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# **Innovative Competence, How does the Republic of Ireland Fare and does it Matter?**

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# **Innovative Competence, How does the Republic of Ireland fare and does it Matter?\***

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## **ABSTRACT**

Economic growth is central to improved living standards, in turn; innovation and the spread of economically useful knowledge are essential inputs for sustainable productivity based growth. This paper discusses the idea of innovative competence, examines whether it matters for long-run prosperity, considers the National Innovation System (NIS) and innovative competence of the Republic of Ireland, and proposes some reforms. Inherent characteristics of knowledge imply that a self-regulating market will invest less than the socially optimal amount in knowledge generating activities. This suggests a rationale for public investments in Research and Development (R&D) as well as in other knowledge generating and diffusing activities. However, it is unwise to conflate innovation with R&D or to treat innovation as a linear process. Technological change does not occur in a perfectly linear sequence, but through feedback loops within the economic and social systems. Even so, it is notable that the Republic of Ireland invests significantly less in R&D than other small open economies in Western Europe. In addition, the Republic invests less per pupil in third level education and has one of the weaker broadband networks in Western Europe. These are concerns given the negative long-term implications for innovative competence and productivity led growth. In spite of these concerns the Republic generally performs well across a range of innovation indicators compared to the majority of other EU countries. This suggests the Republic has a reasonably robust NIS upon which to build.

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# **Innovative Competence, How does the Republic of Ireland fare and does it Matter?**

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## **1 . INTRODUCTION**

The world is changing and the Republic of Ireland's industrial and enterprise strategies will have to evolve if we wish for the Republic's economy to thrive in this new reality. One constructive step that the Irish government can take is to renew its focus on innovation policy with a view to building a world class innovation system. Technological change and innovation have long been of fundamental interest to economists because of the belief that sustainable long-run economic growth and development along with improvements in quality of life depend on the ability of the economy to produce and diffuse new innovations.<sup>1</sup> What do we mean by innovation? Innovations are usually combinations of two or more existing ideas that manifest as new products or services, new processes, new markets, new sources of supply or even new organisations.

Innovation policy can loosely be interpreted as the set of policies that impact in any way on innovation. However, innovation policy is usually interpreted more narrowly as the set of policies created with the intent to affect innovation (Edquist, 2004). The concept of 'innovation' should not be conflated with that of 'invention'. Economically relevant innovation refers not just to the creation of a new technology or the first application of a new idea or process, but also to technological diffusion and to the use of that innovation in new contexts and by different actors within the economy (Fagerberg, 2015). Indeed for most countries technology diffusion may be a more significant driver of growth than new-to-the-world inventions.

Useful ideas, unlike labour, land and capital, are non-rivalrous in use and explain economic growth by giving rise to economies of scale. The greater the spread or diffusion of economically useful ideas the greater the economy-wide benefits (McDonnell, 2015). The OECD points to the need for countries to increasingly move away from bricks and mortar

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<sup>1</sup> Economic growth can come from the accumulation of factor inputs (labour and capital) or from productivity gains arising from technological progress and innovation, scale economies, and efficiency of factor use.

investments and toward accumulating intangible knowledge-based capital (OECD, 2013). Yet inherent characteristics of knowledge mean that a self-regulating market will invest less than the socially optimal amount in knowledge generating activities. This provides a rationale for public investments in Research and Development (R&D) and other knowledge generating and diffusing activities. Economic theory is less clear on the optimal level of public and private investment in R&D and other knowledge generating activities.

Rates of technological change and adoption vary greatly across countries, regions, industries, firms, households and individuals. The concept of 'National Systems of Innovation' (NSI) was developed in the late 1980s and early 1990s to explain why different economies and societies differ in their rates of innovation (Edquist, 2004). According to David Jacobson (2013): *"the interacting institutions at the heart of a system of innovation include the educational, cultural, social and economic, as well as the policy and political factors that influence how creative, entrepreneurial and change-oriented people are, in the social formation of which the system of innovation is part."*

The government will always be the NSI's key actor. Governments can use fiscal and other policies to address systemic market failures related to the underproduction and slow diffusion of knowledge and innovation. It can also support enterprises in the development of their own innovative and absorptive capacities. Finally, the government plays a key role in the development of innovation inputs most importantly through its funding of R&D, education, and knowledge infrastructure. The Irish government's *Innovation 2020* strategy commits to a research intensity target of 2% of GDP with one quarter of this coming from public investment in R&D.

While it is unwise to conflate innovation with R&D or to treat innovation as a linear process, it is notable that the Republic invests significantly less in R&D than do other similar small open economies in Western Europe. Government outlays are also below the OECD and EU averages. In addition, the Republic invests significantly less than peer countries on education per pupil, and the Republic has one of the weaker broadband networks in Western Europe.

The Republic is not a world leader when it comes to innovation according to most metrics with much innovative activity confined to multinational firms. Overall, the OECD (2013) find that investment intensity in knowledge-based capital is in the bottom half of OECD countries for which data are available, and that while the Republic is making progress in

building up its scientific capabilities, its innovative capacity remains weaker than in other small advanced economies. These are concerns given the possible long-term implications for the Republic's innovative competence and by extension the Republic's prospects for productivity led growth.

The paper proceeds as follows. Section 2 establishes the importance of knowledge, innovation and technological change for long-run economic growth and briefly considers the implications for policy arising from a range of modern theories of economic growth. Section 3 discusses the main macro level drivers of technology diffusion with an emphasis on factors influencing the flows and density of economic and information connections within the system. Section 4 outlines the innovation systems concept and its relevance for innovative competence. The main elements of the Republic's innovation system and policy are then described. Section 5 considers the Republic's comparative innovation performance while Section 6 identifies possible reforms and concludes.

## **2. KNOWLEDGE, INNOVATION AND THE WEALTH OF NATIONS**

Economic production depends on the application of useful knowledge and there is a substantial body of empirical and theoretical work attributing much of the long-run fluctuations in economic output to technological change (Kydland and Prescott, 1982; Aghion and Howitt, 1992; Mokyr, 2002). It has even been argued that the application of new ideas in economically useful ways is the only sustainable source of long-term economic growth. According to Aidan Kane (1999): *"For academic economists, the question...what are the sources of technological progress...appears now to be almost co-extensive with the question...what determines the wealth of nations."*

For conceptual purposes we can broadly identify two types of economic growth, namely, extensive growth and intensive growth. Extensive growth is the growth obtained by adding more units of labour or capital, or both, whereas intensive growth is the growth obtained by increasing the average productivity of labour or capital, or both. Extensive growth is constrained in the long-run because diminishing returns to capital and labour make it impossible to sustain economic growth in the absence of productivity improvements. Extensive growth is also constrained by resource and demographic constraints. An important implication is that sustainable increases in per capita output can only be

achieved in the long-run through intensive growth (McDonnell, 2013).<sup>2</sup>

So where does this intensive growth come from? Intensive growth comes from combining and applying knowledge, ideas, and technologies in innovative and useful ways and/or in new contexts that either increases the productivity of capital and labour or leads to the production of an entirely new good or service. As a shorthand we can capture these activities under the heading of *innovation*. Innovation in its widest sense should be understood to encompass any change in the instructions that go into the production process. Joel Mokyr (1992) describes technological change as “*the lever of riches*.” According to this view, our tools for transforming nature are information, words and instructions. Changing the set of instructions related to how we produce something, whether matchsticks or space ships, transforms nature in a different way than before. The new or ‘innovative’ process, as long as it is more efficient in turning inputs into outputs, should gradually diffuse through the economy increasing productivity as it does so.

Technology diffusion is an intrinsic part of the innovation process. Bronwyn Hall (2004) describes technology diffusion as the process by which individuals and firms in an economy adopt novel technologies or replace older technologies with improved versions. Learning in different contexts, along with imitation and feedback effects, will not only enhance the original innovation but spawn new innovations. We can expect innovations to spread through the economy when they are clearly superior to previous technologies. This may occur via *learning-by-observing* processes in the Darwinian sense described by Richard Nelson and Sidney Winter (1982) and by Mokyr (1992). However, as Nathan Rosenberg (1972) points out, the diffusion process can take a long time and is not guaranteed to succeed.

## ***2.1 Knowledge as the key to long-run growth***

Knowledge differs from capital and labour as an input into the production process because it does not exhibit diminishing returns. Once obtained, knowledge is virtually costless, and through continuous learning and the application of useful knowledge we can produce the same value of goods and services for increasingly less effort. Kenneth Arrow’s (1962) *learning-by-doing* growth model describes how the productivity of labour increases with experience. Technological progress caused by learning similarly raises the marginal

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<sup>2</sup> Productivity growth slowed to an average of less than 1% per annum from 2000-2014 in the vast majority of advanced economies.

productivity of capital. According to Arrow (1962, 1991), while the cost of acquiring knowledge is independent of the scale on which the knowledge is eventually used, the benefit obtained from the knowledge very much depends on the scale at which it is eventually used. Once the knowledge is created there is almost zero marginal cost involved with further use of the knowledge. Knowledge once created is also virtually inexhaustible.

The *inexhaustibility* or non-depletion of knowledge generates increasing returns to scale, which in turn generates productivity gains and economic growth.<sup>3</sup> For this reason, Rosenberg (1972) and Paul Romer (1990) argue that the key to influencing long-run economic growth is to first influence the cost of generating, diffusing and obtaining knowledge. A second important characteristic of knowledge is that it is *non-rivalrous*. This means that one person's use of knowledge does not reduce another person's use of the same knowledge. The non-rivalrous nature of knowledge opens up the potential for positive externalities in the economy in the form of spillovers.

A third characteristic of knowledge is that it is only *partially excludable*. Once revealed it can potentially be used by anyone. This means the would-be producer of the knowledge will often be unable to capture all of the benefits from its production and is therefore disincentivized to produce it in the first place. Without policy interventions to change the rules of the game (e.g. by strengthening intellectual property rights) it may be difficult if not impossible for a firm to earn a profit from its knowledge generating activities. In addition, the production of knowledge is a complex, interactive and often unpredictable process with no guarantee of a return. The inherent *uncertainty in the cost of production*, combined with the inability of the producer to internalize all of the benefits of its production, means that a self-regulating market will produce a less than socially optimal amount of economically useful knowledge. The likelihood of market failure provides a rationale for interventionist technology policy.

