Research Policy xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

# Innovation in times of crisis: National Systems of Innovation, structure, and demand☆

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ARTICLE INFO

*Article history:*
Received 17 July 2009
Received in revised form 31 August 2010
Accepted 2 September 2010
Available online xxx

*Keywords:*
Persistency of innovation
Business cycles
National System of Innovation
European Innovation Policy
Economic crisis

ABSTRACT

This article addresses the impact of the current economic downturn on innovation across Europe. Using micro- and macro-data, we investigate to what extent some structural characteristics of National Systems of Innovation, along with demand, affect firms' persistency in terms of innovation investment. It emerges that the effects of the economic downturn in terms of firms' innovation investment are not the same across European countries. The competences and quality of the human resources, the specialization in the high-technology sector, together with the development of the financial system seem to be the structural factors which are able to offset the effect of the economic downturn on innovation investments of firms across Europe. Finally, some considerations about policies during recessions are discussed.



## 1. Introduction

Strangely enough, economists of innovation are not participating in the debate about the causes and impact of the ongoing global crisis (for an exception, see Perez, 2009a). This is probably due to a general belief that innovation has little to do with economic crises. However, since Schumpeter we have known that innovation is a fundamental source of economic fluctuations. Following his contribution on business cycles (Schumpeter, 1939), the relationship between innovation and the dynamics of economic development has been largely addressed in the "long waves" literature following the 1970s recession (Mensch, 1979; Van Duijn, 1983; Freeman, 1984; Tylecote, 1992; Perez, 2002). Concerning the relationship between innovation and business cycles, two extreme hypotheses can be outlined: according to the first, innovation is *cyclical* and therefore firms tend to reduce their innovation efforts during the downswing of the economy, while according to the second, it is instead *counter-cyclical* and claims that recessions are a fertile environment for firms to innovate.

The macroeconomic dynamic is the result of firms' behaviours: while some firms will exhibit a *persistency* in investing in innovation during recessions, others will not. Persistency of innovative activities can be contingent on several factors. Some can depend on firm-specific characteristics, such as strategies, management's attitude, stage of development and so on. Others can impinge on the cumulative and path-dependent nature of innovation, technological change and scientific research. Particular trends of cash flows and profits can also play a role. Finally, industry-specific dynamics of the demand, profit opportunities and technological opportunities can also play a part. However, a good deal of theoretical, empirical and historical research has demonstrated that the national institutional setting has a major impact upon how the economic agents behave and how firms perform (Freeman, 1995; Hall and Soskice, 2001; Nelson, 2001; North, 2005). National institutions shape not only the structural conditions of countries, but also *their ability to respond to changes*. We assume that this is even more prominent in the event of a major economic downturn. The National System of Innovation (NSI) approach – an institutional conception *par excellence* – has framed innovative activities and the way firms do things within the institutional national context (Lundvall, 1992; Nelson, 1993; Freeman, 1995). This paper aims to investigate the role that structural characteristics of NSI, along with demand, play in explaining persistency in the innovation behaviour of the firm during a major recession.

☆ We wish to thank the editor, three reviewers, Marion Frenz, Frederick Guy for their comments to a previous version of the paper. We also benefited from the comments received at a Conference held at the University Bocconi of Milan, September 2009, at a seminar at SPRU, University of Sussex, October 2009. Thanks to Hugo Hollanders, Keith Sequeira, to the DG Enterprises and Industry of the European Commission for allowing us to use the data of the Innobarometer and the European Innovation Scoreboard. Last but not least, we wish to thank Gary Sheumack, Andrew Szabados for English language revisions.

