Introduction

Institution Systems, Policies and Management

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I.1 Introduction

This book is about innovation, its policy, its institutional systems and its management. It is the result of an international conference held in Montreal in July 2016 where 290 speakers presented as many papers on innovation. It collects some of the best presentations on the three related topics of innovation: policy, systems and management.

I.2 On Institutions

Institutions are the canvas on which economic activity is knitted (Nelson 2005). All institutions are different from one country to the next, because they show the 'scars' of history (David 1994). We recognize four types of institutions that have an impact on innovation (Niosi 2010).

(a) Public policies that shape economic activity. They include, of course, R&D and innovation policies, but also education policies, financial policies, immigration policies, and other systemic policies. The market for human capital is built by public policies on education and immigration. Countries that require human capital can either train it at home or attract it with adequate policies; in absence of carefully developed education and immigration policies, the labour market will not offer the skilled people the country requires for innovating and developing. And the adoption of advanced technology requires an educated population.
(b) Organizations: all economic and innovative activity takes place within organizations such as private and government-controlled companies, universities, public research laboratories, venture capital firms and others. Organizations are bundles of routines and

capabilities. Firms have different structures in different countries on the basis of human resource availability and strategies required to deal with different environments. Thus, the origins of Japanese and Korean conglomerates are to be found in the small numbers of highly skilled managers in both countries. The routines matter also in public organizations: in some countries (mainly OECD but also some East Asian ones, like Singapore) academic positions are open to all candidates from any nation; in most developing countries, positions are open only to local citizens. Not by chance, research universities in which positions are open to the world are far more productive than those that only recruit local academics (Mohrman et al. 2008). The administration of these organizations has several dimensions, and includes innovation management.

(c) Routines within these organizations: capabilities and routines vary from one organization to the next. All firms are different (Nelson 1994), and also all public organizations are dissimilar. These differences are based on different histories and strategies, and also on the availability of resources in different regional and national contexts. One example will suffice. In most developing countries, government officials are recruited among members of the party in power. In others – mainly OECD and East Asian countries – meritocratic bureaucracies held the key positions in the public administrations. Empirical analysis shows that the quality and stability of public policies depend on the existence of stable and professional meritocratic bureaucracies (Rauch and Evans 2000; Dahlström et al. 2012).

(d) Culture: this is the most 'opaque' but nonetheless determinant, among the four components of the institutional canvas (Inglehart and Baker 2000). Religion, the treatment of women, castes, immigrants and ethnic minorities are among the most important. Religion first: as Weber noticed a century ago, Protestant countries are on average more developed than Catholic, and these more advanced than Islamic countries, but within each nation, values tend to be homogeneous following the cultural majority. Thus German Catholics' cultural and economic behaviour is similar to that of German Protestants. In addition, ethnic and religious fractionalization has a negative effect on economic development because of the probability of civil conflict (Montalvo and Reynal-Querol 2005). Second, culture includes also public attitudes

towards women in education and employment: it is clear that countries where women are barred from higher education and job opportunities will experience less innovation and economic development because an important part of the population is excluded from economic activity (Metcalfe 2011). Finally, the treatment of ethnic minorities is also crucial. India is unique in its caste system that affects a quarter of its population, and has not disappeared because of the meritocratic requirements of public office (Subramanian 2015). On the other hand, most OECD countries, including Canada, Finland, Japan, New Zealand, Singapore, South Korea, the United Kingdom and the United States have different affirmative action policies, and several of them welcome educated immigrants. In the Gulf countries, conversely, it is extremely difficult for an immigrant to obtain citizenship, including migrants from other Muslim countries.

I.3 On Innovation Policies

More often than not, neoclassical economics is blind to policy interventions. For many of these economists, at least theoretically if not always in their day-to-day practice, markets are supposed to be efficient enough not to need government inputs: Adam Smith's invisible hand should provide innovation through the benefits of specialization and the division of labour within the market and within the firm (Pavitt 1998). Individuals endowed with rational choice and perfect information do not need advice or incentives from policy makers.