Rosenberg (1972) argues that the net cost of knowledge is the main determinant of the rate of innovation. Knowledge is neither freely available nor omnipresent. Every innovation or incremental advance in the stock of knowledge has its own cost of production. Rosenberg suggests that the incentive for engaging in innovation activities will increase if the cost of producing or acquiring an innovation falls without a commensurate decline in the benefits of the innovation. In a similar vein, Romer (1990) describes how

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<sup>3</sup> It is these increasing returns to scale that counteract the effect of diminishing marginal returns to capital and labour.

*'influencing the cost of finding new ideas'* is the key to economic growth. The rate of innovation is therefore not only influenced by the market and market players but by the economy's institutional constraints to the extent that these institutions influence the costs and benefits of engaging in knowledge production and other innovative activities (McDonnell, 2015). Rosenberg's and Romer's arguments point to the significance of certain enabling keystone technologies, for example broadband internet access technologies. Broadband reduces the search costs associated with finding and using new knowledge and through this mechanism increases the long-run growth rate.

The potential for new ideas is effectively limitless. Romer (1992, 1993) emphasizes the vast number of ways in which any economic activity can be conducted and argues that technological change offers the prospect of continuous growth in living standards. Romer describes each known combination of actions or instructions as a known technology. Each alternative possible combination of actions is seen as a potential innovation. He gives the example of sewing a shirt, an activity which requires fifty two separate actions and argues that even if most possible sequences of action are wildly impractical it is still *"extremely unlikely that any actual sequence that humans have used for sewing a shirt is the best possible one."* Romer's point is that the potential for continuous economic growth exists within the vast search space of untried combinations of actions.

Crucially, because this type of growth does not depend on increasing volumes of capital, labour, land, or other natural resources, it is at least potentially compatible with environmental sustainability and deteriorating demographics. The rest of this section will discuss the major modern schools of thoughts relevant to long-run economic growth as well as some of the high-level policy implications arising from these theories.

## ***2.2 The new or 'endogenous' growth theories***

The new or 'endogenous' growth theories emphasize the importance of investments in technological change, human capital and innovation. The new growth models assume technological change occurs endogenously within the economic system (Barro and Sala-i-Martin, 1995) and that positive externalities arising from innovation have an important impact on long-run economic growth and development. These models view new ideas and technical change as being determined, or *induced*, by the purposive motivations and decisions of rational and optimising economic actors. In this sense technical change is considered endogenous to economic activity.

The new growth models emerged in the 1980s. Their central proposition is that capital accumulation when taken in its broadest sense to include human capital does not exhibit diminishing returns (Mankiw, Romer and Weil, 1992). The process of economic growth in the new growth models is driven by the accumulation of human and physical capital together with the production of new knowledge created through Research and Development (R&D) activities (Snowdon and Vane, 2005). They can be thought of as input-output models of innovation where higher levels of investment in innovation inputs, such as education and R&D, will translate into higher levels of innovation outputs and therefore faster levels of economic growth.

Romer (1986, 1990) built on Arrow's (1962) earlier learning-by-doing model by introducing an R&D sector to the economy. He was able to describe how increasing returns to scale could be achieved at the aggregate level through the spillover of technology. The non-rivalrous nature of knowledge goods meant that new ideas, once created, could be used over and over again at no additional cost to the firm (Romer, 1990), while learning externalities among firms caused by knowledge spillover could lead to an expansion of aggregate knowledge (Romer, 1986). As the benefits of a firm's investment in knowledge cannot be fully internalized, the investment in knowledge (R&D) by one firm generates a positive externality that increases the productivity potential of other firms and economic actors.

An important implication arising from these models is that the public benefits to R&D will exceed the private benefits. Charles Jones and John Williams (1998) find that the social, i.e. economy wide, rate of return to R&D is between two and four times the private rate of return to R&D. However, the inability of knowledge producers to internalize all of the benefits of their investments in R&D reduces their incentive to undertake such activity in the first place. In addition, while knowledge has a once off payment, the size of the payment is of unknown cost beforehand. This makes knowledge production inherently risky and further diminishes the private incentive to produce knowledge.

The new growth models therefore predict that, when left to its own devices, the market will produce less than the socially optimal amount of new knowledge. The resulting market failure in the production of knowledge is a standard rationale advanced in support of activist technology policy, whether in the form of R&D subsidies or tax breaks for the private sector or in the form of direct government investments in R&D, education, knowledge infrastructure, and supports for the diffusion of innovations.

### **2.3 The evolutionary or 'path-dependent' growth theories**

While the new growth models treat technological change as endogenously induced, the evolutionary or *path-dependent* theories of economic growth emphasise that economic change actually occurs as part of a historically grounded and dynamic path-dependent process characterised by permanent disequilibrium (Nelson and Winter, 1982; Mokyr, 1992). Path dependency theories reject the endogenous growth models' assumption of rationally optimising individuals.

Instead, these models stress that dynamic change happens over historical time with the rate and type of technological change occurring as part of a probabilistic stochastic (semi-random) process characterized by uncertainty. New ideas, like genetic mutations, are not entirely random. All ideas emerge out of something else, and are almost always variants on ideas that already exist. Bart Verspagen (2004) contrasts the steady-state or 'clockwork' growth pattern of the new growth theories with the more uncertain growth trajectories predicted by the evolutionary growth theories. Innovation is seen as blind, with its success or failure partially driven by economic processes (Metcalf and Georgiou, 1997).

Uncertainty of outcome is a function of what Mokyr (1992) describes as the Darwinian nature of technological change. According to this view, markets are treated as selecting, or adopting, new innovations or 'novelties' within a constrained Darwinian process. Innovations occur stochastically within the economic system, with the eventual success or failure of a particular innovation unknown in advance. The novel idea underpinning the innovation can be seen as synonymous with a mutation. The innovation's eventual success or otherwise will partially depend on luck and context, but will also depend on the innovation's own characteristics such as its usefulness, its applicability, its compatibility with existing technology and its relevance to perceived needs.

According to Kurt Dopfer (2005), no single organization or individual can perfectly foresee the path of economic change or the potential of a new innovation. Firms are far from possessing perfect rationality under all circumstances and organizations and individuals are deemed to act under conditions of *bounded rationality*. Bounded rationality means that economic actors are only partially rational and experience cognitive limitations and biases in their ability to formulate; process and solve complex problems (Kahneman, 2003 and 2011). Individuals and organizations must learn and search experimentally in uncertain and permanently changing environments and with uncertain outcomes (Hanusch and Pyka,

2005). Uncertainty of outcome and even lack of basic awareness of potential outcomes will often prevent economic actors from engaging with or investing in innovation. This suggests a rationale for governments to minimize the risks involved in innovative activities as well as a rationale for providing general awareness of the potential benefits of innovation and new technologies.

The evolutionary growth theories emphasize that an important role of government is to create an environment and set of incentives that encourages and facilitates the generation of economically useful new ideas or 'mutations', that removes blockages or barriers to innovation, and that supports the transfer of knowledge and diffusion of new ideas at the individual, organizational and economic system levels.

#### ***2.4 The complex system or 'complexity' growth theories***

Complexity models of economic growth are rooted in chaos theory. These models emphasise that the economy is a complex adaptive system characterised by a multiplicity of interactions between economic actors and by a multiplicity of positive and negative feedback loops (Frenken, 2005 and 2006; Arthur, 2009). Economic analysis is approached from a network or system perspective rather than from production or utility function perspectives. The complexity models see economic growth as an outcome of the exploitation of increasing returns from new and useful innovations. Innovation itself is treated as an ongoing iterative process characterised by positive feedback loops.

According to these models the economy is characterised by non-linear relationships and by emergent properties. Optimal outcomes cannot be guaranteed while new possibilities are continuously emerging as part of a dynamic process within the system. The human capacity to predict the behaviour of complex systems is seen as limited and such models emphasise the difficulty in picking technological winners. Complexity models suggest that rather than focusing on picking winners, policymakers should instead seek to nurture a diverse, dynamic and competitive marketplace of ideas with its own internal processes of Darwinian selection. Culture, networks and institutions are seen as important because they influence the spread and adoption of ideas. One policy implication is that innovation is enhanced by having an open society with the rate of innovation a function of the prevailing socio-economic environment, including beliefs, types of knowledge flows, sets of incentives, and legal, political and cultural rules of the game.

## ***2.5 The neo-Schumpeterian growth theories***

According to the neo Schumpeterian framework the transformative processes driving economic change are endogenous to the economic system and a function of knowledge production, innovation and entrepreneurship occurring at the micro level (Hanusch and Pyka, 2005). While these models (Grossman and Helpman, 1991; Aghion and Howitt, 1992) retain many elements of the new growth framework, they seek to incorporate the evolutionary perspective of technological change as an uncertain and path-dependent process, as well as an understanding of the economy as a complex system characterised by networks and feedback loops. Darwinian competition between innovations, rather than competition between firms, is seen as the central force propelling economic growth. The economy enters a new phase of growth when a new and more efficient technology spreads throughout the economy. The new technology renders older products and services obsolete and raises the economy's productive potential. Jobs, businesses, and even industries, which are unable or unwilling to adapt to the new reality will eventually be replaced by those better able to exploit the newer more efficient and useful technology.

This process of economic upheaval and change is seen as perpetual and a feature of the economic system. Economic change ebbs and flows along with what Joseph Schumpeter (1942) calls the "*creative gales of destruction*." Over time the newer innovations are themselves displaced by the next wave of innovations and the productive potential of the economy increases yet again as the economy fluctuates and remakes itself in turmoil. Economic growth is therefore seen as sustainable ad infinitum provided the process of creative and destructive innovation is not impeded (Aghion and Howitt, 2009).

Philippe Aghion and Peter Howitt (2009) identify two main inputs to innovation:

- a) The expenditures made by the public and private sectors to produce innovations, and
- b) The publicly available stock of innovations already produced by past innovators.

Certain transformative technologies or macro inventions will generate periods of radical economic change although such periods of change are punctuated by more extended periods of smoother economic development and incremental change. Timothy Bresnahan and Manuel Trajtenberg (1992) and Elhanan Helpman and Trajtenberg (1998) develop the

concept of General Purpose Technologies (GPTs) to explain the periodic occurrence of radical economic change and leaps and bounds of innovation. GPTs are described as technologies possessing at least three particular characteristics:

1. A high **potential for improvement**,
2. A **pervasiveness in the economy**, and
3. An **ability to enhance connectivity and innovation potential** within the economy.