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doi:10.1016/j.respol.2010.09.001

A major drop in demand represents the usual landscape throughout severe recessions. While scholars largely accept the fact that a major fall in demand would bring about a reduction in innovation activity, other fundamental issues are at stake here. How important are structural characteristics of the countries vis-à-vis the dynamic of the demand? Further, what are the structural dimensions that are more relevant? How do structural dimensions and demand interact at the country level? These questions are central for a broader understanding of the role played by national institutions and policies – as encompassed along the NSI dimensions – as a source of persistency of innovation over the business cycle. The NSI literature has already widely shown the prominence of some country-specific factors in shaping the patterns of innovation of firms (Lundvall, 1992; Nelson, 1993; Malerba and Orsenigo, 1999). Cefis and Orsenigo (2001) have shown persistence of innovative activities in a cross-country comparative perspective. This article builds on this research by shedding some light on the role of country-specific characteristics as determinants of firms' innovation behaviour, in cases of adverse events such as a major financial crisis. This would provide some relevant theoretical insights, as well as policy recommendations for recovery and long-term growth.

Our empirical analysis is carried out merging three sources of data, both at the country and firm level. Data concerning the macroeconomic performance are taken from Eurostat "Euro-indicators", while data related to innovative performance are derived from the *European Innovation Scoreboard 2008* (European Commission, 2009a). Firm-level data are taken from the *Innobarometer Survey 2009* (European Commission, 2009b).

The paper is organised as follows: In the next section, we put forward the theoretical background of the empirical analysis. Section three presents the data sources and the methodology. Section four explores the impact of the recession on firms' innovation investments in a descriptive fashion. Section five presents the results of the econometric analysis addressing the differences of the firms' innovation behaviours across the different countries. Section six discusses the results, suggests some policy implications, and points out the limitation of the analysis. Finally, the last section contains our conclusion.

## 2. National Systems of Innovation and the persistence of innovation during recessions: structure, investment, and demand

### 2.1. National Systems of Innovation and the persistence of innovation

The NSI concept rests on one fact and two well-established beliefs: (i) countries exhibit systematic differences in terms of economic performance; (ii) the latter largely depends on different technological and innovation capabilities on the one side, and development of institutions on the other side (Castellacci, 2008; Fagerberg and Srholec, 2008; North, 1990, 2005; Fagerberg, 1994; Landes, 1998; Mokyr, 2002); (iii) innovation and technology policies are an effective tool for fostering innovation performance of countries. The way in which firms carry out innovation activities and set their learning processes is affected by a number of specific national factors (Archibugi and Pianta, 1992; Archibugi and Michie, 1997; Lorenz and Lundvall, 2006), including the nature of the scientific and technological institutions, the education and training system, the financial system, the structure of the labour market, and industrial specialization.

The NSI structure has also been associated to the persistent nature of innovation activities. Innovative activities are cumulative and persistent at the micro level (Nelson and Winter, 1982; Geroski et al., 1997; Patel and Pavitt, 1997; Cefis and Orsenigo, 2001). Previous literature has already shown how the sectoral dimensions of patterns of innovation are country specific (Malerba and Orsenigo, 1996, 1999) as well as firms' persistency in innovating (Cefis and Orsenigo, 2001). Building on this literature, we explore whether some structural features of the NSI also affect firms' innovation behaviour in cases of economic downturn. Investigating the role played by some specific characteristics of the NSI in relation to exogenous shocks is something new and worth exploring, and also raises some key issues. Do countries which have been accumulating larger "stocks" of knowledge embodied in human resources, learning institutions and companies show a greater persistency in their innovative activities? Which kind of industrial structure and technological specialization is more sensitive to a macroeconomic shock in terms of innovation? In what follows, we develop on the conceptualization of NSI in order to derive the central argument to this paper's analysis.

In their conceptualization of NSI, Lundvall and colleagues (Lundvall, 1992; Lundvall et al., 2002) go beyond the *"technonationalism"* that had inspired Nelson's conceptualization of NSI (Nelson, 1993), in order to recognize that the ability of countries to foster innovation is dependent upon social capabilities, that are not solely based on science and technology. Within this broadened context "the national system of innovation is constituted by the institutions and economic structure affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993, p. 267). At the core of the latter definition of NSI resides the microeconomic theory of innovation derived from the Neo-Schumpeterian strand of literature, the assumptions of bounded rationality of agents, the role of tacit knowledge, as well as the role played by institutions on economic activities. Regarding the former, the main message taken on board in the NSI is the systemic nature of innovation activity. Firms carry out innovation through extensive interactions with several actors outside their boundaries, such as universities, research centres, users and suppliers. Crucially, this activity occurs within a specific (national) institutional context.