Yet, in Solow's model, innovation is exogenous to the market and thus there is an opportunity for government intervention (mainly through university or public sector research). Another, more recent approach with a more Schumpeterian flavour would argue in favour of endogenous innovation within a neoclassical growth model (Grossman and Helpman 1991). This current would accept policy intervention, but proposes 'one-size-fits-all' horizontal policies such as tax credits for R&D (Mohnen in this volume).

Other economic evolutionary currents exist and they are not Schumpeterian. Rahmeyer (2012) has emphasized that in Marshall, innovation and economic development are a side effect of the normal manufacturing process and the division of labour, an approach that is close to

the gradual approach of Adam Smith, where the competitive forces of the environment lead to economic evolution. Also, both the Product life cycle (Vernon 1966) and the Industry life cycle (Klepper 1997) economic approaches are evolutionary but they are not Schumpeterian.

I.3.1 Innovation Policy for Incremental Innovation

Innovation policy has been interpreted in two different senses. The narrow definition is the policies that are meant to affect innovation (i.e. tax credits for R&D). The broad definition includes all policies that have an impact on innovation, such as venture capital policies or higher education policies (Fagerberg 2016).

The differences between incremental and radical innovations have been many times discussed but no generally admitted definition exists. Table I.1 recalls some of the differences between incremental and radical innovation.

Table I.1 *Incremental and radical innovation compared*

Dimension of radicalness	Incremental	Radical	Authors
Impact on the industry	Low	High	Acemoglu & Cao (2015)
Source of subsequent innovation	No	Yes	Ahuja & Lampert (2011)
Older technology remains substitute for new	Yes	No	Arrow (1962)
Cost reductions	Low	High	Green (1995)
Competitive advantage to adopters	Low	High	Kumar et al. (2000)
Benefits brought if successful	Low	High	Kumar et al. (2000)
Adoption risks	Low	High	Kumar et al. (2000)
Technical uncertainty levels	Low	High	O'Connor et al. (2013)
Market uncertainty levels	Low	High	O'Connor et al. (2013)
Resource uncertainty levels	Low	High	O'Connor et al. (2013)
Organizational uncertainty levels	Low	High	O'Connor et al. (2013)

At the basis of an evolutionary economic policy, one must consider several key facts. First, innovative activities are endogenous to the economic system because firms must regularly introduce new products and processes in order to survive in competitive markets. But all firms and sectors are different, thus one-size-fits all innovation policy is not the best type of incentive for innovation. Innovation policies are key components of innovation systems. Second, uncertainty, not just risk, pervades decisions about R&D and innovation; economic agents only know ex-post the results of such investments. Trial and error is part of any technical choice by private firms. Third, therefore, agents do not maximize revenues or profits; within the same industry, firms look for different solutions because they do not know ex-ante the correct answer, and they have different assets and capabilities. Variety is thus another major consequence of bounded rationality. Fourth, asymmetric knowledge is not a hindrance to the performance of the market, but often the source of profits and technological breakthroughs, thus the source of economic growth: some agents know technologies and related opportunities that others do not know, and they create new products or processes that create destruction of competitors (and profits to the innovators) or imitation and radical innovation, or innovation cascades (series of radical innovations). Fifth, externalities do represent market failures,[1] but they are also the sources of economic growth, as knowledge leaks out of the original innovator and creates both consumer and producer benefits. Finally, perfect competition may not be a desirable state of the economic markets: almost all modern inventions have come either from monopolistic and oligopolistic markets, or from universities and government or non-profit laboratories. On the basis of such theoretical premises, Lipsey and Carlaw (1998) arrived to the same policy implications on the basis of the observation of rapid catching-up in South East Asia: there are no ready-made one-size-fits -all policy sets for technological change or human capital. Each catching-up country must devise its own set of innovation policies on the basis of its specific endowment of natural resources, human capital, internal market characteristics and government capabilities. One of the

[1] Lipsey and Carlaw propose to keep the market failure concept, but to redefine it. 'Whereas in neoclassical theory the market fails when it does not achieve the unique optimal equilibrium, it fails in the structuralist-evolutionary theory when it does not lead to some desirable and attainable state' (Lipsey and Carlaw 1998).

goals of this book is, however, to try to uncover some important regularities in the implementation of such policies.