Historical examples of GPTs include but are not limited to steam power; the telegraph; electricity; the railroad; the microprocessor, and internet access technologies. These technologies all lowered transportation and/or communication costs and therefore the cost of accessing new knowledge. The new and more densely connected economic system that follows in the wake of the diffusing GPT gains an enhanced capacity to absorb and exploit new ideas. Vernon Ruttan (2008) argues that GPTs encourage greater investment in R&D because they reduce the cost of knowledge and therefore increase the productivity of R&D investments. The introduction and subsequent development of a GPT therefore opens up a wave of new possibilities for innovation and propels the economy forward. Broadband is a contemporary example of such a GPT.

### **3. TECHNOLOGY DIFFUSION AND INNOVATIVE CAPACITY**

There has been a wide variation in the rates and speed of acceptance of even successful innovations. Zvi Griliches (1957) and Edwin Mansfield (1963) find that successful technologies tend to exhibit a path dependent S-shaped diffusion curve over time. What causes the variation in the diffusion processes of different technologies? It may be that the diffusion process is influenced by the characteristics of the technology itself such as its complexity, trialability, and observability, as well as by certain characteristics of potential technology adopters, for example their income levels and their levels of educational attainment. The wider socio-economic environment will also influence the diffusion process as will the density and nature of social networks (Rogers, 2003).

Paul Geroski (2000) describes a number of models of technology diffusion. The two most influential of these models are (A) the *epidemic model* based on awareness of the technology transmitted like an infection through social networks and other channels of

communication, and (B) the discrete choice or *probit model* based on heterogeneous but rational firms and consumers adopting the technology when their expected net benefit from doing so exceeds the perceived opportunity cost. Expected net benefits will depend on the potential adopter's particular characteristics including their knowledge, biases, preferences and capabilities.

More recently a number of diffusion models drawing on principles from complexity theory have been developed. These include *complex network models* which show how network relations between innovating agents affect the rate of innovation (Cowan, 2004), and *percolation models* which show how the diffusion process can exhibit regional variation with widespread diffusion in some areas and low levels of diffusion in other areas (Frenken, 2006).

### ***3.1 Transport and communication technologies***

The historical diffusion or spread of new ideas, not to mention the preservation of existing ideas, has been aided by the development of a series of information and communication technologies (Mokyr, 1992). Improvements in communication technologies (e.g. the printing press, telegraph, and internet) have transformed the codification, transmission and diffusion of new knowledge, and have increased the durability of existing knowledge. Improvements in communication technologies increase the connectivity of individuals and organizations and in so doing increase the density of the economic system. This facilitates the transmission and observability of useful ideas and therefore the diffusion of innovations. Advances in transport technologies have similarly helped increase connectivity.

A contemporary example is broadband access technology. Broadband is important for innovation because it provides access to the World Wide Web and other online applications. This access increases the stock of knowledge available to any given individual. Broadband also reduces the barriers and various costs associated with accessing knowledge. As such, broadband facilitates the diffusion of the global stock of knowledge and increases the probability of a randomly chosen individual exploiting a randomly chosen idea for economic or other advantage.

### ***3.2 Effective population size and density***

Michael Kremer (1993) argues that the rate of innovation is related to population size,

while Jared Diamond (1997) shows how regions with higher population densities have consistently produced new technologies at exponentially faster rates than regions with lower population density. The spillover concept is useful as an explanation for this phenomenon. Greater proximity to other people makes you more likely to become aware of other people's ideas and knowledge and thus more likely to adopt those ideas or even combine those ideas with other ideas as a new innovation. Bettencourt, Lobo, Helbing, Kuhnert and West (2007) have found that the per capita level of innovation is higher in locations with large populations and large population densities such as cities. They also find that there is super-linear scaling of innovation in urban environments so that, for example, a city that is ten times larger than its neighbor will be more than ten times as innovative.

One implication is that by enhancing the density and proximity of connections within the economic system we can enhance the rate of innovation and long-run growth. In recent times the wide-scale availability of Internet access and Web 2.0 technologies can be seen as increasing the effective population and effective population density of the environment that people have proximity to, albeit a virtual proximity as opposed to physical proximity. In this sense, the Web functions like a virtual city (Johnson, 2010).

### ***3.3 Education and human capital***

Skill levels and educational attainment are sometimes used as proxies for what the OECD (1998) term human capital. Human capital represents the knowledge, skills, competences and creativity of individuals that is relevant to economic activity. It is reasonable to suppose that human capital is associated with greater capacity to identify, adopt and use new technologies. Certain types of learning and experience may also facilitate creativity and greater openness to new ideas. Barro and Sala-i-Martin (2003) consider human capital a necessary input for and complement to innovation and technology diffusion and there is evidence that strong education systems are associated with increases in the long-run per capita growth rate.

Skill levels and cognition for the population as a whole (i.e. not just the top of the achievement distribution) appears to exert a positive effect on growth (Hanushek and Wößmann, 2007). Learning-by-doing (Arrow, 1962 and 1991) and life-long training and up-skilling are both relevant to technology diffusion to the extent that they expose individuals to new ideas and practices. Caselli and Coleman (2001) find that differences in human capital and educational attainment explain much of the variation in technology

adoption rates between firms.

### ***3.4 Institutions as the rules of the game***

Technology diffusion is influenced by the surrounding institutional environment. Each society operates under its own set of legal and cultural 'rules of the game' which Douglass North (1990) calls institutions. The rate of innovation depends not just on the market and on market players but also the institutional constraints. Examples of institutions include, but are not limited to, the education system, the strength and predictability of property rights, the workings of the financial system, the regulatory system, the pervasiveness of corruption, the quality of governance, the level of political stability, fiscal policy including the availability of subsidies and the design of the tax system, the legal system including the existence of patent law, as well as social and cultural norms (World Bank, 1997).

Institutions influence the costs and benefits of engaging in knowledge production and other innovative activities and therefore influence the overall rate of innovation. The costs of knowledge search and knowledge production are crucial determinants of the volume of innovative activity as the profits from an idea provide much of the incentive to innovate. Falling cost of knowledge acquisition means higher expected returns to innovative effort and *ceteris paribus* a higher volume of innovative effort.

### ***3.5 Innovative and absorptive capacity***

The economic system's ability to generate original ideas and to communicate, diffuse and assimilate existing innovations is referred to by Furman, Porter and Stern (2002) as its 'Innovative Capacity'. At a national level we can think of it as National Innovative Capacity (NIC). Innovation is an interactive process and the 'Innovation Systems' concept was developed to explain why economies and societies differ in their rate of innovation and in their rate of diffusion of innovation (Freeman, 1991; Lundvall, 1992; Nelson, 1993; Edquist, 2004). The approach emphasizes the systemic nature of innovation processes. The economy's institutional structures are key to the innovation process to the extent that they condition the incentives, expectations, and behaviour of economic actors as well as the type and strength of knowledge flows.

At the organisational level the idea of 'absorptive capacity' is used to capture the ability of the organisation (e.g. a firm or public agency) to identify, value, assimilate and apply new knowledge (Cohen and Levinthal, 1990). Small enterprises in particular may have weak

capacities and if the organisation lacks sufficient capacity the new idea or technology will fail to diffuse. The concept of absorptive capacity provides a rationale for government to publicise the potential benefits of new innovations; to provide high levels of funding for education in order to improve individual and general capacities; to encourage personnel mobility between academia and industry, and to establish and support flows of information between producers and potential users. It also provides a rationale for fiscal incentives to encourage technology diffusion. The absorptive capacity concept can equally be applied at the individual or consumer level.

#### **4. INNOVATION SYSTEM – INSTITUTIONS AND ACTORS**

National Innovative Capacity (NIC) and long-run economic growth depend on the quality and dynamism of the National Innovation System (NIS). Economic history and path dependence play significant roles in the evolution of an NIS. This means that national systems can be radically different and indeed optimal policies for one era or region may not be appropriate in a different context. Improving innovative competence is not simply a matter of increasing innovation inputs, although the volume of innovation inputs is certainly important. Innovative competence also depends on the presence of dynamic Science, Technology and Innovation (STI) actors, operating within the confines of compatible institutions and with systemic linkages inducing the accumulation and diffusion of knowledge.

##### ***4.1 Innovation systems***

The NSI approach emphasises the systemic nature of innovation processes. The level and types of knowledge flows in the economy as well as the nature, density and strength of the relationships between people and organisations are seen as crucial to innovation. The importance of horizontal linkages allowing new knowledge to diffuse throughout the economy is emphasized. According to the conceptual framework described by Pontikakis, McDonnell and Geoghegan (2005, 2006) a system of innovation comprises:

- i. The institutions or organizations engaged in innovation related activities
- ii. The environment in which these institutions operate and
- iii. The linkages between these institutions

Technological change does not occur in a perfectly linear sequence, but through feedback loops within the system. The flows of technology and information among people,

enterprises and institutions are crucial to learning and interaction, and therefore crucial to the innovative process (Pontikakis et al., 2006). Equally, the nature of the interactions between the various actors will help determine the success or otherwise of the NIS in delivering innovation.

Economic actors have heterogeneous motivations and incentives for collaboration. Different motivations can vary from increased profits to job creation and engagement in innovation need not translate into collaboration. Innovation policy must take account of these heterogeneous motivations. Lack of awareness of potential opportunities is a barrier to collaboration, particularly when it comes to firms with low absorptive capacity operating without specialist staff. Higher Education Institutes (HEIs) can play an important role as networking, information sharing and collaboration nodes with outreach programmes for Small and Medium Sized Enterprises (SMEs) within their region. The Republic's Department of Jobs, Enterprise and Innovation (DJEI, 2016) has pointed to econometric analysis suggesting €1 of public investment in HEI-enterprise R&D collaboration programmes leads to between €2 and €3 return in terms of net economic value added in the short-term with larger returns in the long-term of between €4.50 and €11.00.

#### ***4.2 Policy evolution in the Republic of Ireland***

While innovation is now part of the policy mainstream, Patrick Collins and Dimitrios Pontikakis (2006) argue that science, technology and innovation were far from the policy making agenda prior to the 1970s. Attracting high-tech multinationals was central to industrial policy. The Telesis report (1982) criticized the narrow focus of Irish industrial policy while the Science and Technology Act of 1987 attempted to integrate science and technology with industrial policy. The stated goal was to develop the level of technological capability necessary to underpin the development of industry. Technology was identified as a major force in the creation of wealth and jobs.

