as a European single market for e-communications and this also hampers the creation of a pan-European world-class e-infrastructure.
- **Competition policy should be revisited to mirror the peculiar dynamics of the ICT ecosystem**. This is particularly true for what concerns rules on abuse of dominance, but also more generally for all those instruments and criteria used in antitrust law, which mirror traditional neoclassical economics, from market definition to the use of market shares, up to the identification of suitable remedies.
- **Data protection rules and IPR policies** should be made, to the extent possible, simple and compatible with new, data-driven business models.
- **Better regulation tools should focus on long-term innovation impacts, including in the ICT sector.** However, such impacts should be intended as means, not ends, as innovation is not a goal *per se*, but rather an important precondition of sustainable development. The "innovation principle", in other words, should be translated into an "innovation for whom?" question, or a question related to the purpose of innovation and policies designed to promote it[118].
- **Policymaking should avoid incumbency biases and accommodate innovative business models** that make use of big data and more generally transformational ICT applications. Possible ways to make policy more flexible and adaptive include: (i) the use of regulatory sandboxes and other experimental approaches to allow for the ongoing monitoring of the market and social impacts of innovative techniques; (ii) the incorporation of technology roadmaps and the opinion of multi-stakeholder platforms as input into the policymaking process, to ensure that innovative, welfare-enhancing technologies are adequately represented in policy processes and outcomes; (iii) the ongoing monitoring of policy impacts, including through open government techniques.

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[118] The importance of accounting for innovation impacts of all legal rules is increasingly acknowledged among scholars. For example, in a recent paper Battaglia, Larouche and Negrinotti even question whether the EU can be said to have an innovation policy, claiming that "It is remarkable that, in major policy initiatives where innovation plays a central role, such as the Lisbon Agenda and its successor Europe 2020, little attention is paid to those areas of the law which influence the incentives to innovate, namely competition law, intellectual property law, sector-specific regulation (especially electronic communications regulation) and standardization". The authors observe, in particular, the inconsistency between EU innovation policy and the underlying rationale of European Commission decisions in the pharmaceutical sector, which seem to dance to a completely different drummer. More generally, competition policy should be handled by the European Commission in a way that is innovation-compatible, and should therefore place a greater emphasis on long-term dynamic efficiency rather than short-term static efficiency effects of market outcomes.

4 Conclusion - Policy implications

The report maps interrelations between foundations, features and trends of the ICT ecosystem; and their consequences for ICT innovation and for ICT policies. Analysing these interactions and interrelations, leads to the formulation of a number of policy recommendations.

In the physical layer, EU policy should prioritize the deployment of a robust, resilient ultra-fast broadband network throughout the European Union. Scalable technologies such as optical fibre networks could be used and more resources could be devoted to the development of the digital infrastructure, including both fixed and wireless networks and cloud storage facilities. This would be helped by a more coordinated spectrum policy throughout the EU28, and effective EU involvement in the 5G standard development.

In addition, it is important that the regulatory framework for digital services be streamlined, by abandoning the current silo approach and implementing symmetric, principles-based regulation, rather than asymmetric access regulation. Overall, platform regulation such as platform neutrality should be avoided as it contrasts starkly with the Internet's current evolution. Instead, policymakers should engage with online intermediaries by developing principles of responsible cooperation in the monitoring and enforcement of specific legal rules, including counter-terrorism, copyright, and privacy.

In terms of innovation policy, the role of instruments for the promotion of public and private R&D seems to be most relevant for the physical (and partly the logical) layer of the ICT ecosystem. At higher layers of the ICT ecosystem, more agile instruments and innovative demand-side innovation policy are likely to be particularly effective. Instruments such as prizes and challenges, and pay-for-success schemes are potentially suited for the application layer. And policies should seek to facilitate data-driven innovation.

It is important that the governance of innovation policy should be improved in order to create an environment that is more directly conducive to ICT innovation. At the moment, there seems to be an excessive level of complexity in the governance of innovation policy at the EU level. This can hamper the ICT ecosystem even more than other parts of the economy due to the former's fast product cycles, and the prevalence of very small ventures and even ventures with a single entrepreneur, especially at the higher layers. Possible improvements, not exclusive to ICT, would include the consolidation of existing research and innovation platforms; and the identification of a limited number of organizations in the management of ICT research and innovation projects, which could then develop technology roadmaps related to specific societal challenges. Most of these actions would become more effective if they were coupled with a strengthening of institutional capacity at the regional and local level.

Greater efforts must also be made to improve the availability of skills. Europe needs a major reflection on the future of jobs. Education is a fundamental driver of ICT uptake and competitiveness, and must include a high-quality university system, widespread e-skills and digital literacy among both firms (in particular, SMEs) and citizens. Importantly, the skills needed are not a single set, but rather a combination of notions, capabilities and attitudes that can help fill all the current gaps in the EU job market, at the various layers of the ICT ecosystem. The recommended skill set includes, i.a. coding skills; creativity skills; Science Technology Engineering and Maths (STEM) education; cross-disciplinary skills; managerial skills; financial and accounting education; and leadership and team-working skills. All these skills must be developed and constantly updated.

Finally, what matters for innovation is not exclusively innovation policy, especially at the EU level. There is considerable evidence in the EU that existing instruments and funding channels need to be simplified, and complicated and burdensome legislation eliminated (especially for SMEs). Apart from the need to simplify regulation by removing unnecessary red tape, it is vital that regulation be made innovation-friendly. This also applies to important horizontal policy areas such as competition policy, data protection and copyright policy. In addition, policymaking should avoid bias in favour of incumbents and accommodate innovative business models that make use of big data and more generally transformational ICT applications. Possible ways to make policy more flexible and adaptive include:

(i) the use of regulatory sandboxes and other experimental approaches to allow ongoing monitoring of the market and social impacts of innovative techniques;

(ii) the consideration of technology roadmaps and the opinion of multi-stakeholder platforms in the policymaking process, to ensure that innovative, welfare-enhancing technologies are adequately represented in policy processes and outcomes;

(iii) the ongoing monitoring of policy impacts, using, for example, open government techniques.

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