Evolutionary economics, comprising uncertainty and risk, believes policy in general and innovation policy in particular is needed to foster economic growth, and proposes to keep open alternatives. Not only do economic agents not have complete knowledge about their choices but also the spectrum of available choices is fairly opaque, and is continuously changing. Take, for instance, today's energy policy. Technical change is very fast in most renewable energy options. The race between solar, hydro, wind, geothermic, biomass and wave solutions is far from showing a clear winner, even if today solar photovoltaic is starting to take the lead. In addition, the combination of these technologies may change from one region to the other according to particular natural conditions. Evolutionary innovation policy would suggest keeping open several of these routes to solve climate change problems and reduce global warming.

The innovation policy choices become more complex and costly when one thinks that innovation institutions form innovation systems: sectoral technologies are complex systems in themselves, and technical solutions evolve. Also, within the same technical choice, several alternative policy instruments may be required, from direct subsidies to private sector innovation and R&D, to mission-oriented policies such as the establishment of government laboratories, incentives to academic research and industry-university consortia, to the development of a venture capital industry or increasingly 'grand-challenge' policies. Table I.2 shows the links between the kind of innovation aimed at and the type of innovation policy.

One short example will suffice. A country adopting solar PV renewable energy will have to decide whether to put efforts into improving solar cells (semiconductors), advanced solar glass, batteries, mechatronics or other components. Also, it has to decide whether to keep doing basic research (i.e. on solar cells and batteries), or aim at applied research on mechatronics, advanced glass or microgrids.

I.3.2 Innovation Policy for Radical and Cascade Innovation: From Path-Following Innovation Policy to Path Creating, Mission-Oriented and Grand Challenge Policies

In addition, neoclassical economics explains government policy on the basis of the need of reducing market failures. Other authors with a less

Table I.2 ***Grand challenges, incremental and mission-oriented innovation policies***

Innovation policies	Incremental	Mission-oriented	Grand challenges
Time span	Permanent or long term	Permanent	Short to medium term
Goal	Induce incremental innovation, path following	Continuous support to important sectors, for radical or incremental innovation	Strong effort to solve a STI or a social major problem or create an innovation or a new institutional path
Examples	Tax credits for R&D (i. e. SR&ED, Canada)	Agriculture, climate change, defense, health, green energy, transportation and space policies	Human Genome Project International (1990–2003) US SunShot Initiative (2011/2020)
Initiative of projects	Companies	National Governments	National governments
Institutional forms	An agency runs the program (i.e. IRAP, Canada)	Government laboratory, permanent program	National public/ private partnerships and/ or international coalition
Authors	Bloom et al (2002)	Mowery (2009)	Ulnicane (2016)

neoclassical flavour argue that system failures explain government policy. Such system failures were defined as those related to the 'institutional setting, market structure and governance issues' (Avnimelech and Teubal 2008: 154). Of course, governments are part of the economic system, but only they have the legal authority to modify the institutional setting, the rules of the game, market structures and governance issues. Both types of innovation policy are usually aimed at incremental and path-following technical change. More recently, on the basis of Asian rapid industrialization but also on the experience of OECD countries'

Great Challenges innovation policies (i.e. the EU Framework Programs, the international Human Genome Program or the Human Proteome Program, or the US SunShot Initiative) it has been argued that innovation policy should not concentrate on market or system failures but more on attaining public objectives of great importance, key missions at the national or international levels, and/or market creation. Such goals may also be pursued at the regional level, such as California's stem cell policy or solar policy (Taylor 2008; Foray et al. 2012; Mazzucato 2016). The concept of path creation has also been used to describe regional innovation ruptures from path dependency and local inertia (Dijk and Yarme 2010; Essletzbichler 2012; Lee 2013). Regional path-creating policy strategies are covered by the concept of 'smart specialization strategies' (see Foray in this book). Lee (2013) has analyzed national path-creating catching-up strategies in South Korea. Historical experiences have shown that path dependence and inertia can be broken by an accumulation of resources and political forces in large projects.

Grand challenge policy is more a path-creating than a path-following public intervention (Schienstock 2007; Foray et al. 2012; Sidow et al. 2012). Grand challenge policy is not a short-term type of policy, but a long-term type of public intervention. Some of the most astounding grand challenges were those of the Human Genome and Human Proteome projects that opened entirely new fields of research. But they are far from unique.[2]

This, far from simple, evolutionary innovation policy sees a range of strategy options within innovation systems.