The Culliton report (1992) highlighted structural weaknesses in industrial policy as well as the need to improve product technology and move progressively into higher productivity industries and niche areas. A sustained lobbying campaign developed to push for a coherent innovation policy and this led to the establishment of a Science, Technology and Innovation Advisory Council and a White Paper on Science, Technology and Innovation. Innovation and R&D were now seen, at least in official rhetoric, as key to economic development. Nevertheless expenditure on R&D was just two thirds of the EU average in

the first few years of the 21<sup>st</sup> century (Collins and Pontikakis, 2006). The Irish Government produced an action plan in 2004 which targeted an R&D spend of 3% of GDP by 2010 although this goal was not achieved. Total R&D expenditure (GERD) was a little over 1.5% of GDP in 2011 and well below the OECD median (OECD, 2013). Business R&D expenditure (BERD) was close to 1% of GDP; similarly well below the OECD median, and lagging far behind that of the leading innovating economies.

### 4.3 Key STI actors

NSI supporting institutions include the public administration apparatus; the financial system; the legal and regulatory framework; cultural attitudes, and the education system. According to a recent OECD (2013) assessment, the Republic *“provides a favourable environment for innovative activities thanks to strong institutions, fine universities, good infrastructure, a well-educated workforce and policies friendly toward foreign direct investment.”* However, the presence of well-functioning and compatible institutions merely *permits* the development of a successful NIS. They do not themselves deliver innovation. It is the actions of the STI actors that ultimately must propel the NSI.

STI actors include policy makers and policy enactors, as well as technology lobbyists, technology users and technology producers (see Table 4.1). Central government and subsidiary public sector bodies are obviously key actors within the system. Industry, including indigenous and multinational enterprises but also lending institutions such as venture capital funds and investment banks, and academia, including universities, institutes of technology and other research centres, are also crucial STI actors as technology users, producers and lobbyists.

**Table 4.1 STI Actors, Republic of Ireland**

| STI Actor Role | Examples                                       | Sample Contributions        |
|----------------|------------------------------------------------|-----------------------------|
| Policy Maker   | Government Departments (DJEI)/EU Commission    | Funding/strategic direction |
| Policy Enactor | Public Agencies (e.g. SFI, HEA, EI, IDA, IRC)  | Regulation/coordination     |
| Tech Producer  | Enterprises/Academia                           | Knowledge/skills/products   |
| Tech User      | Foreign and domestic Markets                   | Demand/spillover            |
| Tech Lobbyist  | Academia/Industry Associations/Consumer Groups | Analysis/information/demand |

**Source:** Table is developed from Pontikakis et al., (2005)

The Department of Jobs, Enterprise and Innovation (DJEI) plays the key role in developing, promoting and coordinating innovation, research and development policy. According to the

DJEI (2016) its innovation policy is shaped by four interrelated objectives:

- Building a world class research system within HEIs through investments in human capital, infrastructure and underpinning sciences and technologies
- Broadening and deepening the enterprise R&D base, its absorptive capacity and its ability to develop and commercialize intellectual capacity
- Strengthening the system of knowledge exchange through formal collaborations, human capital mobility and knowledge transfer infrastructure
- Investing in government research organizations and funding programmes to underpin public policy

DJEI funds Enterprise Ireland (EI), Science Foundation Ireland (SFI) and the Programme for Research in Third Level Institutions (PRTL). EI is responsible for the development and growth of Irish enterprises in world markets including helping enterprises innovate. SFI was modelled on the US National Science Foundation and invests in academic researchers and research teams in order to generate new knowledge and leading edge technologies in the fields of science, technology, engineering and maths (DJEI, 2017a).

IDA Ireland plays the lead role in attracting foreign direct investment to the Republic. This makes it an extremely important innovation actor as almost two thirds of the Republic's business R&D (BERD) is performed by foreign owned entities (65.2% in 2013). SFI and IDA Ireland work in partnership to stimulate investment from technology based multi-nationals to establish R&D facilities in the Republic (DJEI, 2015a).

The Higher Education Authority (HEA) is the statutory planning and policy-advisory body for higher education and research in the Republic as well as being the statutory funding authority for Irish universities and institutes of technology. The Irish Research Council (IRC) is an associated agency of the Department of Education and Skills established in mid-2012 as a merger of two former councils and mandated to fund research within and between disciplines, provide policy advice on postgraduate education and more general research matters, and support the education and skills development of early stage researchers.

According to Smith (2004) and Fagerberg (2015), EU surveys of firms' innovative activities and the factors that influence these activities show that the most important sources of innovation for firms are within the firm itself. The most important external sources of information are customers and suppliers, followed by other firms in the industry or sector,

then public sources such as conferences and journals. Universities and public research institutes are found to be amongst the least important sources of information. This can be interpreted in either of two ways. Business and public research linkages are fundamentally ineffective as knowledge transfer mechanisms, or, alternatively, there is significant scope to improve knowledge transfer to firms by reforming the framework of interaction between business and public research linkages and establishing incentives to engage and collaborate.

In this context Knowledge Transfer Ireland (KTI) was established in 2013. It is part of EI and is the national office responsible for helping business to connect and engage with the research base (universities, institutes of technology, government agencies and other publically funded research institutes) and with developing the knowledge transfer framework, infrastructure and system. Its objective is to maximize the flow of technology, ideas and expertise into companies and drive innovation in products and services. KTI keeps track of patents and other intellectual property outcomes of research and maintains a database of experts on various issues.

#### ***4.4 Funding innovation***

STI funders provide resource inputs and STI performers provide innovation outputs. Different actors will have different incentives for engaging in innovation. For example, policy makers might be focused on job creation and economic growth, whereas non-government technology producers are more likely to be focused on profits and their own capacity building. Government funding for innovation can be direct in the form of subsidies for education, R&D and technology transfer, or indirect in the form of tax exemptions for R&D costs and special depreciation rates for R&D capital. According to DJEI (2015a) the enterprise development agencies (EI and IDA Ireland) provided €149 million to support in-company R&D in 2013. This investment is estimated to have leveraged circa €400 million of private investment. The Republic introduced an R&D tax credit in 2004 the cost of which appears to have been close to €500 million in 2014 (DJEI, 2017b).

The DJEI (2016) point to evidence of a correlation between firm engagement in R&D and stronger sales, exports, value added and employment performance. Of course correlation does not imply causation. More significantly they point to econometric analysis estimating that a €1 increase in grant paid leads to a €1.64 increase in R&D carried out by firms when

based on ‘similar’ firm analysis.<sup>4</sup> The DJEI also point to econometric analysis estimating that 60% of the R&D carried out under the Republic’s R&D tax credit was ‘additional’ meaning it would not have taken place without the tax break. The evaluation found that for each €1 of foregone tax revenue, €2.40 of additional R&D was carried out. A Knowledge Development Box (KDB) was announced in the 2016 Budget. The KDB offers a reduced corporate tax rate of 6.25% for profits arising from patents, copyrighted software or Intellectual Property (IP) equivalent to a patentable invention. The stated goal of this policy is to encourage enterprises to undertake R&D in the Republic.

Gross domestic expenditure on R&D (GERD) increased from 1.28% of GDP in 2007 to 1.49% of GDP in 2014, mainly thanks to an increase in private sector R&D (OECD, 2016). Private sector R&D (BERD) is largely concentrated in close to market activities. The Republic’s GERD intensity was well below the OECD’s GERD intensity of 2.38% of GDP. GERD grew at an annual rate of 3.5% in the Republic between 2009 and 2014. This was faster than the annual growth rate of 2.3% in the OECD. However, publically financed GERD declined by an annual average rate of 0.9% of GDP between 2009 and 2014, whereas it grew by 2.5% in the OECD. In 2014 publically financed GERD was just 0.4% of GDP in the Republic compared to 0.61% in the OECD (OECD, 2016). The DJEI (2015a) notes that government expenditure aimed at strengthening the Republic’s R&D capabilities and infrastructures was, at €735 million in 2015, broadly the same as it had been a decade earlier when it was €727 million in 2005. The DJEI also acknowledge that the intensity of government investment in R&D is less than half that of comparator countries and below the EU average. The case in economic theory for higher levels of spending on R&D related fiscal supports and on public R&D appears compelling and there is also empirical support for higher levels of spending (Berlitz et al., 2015).

#### **4.5 The Innovation 2020 targets**

*Innovation 2020* was launched in December 2015 and is the Republic’s latest strategy for R&D, science and technology (DJEI, 2015b).<sup>5</sup> It covers the period 2016-2020 and sets out a roadmap which it hopes will make the Republic a global innovation leader in what it describes as strategically important areas relevant to the economy and society. Innovation

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<sup>4</sup> It was estimated that a return of €5 Economic Value Added (EVA) was achieved in the short-run for every €1 of grant approved by IDA as well as a return of €25.50 in the long-run. EI grant-funding provided €1.82 in net EVA in the short-run.

<sup>5</sup> The previous strategies were the *Technology Foresight Exercise* and the *National Development Plan* (2000-2006) and the *Strategic Science, Technology and Innovation 2006-2013 and Research Prioritisation Exercise* (2006-2015). Public R&D funding to HEIs actually fell during the time period of the second of these plans.

2020 points out that so called innovation leaders such as Denmark and Finland have public investment in STI that is twice that of the Republic if measured as a percentage of GDP (DJEI, 2015b). The strategy is being implemented by a multi-stakeholder implementation group as part of what is described as a whole-of-government approach.

The Innovation 2020 strategy aims to increase total investment in R&D in Ireland, led by the private sector, to 2.5% of GNP (about 2% of GDP). The proposed split is three parts private sector funding to one part public sector funding implying a fairly modest public sector funding goal by Western European standards of 0.625% of GNP in 2020. The very strong performance of GNP in the interim combined with reasonable forecasts of potential growth and inflation suggests a figure of €6.6 billion will be required to meet the Innovation 2020 target of 2.5% including over €1.6 billion of public investment.<sup>6</sup> While these targets might seem ambitious their achievement will not place the Republic in the vanguard of innovating countries in terms of the relative scale of innovation inputs.

## **5. COMPARATIVE PERFORMANCE**

The OECD (2016) points to a number of innovation weaknesses. In particular, they estimate that the ease of entrepreneurship in the Republic is below the OECD median, owing to what they describe as difficult licensing and permit systems and complex regulatory procedures. The OECD also note that the number of young patenting firms and the level of ICT investment are well below the OECD median while the problem-solving of older adults and the fixed broadband subscription rate are below the OECD median.

The Republic ranks 7<sup>th</sup> out of 128 countries in Cornell's 'Global Innovation Index' (WIPO, 2016) and performs particularly well under the 'Knowledge & Technology Outputs' heading (3<sup>rd</sup><sup>7</sup>) and under the 'Business Sophistication' heading (8<sup>th</sup>). The Republic's lowest ranked category is for 'Human Capital & Research' with an overall ranking of 20<sup>th</sup>. Within this category the Republic ranks just 33<sup>rd</sup> for percentage of graduates in science and technology and 30<sup>th</sup> for expenditure on education as percentage of GDP. The Republic also performs relatively poorly in certain aspects of market and business sophistication for

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<sup>6</sup> The estimate is based on a nominal GNP forecast for 2020 of around €263 billion.

<sup>7</sup> Within this heading there is a sharp difference between 'Knowledge Creation' (31<sup>st</sup>) and 'Knowledge Diffusion' (1<sup>st</sup>). The knowledge diffusion ranking is composed of indicators related to Foreign Direct Investment (FDI) outflows and Intellectual Property (IP) receipts suggesting the Republic's overall ranking for knowledge outputs has more to do with the Republic's multinational enclave and less to do with the underlying strength of its innovation system.

example ease of getting credit (27<sup>th</sup>) and intensity of local competition (65<sup>th</sup>).

### **5.1 The European Innovation Scoreboard**

The European Commission (2016) publishes an annual European Innovation Scoreboard which compares the relative innovation performance of thirty six countries including the twenty eight EU countries.<sup>8</sup> The 2016 edition of the scoreboard uses data up to and including 2015. The best performing EU economies are found to be Sweden, Denmark, Finland, Germany and the Netherlands. The innovation indicators used to construct the scoreboard are categorized under three separate headings: *enablers*, *firm activities* and *outputs*. There are three categories (*human resources*, *quality of research systems*, *finance and support*) and eight indicators under the ‘enabler’ heading; three categories (*firm investments*, *linkages and entrepreneurship*, *intellectual assets*) and nine indicators under the ‘firm activities’ heading, and two categories (*innovators*, *economic effects*) and eight indicators under the ‘outputs’ heading (see Table 5.1 with Irish over performance in dark red and under performance in light blue).

Clearly these indicators are not of equal importance. For example, ‘*R&D expenditure as a percentage of GDP*’ has a vastly more significant impact on innovative competence than does ‘*non-EU doctorate students as a percentage of all doctorate students*’. Other indicators seem arbitrary, for example, ‘*patent applications in societal challenges*’, or overly specific, for example, separating ‘*community trademarks*’ from ‘*community designs*’. In addition, important indicators, such as the quality, cost, and availability of important innovation infrastructure such as high-speed broadband are not included within the scoreboard. As such, the scoreboard should not be considered a comprehensive ranking of countries’ national innovative competence. Even so, there is value in discussing the findings from an Irish perspective as doing so may allow us to identify potential weaknesses in the Republic’s NIS.

The EU Commission ranks the Republic of Ireland 6<sup>th</sup> out of 28 EU countries in terms of innovation performance. This places the Republic in the 2<sup>nd</sup> tier of innovating countries and classified as a *strong innovator*. The Republic’s performance has improved from 8<sup>th</sup> in 2014 and 10<sup>th</sup> in 2013. The Republic is ranked 3<sup>rd</sup> in ‘*human resources*’, the ‘*research system*’ is ranked 9<sup>th</sup>, ‘*finance and support*’ is ranked 16<sup>th</sup>, ‘*firm investments*’ is ranked 17<sup>th</sup>, ‘*linkages & entrepreneurship*’ is ranked 8<sup>th</sup>, and ‘*intellectual assets*’ are ranked 16<sup>th</sup>. The Republic is

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<sup>8</sup> The eight non-EU countries are Iceland, Israel, Macedonia, Norway, Switzerland, Serbia, Ukraine and Turkey.

ranked 1<sup>st</sup> in terms of '*innovators*' as well as 1<sup>st</sup> in terms of '*economic effects*'. While the NERI (2016) has previously expressed concern at the low level of per pupil public spending on education institutions it appears that the Republic is actually doing relatively well in terms of human resource indicators. Ireland's rankings for '*linkages and entrepreneurship*' (ranking 2<sup>nd</sup> for SMEs innovating in-house) and for '*innovators*' (notably ranking 2<sup>nd</sup> for SME marketing/organizational innovations and 2<sup>nd</sup> for employment in fast-growing firms of innovative sectors) suggests that the Republic's NSI is performing relatively well overall.

While the Republic does not rank particularly badly in any one category it does underperform the EU average in three of the categories. The first of these is '*finance and support*' where the underperformance is entirely attributable to the Republic's low level of public R&D expenditure as a percentage of GDP which ranks 23<sup>rd</sup> in the EU and 29<sup>th</sup> out of 36 countries ranked. If the Republic was to double its current level of spending from 0.4% of GDP in 2015 to 0.8% of GDP it would still only rank 10<sup>th</sup> out of 36 countries.<sup>9</sup> Denmark is the leader with public R&D expenditure of 1.09% of GDP.

An important caveat is that distortions to GDP and GNP in 2015 have diminished the value of using GDP and GNP as denominators when comparing the Republic with other countries. In addition, there is debate within the Republic as to the appropriateness of GDP as a measure of fiscal capacity due to the significant presence of US multinationals and the attendant distorting impact on GDP. The argument is that the portion of GDP in excess of GNP has a reduced taxable capacity. With this in mind the Irish Fiscal Council has developed a hybrid GDP/GNP metric intended to better reflect fiscal capacity. If we apply this hybrid measure as the denominator and use 2014 data we find that the Republic is still underperforming relative to the EU as a whole, with spending at about three fifths of the EU average, but that it improves in ranking to 20<sup>th</sup> in the EU in 2014 and to 25<sup>th</sup> out of the 36 countries ranked. The Republic's performance in this area has been on a downward trend relative to the EU since 2010, reflecting austerity related cutbacks (see Chart 5.1).

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<sup>9</sup> Recall that the Innovation 2020 target is just 0.625% of GNP, a figure that is projected to be around 0.5% of GDP.

## Table 5.1 European Innovation Scoreboard Indicators

| Category                                        | Indicators                                                                                                                                | ROI   | EU    |
|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|
| Human resources                                 | New doctorate graduates per 1000 population aged 25-34                                                                                    | 2.1   | 1.8   |
|                                                 | Percentage population aged 30-34 having completed tertiary education                                                                      | 52.3  | 38.5  |
|                                                 | Percentage youth aged 20-24 having attained at least upper secondary level education                                                      | 92.8  | 82.6  |
| Open, excellent and attractive research systems | International scientific co-publications per million population                                                                           | 1,080 | 459   |
|                                                 | Scientific publications among the top 10% most cited publications worldwide as percentage of total scientific publications of the country | 11.7  | 10.5  |
|                                                 | Non-EU doctorate students as percentage of all doctorate students                                                                         | 14.3  | 17.8  |
| Finance and support                             | R&D expenditure in the public sector as a percentage of GDP                                                                               | 0.40  | 0.72  |
|                                                 | Venture capital investment as a percentage of GDP                                                                                         | 0.086 | 0.063 |
| Firm investments                                | R&D expenditure in the business sector as a percentage of GDP                                                                             | 1.11  | 1.30  |
|                                                 | Non-R&D innovation expenditure as percentage of total turnover <sup>10</sup>                                                              | 0.39  | 0.69  |
| Linkages & entrepreneurship                     | SMEs innovating in-house as percentage of all SMEs                                                                                        | 38.8  | 28.7  |
|                                                 | Innovative SMEs co-operating with others (percentage of all SMEs)                                                                         | 12.0  | 10.3  |
|                                                 | Public-private scientific co-publications per million population                                                                          | 34.3  | 33.9  |
| Intellectual assets                             | Patent Cooperation Treaty (PCT) patent applications per billion GDP (in PPS€)                                                             | 2.40  | 3.53  |
|                                                 | Patent Cooperation Treaty (PCT) patent applications in societal challenges <sup>11</sup> per billion GDP (in PPS€)                        | 0.65  | 1.01  |
|                                                 | Community trademarks per billion GDP (in PPS€)                                                                                            | 6.03  | 6.09  |
|                                                 | Community designs per billion GDP (in PPS€)                                                                                               | 1.59  | 4.44  |
| Innovators                                      | SMEs introducing product or process innovations as percentage of SMEs                                                                     | 35.7  | 30.6  |
|                                                 | SMEs introducing marketing or organizational innovations as percentage of SMEs                                                            | 49.6  | 36.2  |
|                                                 | Employment in fast growing firms of innovative sectors (percentage of total employment)                                                   | 23.4  | 18.8  |
|                                                 | Employment in knowledge-intensive activities as percentage of total employment                                                            | 20.2  | 13.9  |
| Economic effects                                | Medium & high tech product exports as percentage of total product exports                                                                 | 52.1  | 56.1  |
|                                                 | Knowledge-intensive services exports as percentage of total services exports                                                              | 88.5  | 63.1  |
|                                                 | Sales of new-to-market and new-to-firm innovations as percentage of turnover                                                              | 9.3   | 12.4  |
|                                                 | Licenses and patent revenues from abroad as percentage of GDP                                                                             | 2.53  | 0.54  |

Source: European Commission (2016)

<sup>10</sup> This includes, for example, investment in machinery and equipment and the acquisition of patents and licences. As such this is a proxy for diffusion of new production technology and ideas.

<sup>11</sup> 'Societal challenges' refers to areas where technological change and innovation will be needed to address future challenges such as climate change mitigation and an ageing population. The DJEI (2015a) similarly talk about using a 'grand challenge' approach to innovation in order to address national priority areas including healthy ageing, climate change and sustainable food. It is argued that such an approach might stimulate excitement in the research community and lead to greater collaboration and coordination within the innovation system.