I.4 Innovation Systems

Innovation systems literature represented a major advance in the study of innovation policies. Institutions promoting the production, diffusion

[2] In China, the national and provincial governments have been producing grand challenge policies in several areas such as high-speed trains (Sun 2015), satellites (Erikson 2014) and others. Since the early 2000s, more modestly, US DARPA has launched a series of grand challenges. In 2004–5 DARPA launched a grand challenge for a completely automated vehicle. In 2012, the Robotics Grand Challenge aimed at creating a humanoid robot able to execute complex tasks. In June 2014, DARPA launched the Cyber Grand Challenge (CGC), a competition designed to spur innovation in fully automated software vulnerability analysis and repair. Since 2004, the Gates Foundation has launched a series of grand challenges to solve health and development problems.

and adoption of scientific and technical knowledge were shown to be part of a system, a set of organizations, policies, routines and cultures that have a major impact on the economic performance of the national firms of a country (Nelson 1993). Innovation systems literature distinguishes national systems from regional and sectoral systems.

I.4.1 National Systems

Most of the key innovation institutions in any country are national by scope (Nelson 1993). These include the largest public R&D laboratories, the main universities, the inclusive innovation policies such as tax credits for R&D, cluster policies, venture capital incentives, direct subsidies for R&D and the like. Their impact is felt on the entire nation, within national boundaries, depending of course on the absorptive capabilities of each region.

A national system of innovation is the system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology (Niosi, Saviotti, Bellon and Crow 1993).

The concept was born in the works of Christopher Freeman, Bengt-Ake Lundvall and Richard Nelson, but it has attained widespread global adoption (see Tregua et al. in this volume). Mohnen and Röller (2005) have given empirical and theoretical support to the innovation system concept: they showed that 'the whole is better than the parts', meaning that for companies to adopt innovation practices, a whole package of complementary policies is necessary. Yet, vertically oriented policies tend to increase private firms' innovation efforts.

I.4.2 Regional Innovation Systems

Within any nation, innovative activities are concentrated in particular regions (most often large metropolitan areas) (Feldman and Audretsch 1999).

Regions which possess the full panoply of innovation organizations set in an institutional milieu, where systemic linkage and interactive communication

among the innovation actors is normal, approach the designation of regional innovation systems. (Cooke and Morgan 1998: 71)

The regional perspective does not reduce the importance of the national systems approach. It is complementary to it. Provinces, states, *lander*, municipalities and other subnational levels of government may design and implement policies that strengthen their regional innovation capabilities. In federal countries, like Canada, Germany and the United States, subnational governments have their own innovation institutions. Even supranational governments can nurture regional innovation, like the EU Smart Specialization Program (Foray, in this volume). In addition, regional knowledge externalities, based on proximity, are more evident in metropolitan areas than in entire countries, even when the country is small. Regional policies include specialized public research organizations, universities and regional grants.

I.4.3 Sectoral Innovation Systems

From another angle, sectoral innovation systems (innovation institutions centred on a product or group of products) are also components of a national and international system (Malerba, in this volume). Sectoral systems are international by definition. These are sectors like aerospace, biotechnology or nanotechnology. These sectors are often but not only identical to industries defined by a SIC or NAICS code. They include, in addition to industries, the framing institutions such as national laboratories, vertical policies and academic programmes (OECD 2006a). Other key elements of sectoral systems are the appropriability, cumulativeness and opportunity of the technological regime, the number of innovators and their geographical dispersion (Malerba 2004 and 2005). Yet, it has been shown that the number of innovators varies with the industry life cycle and the type of sector (Klepper 1997).

Also, some sectors are born extremely dispersed and then tend to concentrate, such as aircraft and car production, biotechnology and software services, as argued by the PLC-ILC framework. Other sectors are prone to variety, thus to increasing dispersion, such as computers and semi-conductors (Saviotti 1996; Niosi 2000a).

Thus, the Mark I – Mark II classification does not exhaust the different initial conditions and later evolution of sectors and, implicitly, this dychotomic classification suggests that Mark I sectors always