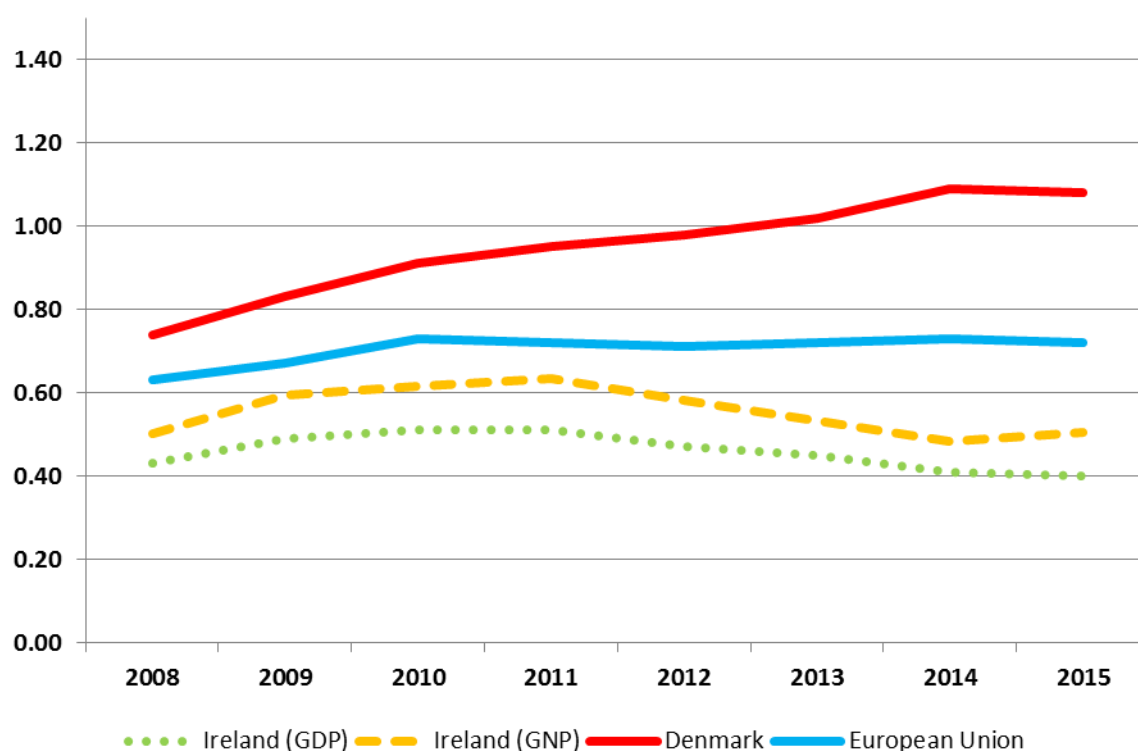
The second broad category where the Republic underperforms is *'firm investments'*. Business R&D expenditure as a percentage of GDP and non-R&D innovation expenditure as percentage of turnover are both below the EU average. However, business R&D is in line with, albeit just below the EU average, when we use 2014 data and employ the hybrid GDP/GNP metric as the denominator. Business R&D expenditure has fluctuated around 1.1% of GDP since 2010 whereas the EU average increased from 1.2% to 1.3% between 2010 and 2015. The Republic is more clearly underperforming in terms of non-R&D innovation expenditure and this is a recent phenomenon that is difficult to explain. Ireland performed relatively well between 2008 and 2012, ranking 8<sup>th</sup> in the EU in each of those years. However, non-R&D innovation expenditure collapsed from 1.01% of turnover in 2012 to 0.30% of turnover in 2013 and has remained low ever since ranking 21<sup>st</sup> in 2015. The reason for this is unclear though the scale of the decline suggests multinational activities may be responsible. On the other hand the decline actually brought the Republic closer in to line with that of other strong innovation performers including the Netherlands, Denmark, Finland and the United Kingdom. Curiously the strongest performers for this indicator tend to be fairly weak performers in the overall innovation scoreboard.

The third broad category where the Republic underperforms is *'intellectual assets'*. The Republic's economy made 2.4 patent applications per billion GDP (PPS€) in 2015 compared to 3.53 applications by the EU although the gap is smaller when using the Fiscal Council's hybrid metric. The Republic's performance in this indicator has improved marginally since 2008. Relative performance is close to the EU average in terms of community trademarks and has been on a generally upward trend since 2008. On the other hand, the Republic performs very poorly in terms of community designs (ranked 22<sup>nd</sup> in the EU) at just over one third of the EU average.

Finally, the Republic's high ranking in the *'employment effects'* indicator is skewed by the large FDI base and by an extreme over performance in license and patent revenues from abroad (ranking 2<sup>nd</sup> in the EU behind Malta). The top performers are Malta, Switzerland, Ireland and the Netherlands, with Luxembourg in fifth place. The top four countries are statistical outliers and it may be that outlying performances are best understood through the prism of distortive multinational tax planning activities. The Republic is the leader in terms of *'knowledge-intensive services exports as percentage of total services exports'* (88.5%) with Luxembourg (88.4%) the only country within 10 percentage points (the EU average is 63.1%). The Republic's ratio is essentially unchanged going back to at least 2008. While it is tempting to attribute part of this over performance to multinational tax

planning and transfer pricing, the Republic also does well in terms of employment in knowledge-intensive activities as percentage of total employment (ranking 2<sup>nd</sup> in the EU at 20.2%). ‘*Medium and high-tech product exports as percentage of total product exports*’ are, at 52%, fairly close to the EU average of 56%. ‘*Sales of new to market and new to firm innovations as percentage of turnover*’ were broadly in line with the EU average from 2008-2010. However, the Republic’s relative performance has trended downwards since then and is now 9.3% compared to the EU average of 12.4%.

**Chart 5.1 Public R&D Expenditures as % of GDP and GNP**



Source: European Commission (2016); CSO (2016a) and author calculations.

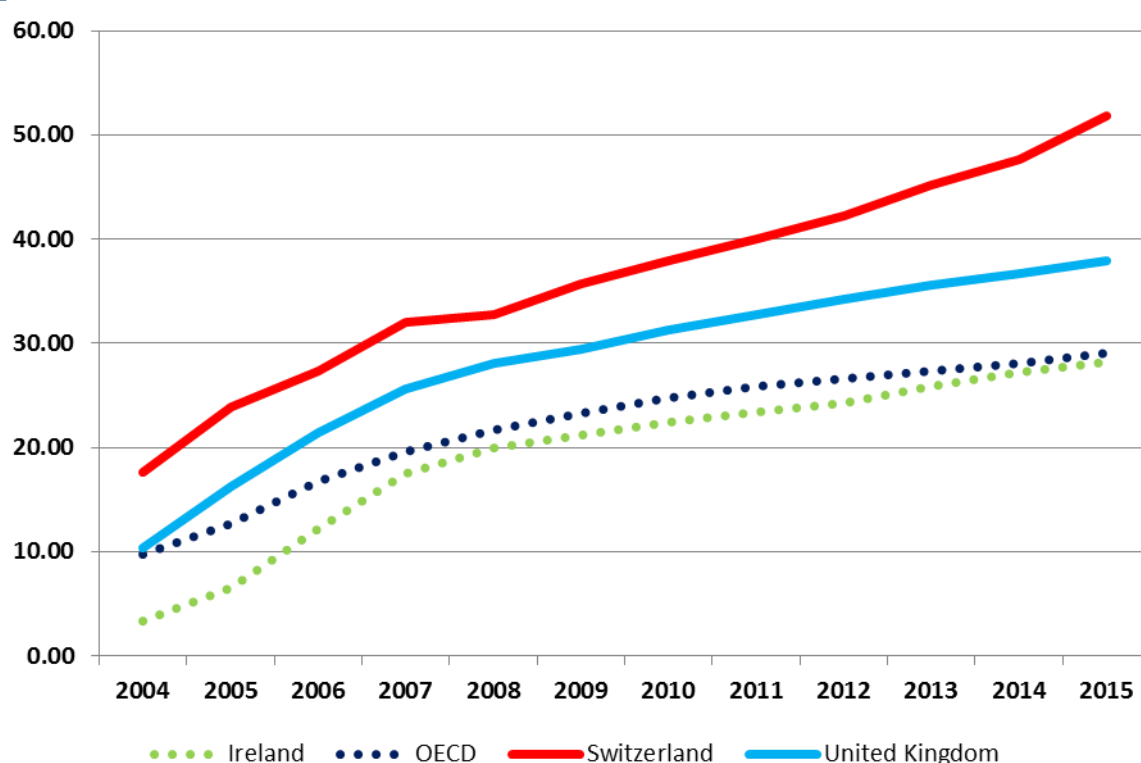
## 5.2 Broadband performance

The Republic’s fixed-line broadband penetration rate (a useful proxy for broadband diffusion) has remained in the bottom half of OECD countries since the broadband diffusion process began in the Republic in the early years of the 21<sup>st</sup> century.<sup>12</sup> Data from the OECD (2017) broadband portal shows that the number of fixed broadband subscriptions per 100 persons in the Republic was 28.2 in 2015. This was reasonably close to the OECD median of 30.3 but far below the best performing countries, for example Switzerland (51.9), Denmark (42.4) and the Netherlands (41.3). The Republic ranks 23<sup>rd</sup> overall in the OECD and

<sup>12</sup> McDonnell (2013) finds that over 80% of the international variation in penetration is explained by the cumulative impact of non-policy related national country endowments and the timing of a country’s broadband take-off. Low population density has been an inhibiting factor in the Republic.

performs poorly in terms of cable subscriptions and especially high-speed fibre subscriptions. There were only 0.1 fibre subscription per 100 persons in 2015 compared to an OECD median of 5.6 subscriptions and the Republic has the 3rd lowest percentage in the OECD of fibre connections in total broadband, exceeding only Greece and Belgium.<sup>13</sup> Broadband penetration improved by 1.75 percentage points in the year to December 2015 and the Republic has been improving slowly relative to the OECD since 2003.<sup>14</sup> However, the Republic has not been improving relative to the top broadband performers such as Switzerland (see Chart 5.2). According to the European Commission (2017) the household penetration rate was 65% in 2015 and 54% in rural areas compared to 72% in the EU and 63% in rural areas.

**Chart 5.2 Fixed Broadband Penetration Rates, Subscriptions per 100 persons**



**Note:** Figures shown are for the fourth quarter of each year.  
**Source:** OECD (2017)

The Republic was a poor performer in terms of broadband quality (speed and cost) in the early years of the 21<sup>st</sup> century but has recently improved to the extent that it is now in the

<sup>13</sup> There is no comparable data for the United Kingdom and Israel.

<sup>14</sup> McDonnell (2013) notes the diffusion path for fixed-line broadband penetration is almost identical to that of the OECD if we adjust for a two year delay in starting the diffusion process relative to most other OECD countries. The Republic's lagging of the OECD may simply reflect the later starting date for initial broadband take-off.

middle of the broadband pack. The Republic is modestly expensive in terms of broadband price. The cheapest available fixed broadband in September 2014 was 28.14 USD PPP per megabit per second (Mbps) compared to an OECD median of 25.18 USD PPP. Download speeds for fixed broadband were better than the OECD median but a little bit worse than the average or mean speed. However, average speeds were less than half of those in Sweden and Japan. Maximum speeds for mobile broadband were at the OECD median.

The Irish government's National Broadband Plan (DCCAE, 2017), which includes an ambitious mapping exercise to establish where commercial operators are delivering broadband services, and therefore ascertain need, has the stated goal of extending high speed broadband to every premise in the country. However, minimum transmission speeds for state-of-the-art data services are likely to continue increasing and there are concerns that the 30Mbps targets will insufficiently future proof the broadband network.

Finally, the Republic is doing well in terms of next generation access (high-speed access) with 79.7% of the population covered in June 2015 compared to 70.9% for the EU. The Republic does not do as well in terms of rural access with just 24.9% of the population covered compared to 27.8% for the EU (European Commission, 2017). The Republic does better in terms of mobile access with rural coverage for 4G mobile ranked 9<sup>th</sup> in the EU at 73%. However, access of fibre to the premises was the 3<sup>rd</sup> lowest in the EU as of June 2015.

### ***5.3 Innovation inputs***

Perhaps the most fundamental area of concern is the need to improve in relation to innovation investments. This includes public supports for R&D and education as well as innovation investments by enterprises. Berlitz et al. (2015) find that an increase of one percentage point of R&D spending in the economy leads to a short-term average increase in GDP growth of approximately 0.05 to 0.15 percentage points. According to the OECD (2016), the republic's GERD intensity was just 1.49% of GDP in 2014 compared to 2.38% in the OECD. Publically financed R&D was 0.40% of GDP compared to 0.61% in the OECD while business expenditure on R&D (BERD) was 1.09% of GDP compared to 1.77% for the OECD.<sup>15</sup>

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<sup>15</sup> The Republic was 11<sup>th</sup> in the EU28 in 2011 with a BERD intensity of 1.03% of GDP. However, this was well below the top performers such as Finland (2.56%) and Sweden (2.22%).

The Republic's success in attracting FDI has created a situation where foreign affiliates perform two thirds of BERD (CSO, 2015). Thus, aggregate figures for BERD intensity may conceal a structural weakness in the R&D capacity of indigenous firms. Changes to the international tax environment may lead to a structural slowdown in FDI to the Republic and, if so, one knock-on effect will be a reduction in BERD intensity. The CSO (2015) estimate BERD was €2.11 billion in 2014 of which €1.94 billion was current spending and €165 million was capital. BERD rose from €1.6 billion in 2007 to €1.87 billion in 2009 before falling to €1.76 billion in 2011. BERD then increased to €2.02 billion in 2013, an increase of 15% over 2011.

Large enterprises accounted for 49.5% of spending in 2013 while the largest 100 enterprises in terms of R&D spend accounted for over 70% of total R&D spending. Four fifths (80.5%) of R&D spending took place in the Southern and Eastern region. Just 6% of funding for R&D expenditure was funded from public funds with 90% funded own company/internal funds. There were 2,000 enterprises engaged in R&D activities in 2013 80% of which were Irish. A total of 24,785 persons were engaged in BERD activities with researchers accounting for 55% of all R&D staff. The CSO (2016b) estimate that total innovation expenditure<sup>16</sup> by Irish enterprises was €3.79 billion in 2014. This was a 3.8% increase on 2012 (€3.65 billion) and a 49% increase on 2010 (€2.55 billion). There was a 50.2% increase in in-house R&D between 2010 and 2012 and a 105.2% increase in acquisition of machinery, equipment and software between 2010 and 2014. Foreign owned enterprises accounted for 61% of total innovation expenditure in 2014 and 69.8% of in-house R&D. Overall, 41.8% of firms engaged in technological innovation expenditure.

The Republic spent €182 per capita on public sector R&D in 2014 (Eurostat, 2016a).<sup>17</sup> This compares to expenditure of €219 in the UK; €462 in Sweden, €538 in Denmark and almost €600 in Switzerland and in Norway (see Chart 5.3). While an economy's innovative capacity depends on far more than just the public spend on R&D it is evident that the Republic has significant scope to increase the R&D budget. Finding ways to increase the per

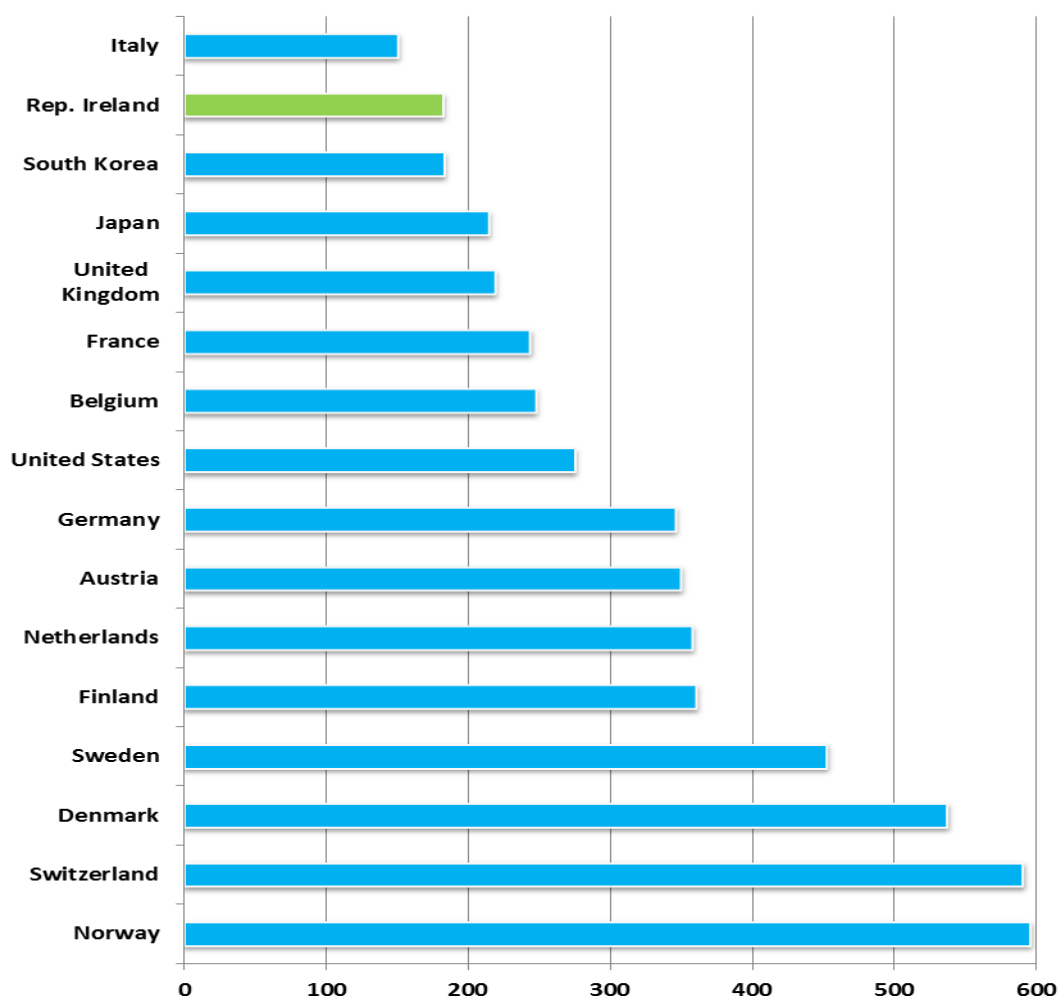
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<sup>16</sup> This includes in-house R&D (€1.88 billion); purchase of external R&D (€0.37 billion); acquisition of machinery equipment and software (€1.24 billion); acquisition of other external knowledge (€0.23 billion), and all other innovation activities (€0.07 billion).

<sup>17</sup> Public spending on R&D in the higher education sector was €684 million in 2014 and €707 million in 2015. Spending in this area peaked at €750 million in 2008 but had declined to €640 million by 2012. Public spending on R&D by the government sector was €130 million in 2014 and €136 million in 2015. Spending in this area also peaked in 2008 (€169 million) before falling to €127 million in 2010.

capita spend (both public and private) from such a low base has the potential to enhance the Republic's long-run growth rate.

**Chart 5.3 Per capita spend on public sector research and development in 2015, selected high income economies, (€)**



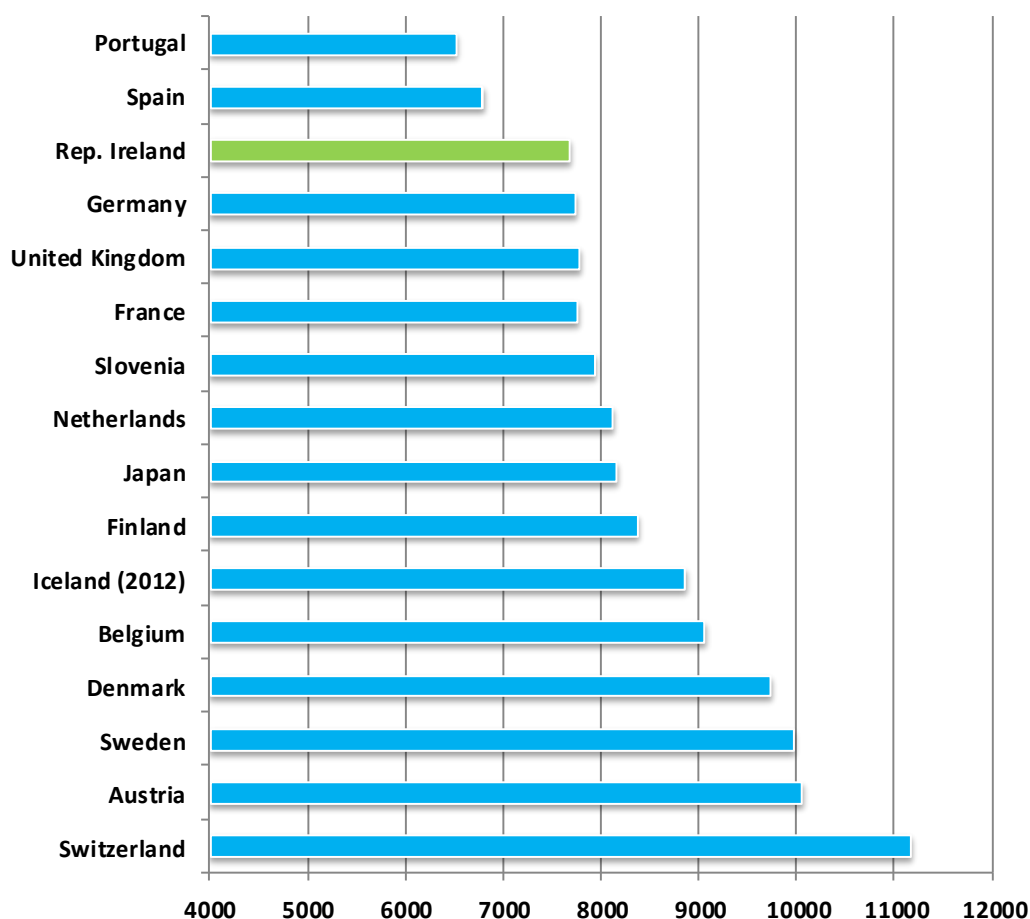
**Notes:** Figures shown are the combined totals for government and higher education R&D expenditure. Definition differs for Germany, Netherlands and the United States. Data is 2014 for Japan, South Korea and Switzerland and 2013 for the United States.

**Sources:** Eurostat (2016a)

Spending on education generates positive externalities for the wider economy to the extent that it represents genuine investment in human capital. Education is a fundamental innovation input. In this context, and despite the Republic having a comparatively young population, it is concerning that government spending on education on a Classification of the Functions of Government (COFOG) basis (Eurostat, 2016b) was just 4.3% of GDP in 2014 compared to 4.9% for the EU, 5.2% for the UK, 6.5% for Sweden and 7.2% for Denmark. The Republic significantly lags the leading countries on a 'per pupil' basis in terms of spending on primary and tertiary education. Increasing the per capita spend on

education to Nordic<sup>18</sup> country levels would increase the Republic's long-run growth potential by enhancing labour force and economy-wide innovative and productive capacity.

**Chart 5.4 Public spending on education institutions per pupil (FTE) in 2013, selected countries (PPS)**



**Notes:** FTE is Full Time Equivalent. Figures are the total for all International Standard Classification of Education levels (ISCED 2011) excluding early childhood educational development. Figures are for public institutions and are expressed in purchasing power standard.

**Source:** Eurostat (2016c)

## 6. POLICY CONSIDERATIONS AND CONCLUSIONS

The importance of R&D spending has been highlighted repeatedly in this paper. However, new ideas and innovations, and how they are generated and diffused, are different from R&D, and often do not result from R&D. A simple focus on R&D would therefore be unwise as innovative capacity depends on more than just R&D. The economy's innovative capacity is a function of education and skills levels, the cost of acquiring knowledge, government

<sup>18</sup> The Nordic countries are Denmark, Sweden, Finland, Norway and Iceland. The Republic of Ireland spent 7,663.4 per pupil in 2013 on a PPS basis. The Nordic country average with Norway data unavailable was 9,230.4 on a PPS basis, or 20% more per pupil than the amount spent in the Republic of Ireland. Switzerland spends over 45% more per pupil than does the Republic of Ireland.

policies that support R&D, and the quality of capital markets, among other things. For example, there is evidence the diffusion of Information Communication Technologies (ICT) has been aided by complementary investments in intangible capital and high-quality human capital, while the availability of finance has implications for a firm's ability to invest in new technology (diffusion) as well as R&D.

The OECD (2013) has made a number of recommendations in relation to the Republic's innovation policy. The main recommendations were:

- Drastically consolidate funding and actions into a smaller number of government agencies in order to increase the effectiveness and cost-efficiency of innovation and research policies and in order to make it easier for business to access support.<sup>19</sup>
- Set up an outward facing one-stop-shop for enterprises to help them connect with the broader innovation system and increase awareness of financial supports for innovation.<sup>20</sup>
- Have independent and regular evaluation of the various innovation policy tools with a view to strengthening programmes with high returns and shutting down programmes with poor returns.
- Give HEIs multi-year funding envelopes in order to better enable them to employ researchers and engage in medium-term research.

Each of these recommendations is sensible. One caveat is that knowledge generation can take time and the advantages gained by constantly shifting resources between programmes as the OECD propose must be weighed against the possibility that too many changes to policy could itself undermine the innovation process or potentially cut-short research programmes with long gestation requirements before they are able to reach fruition. This suggests the need for minimum time horizons for funding. Further suggestions are outlined in the remainder of this section.

## ***6.1 The entrepreneurial state***

Seán Ó Riain (2013) argues that government has played a critical role in the growth and development of successful innovation economies in countries as different as Finland, the

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<sup>19</sup> They pointed out that there were over 170 budget lines, sometimes for small amounts of money, and 11 major funding agencies involved in disbursing the science budget despite its small size by international standards.

<sup>20</sup> The point here is that a complicated innovation support infrastructure may create unnecessary barriers to innovation, particularly for organisations with weak absorptive capacity. An outward facing 'one-stop-shop' could encourage technology adoption at the SME level and help such firms connect with the broader innovation system.

United States, Israel and Taiwan, while Mariana Mazzucato (2013a) argues that Germany's successful competitiveness strategy has been driven by its ability to build a strong innovation system, with patient long-term finance (e.g. KfW), strong science-industry links (Fraunhofer institutes) and above average R&D/GDP spending (2.9% in 2012). Ó Riain (2013) notes that, in relative terms, Irish state investments fall well behind the scale of the investments in promising firms made by other countries, including the United States. An increasing number of the best technological innovations in the United States have come from federal labs, federally funded R&D and networks of firms supported through government schemes (Block and Keller, 2009; Mazzucato, 2013b). The case for state led investment is likely to strengthen as the global economy becomes increasingly characterized by secular stagnation and low levels of private investment.

## ***6.2 A safety net for private entrepreneurship and risk-taking***

One way to encourage innovation, R&D and risk-taking more generally is to ensure there are sufficient safeguards in place so that the cost of failure is not catastrophic for the individual. For example, a bankruptcy regime that doesn't penalize failure encourages greater risk-taking and entrepreneurship and allows entrepreneurs to learn through failure (learning-by-doing) and to then apply the lessons learned in subsequent ventures. Bankruptcy laws and judicial systems that do not excessively penalize failure also help to prevent resources being trapped in inefficient firms that are just struggling along. Failure need to be recognised as an opportunity to learn and rebound, rather than being seen as the end of the game (OECD, 2015). Similarly, social insurance systems should not penalize the formerly self-employed vis-à-vis employees as doing so disincentivises entrepreneurship.

## ***6.3 Career paths for researchers and STEM workers***

Policymakers can incentivise the production and diffusion of innovations by increasing the productivity of R&D and other knowledge production activities. This can be achieved by either reducing the cost of innovation inputs or by improving the quality and efficiency of those inputs. One way to increase the quality of innovation inputs is to invest in human capital. This is because human capital is a complement to the production and exploitation of ideas. There may be an economic case for incentivising (e.g. subsidising) take-up of science, technology, engineering and mathematics (STEM) courses at undergraduate and postgraduate levels to ensure a greater supply of innovating workers with high levels of absorptive capacity. In addition, steps should be taken to ensure there are attractive career paths for STEM workers and researchers. The OECD (2016) cites work proposed by

the Irish Research Council to develop a coherent national strategy to identify and tackle impediments to the career progression and mobility of researchers in the public research system and to provide better career support for PhDs and post-docs. While this will be a very welcome development it needs to be supported through financial commitments.

#### ***6.4 Supports for ICT adoption***

Governments can also support the productivity of innovation activities by investing in those technologies which themselves reduce the cost of knowledge search and the diffusion of useful ideas. Ruttan (2008) makes the point that ICTs have become increasingly pervasive as inputs into the process of technological change. He argues that this is because they greatly increase the productivity of knowledge search and R&D investments, thus encouraging greater private investment in R&D and reducing the degree of market failure in the production of knowledge. This provides a rationale for public intervention to support the development and diffusion of ICTs in general, and Internet access technologies such as broadband in particular. It also provides a rationale for the direct provision of grants to SMEs for the adoption of ICTs.

#### ***6.5 Broadband infrastructure***

Access to high-speed broadband is of particular importance to economic growth because it is a General Purpose Technology (GPT) that boosts the productivity of innovation effort across a wide range of economic sectors including, crucially, the R&D sector (see McDonnell, 2013). While investment in certain forms of infrastructure, for example roads, may only provide a once-off shift in productivity (a level effect), investment in broadband infrastructure may permanently boost the annual rate of innovation and therefore permanently boost the rate of productivity growth. The flip side is that poor quality broadband infrastructure may contribute to lower rates of growth. Ó Riain (2013) argues that weak state investment in broadband in the Republic has constrained the diffusion of new technology industries capabilities into the broader private sector. Belloc, Nicita and Rossi (2012) investigated an array of public policies and found that both supply-side<sup>21</sup> and demand-side<sup>22</sup> policies have a positive impact on broadband penetration, but also that demand-side and supply-side policies are complementary and more effective if taken together.

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<sup>21</sup> These include fiscal incentives, long-term loans programmes, public private partnerships, territorial mapping and initiatives of administrative simplification.

<sup>22</sup> These include provision of incentives for business and household demand, public awareness campaigns, and initiatives of public demand for specific services.

## ***6.6 International patent reform***

The patent system's net effect on innovation levels is unclear. There is little empirical evidence to suggest patents increase innovation and productivity (Boldrin and Levine, 2012) and there may be benefits to reforming the patent system. Jacobson (2013) argues that the unique capabilities of a successful firm to achieve repeated product, process and organizational innovation are better protection of their ideas than patents. Appropriate reforms to the patent system would prevent market incumbents from locking-in advantages, excluding new entrants, and impeding the process of creative destruction so crucial to long-run growth. In particular, patent protection could be made shorter and weaker in certain industries such as the IT sector. Patents could also be subject to use-it-or-lose-it rules. If the inventor hasn't commercialised the invention after a certain number of years other firms could be allowed to use the invention subject to a modest royalty payment for the duration of the patent. Such reforms would have to be pursued at the international level as the impact at the system of innovation level might be counterproductive if the Republic was to pursue them unilaterally.

## ***6.7 Conclusion***

An important point emphasised by the evolutionary, complexity and Schumpeterian schools of economic growth is that there is unlikely to be one 'optimal' policy set or regime that states should aspire to achieve. This implies that innovation policy must constantly evolve and reinvent itself to reflect changing industrial and technological realities and the changing structures of the domestic and global economies. Policy cannot become static while individual policies cannot be assessed or evaluated in isolation from other policies and the underlying system. In any event there is a high level of uncertainty about what type of interventions are effective

This uncertainty does not preclude us from making observations and recommendations. Public investment in R&D and education in the Republic of Ireland appears to be too low while broadband infrastructure in rural area needs upgrading. Remedying these structural weaknesses should be immediate policy priorities.

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