A large body of research has shown the substantial role played by institutions in influencing the behaviour of firms (Hall and Soskice, 2001), their organizational structures (Coriat and Weinstein, 2002), as well as the patterns of economic change (North, 1990, 2005). Here it is enough to say that institutions, as broadly defined as the rules of the game, represent both a *constraint* and *a source opportunity* for agents within economic systems. The way firms innovate, search and learn over time, is then importantly affected by a large array of institutions including the way labour market works, industrial patterns of specialization, industrial relationships, education system and financial structure. In this paper we refer to the current NSI characteristics of countries as *structure.* The current structure of countries can be understood as the result of a path-dependent process. NSI configurations of countries are the outcome of historical processes in which the development of firms, organizations, and industries, interacted with national policies and institutional development over time (Fagerberg et al., 2009).

In order to put forward our central argument, we take stock of three major insights drawing from the discussion carried out so far. (i) NSI characteristics heavily affect firms patterns of innovation and learning. (ii) These characteristics are the result of path-dependent processes in which firms' organizational structures and industrial specialization co-evolved along institutional change and national policies. This leads to different, and sometimes divergent, paths of learning and development of the states that ultimately brings about (iii) considerable cross-country *differences* in their structures. This brings us to the main concern of the paper. That is, to investigate the role of systematic differences in the structures of countries, along with demand, in explaining persistency in the innovation behaviour of the firm during a major recession.

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### 2.2. The considered dimensions of National Innovation Systems

A number of factors play a role in shaping the national environment and affect firms' innovation behaviours during an economic downturn. Already Schumpeter emphasized the relationship between finance and innovation (Schumpeter, 1934. For recent analyses see Santarelli, 1995; O'Sullivan, 2005). A robust financial system might play a role in macroeconomic shocks if it can provide firms with resources to be invested in innovative activities. Inasmuch as firms are inclined to rely on internal funds to finance their innovation activities (see O'Sullivan for the current debate on this point, 2005), the financial constraint is very likely to play a major role during recessions. Different levels of education and training systems of the labour force, together with different configurations of the labour market and welfare state, can generate different patterns of recovery since workers can be easily transferred from mature towards growing sectors of the economy (OECD, 2009b). Finally, a different industrial specialization, e.g. in high-tech manufacturing or knowledge-intensive service sector, could lead to a different impact of the depression on firms' innovation investment depending on the magnitude of the drop in the domestic and external demand across the sectors.

In the empirical analysis carried out in the second part of this paper, four main components of the NSI structure are taken into account: (i) the quality of the "stock" of the human resources of a country, in terms of levels of education and participation in life-long learning activities; (ii) the stock of accumulated knowledge, including R&D and non-R&D expenditures, patents, ICT expenditures; (iii) the "financial depth" of the economic system in terms of the share of venture capital investment and credit towards the private sector from deposit-taking financial institutions; (iv) the industrial specialization of the NSI in terms of the relative importance of the high-tech manufacturing sector and the knowledge-intensive service sector.

### 2.3. Investment and innovation over the business cycle

Both Keynes and Schumpeter agreed that decisions to invest play a crucial role in economic fluctuations. But while Keynes and his followers are mostly concerned with investment as the most dynamic and volatile component of aggregate demand, Schumpeter and his followers argue that the nature of investment is equally important in shaping economic trends. Focusing on investment in innovations, the Schumpeterian tradition indicates that attempts to introduce new products and processes in the market are the qualifying condition for economic growth. Freeman et al. (1982) further elaborated on Schumpeter's intuition by claiming that, in adverse economic environments, investments are likely to be reduced because of low profit margin and a general "pessimistic mood", while in periods of economic expansion there are opportunities for new technology systems to emerge. In this article we focus on how a remarkable macroeconomic shock such as the current economic downturn has shaped firms' *innovation investment* in comparison to the previous period.

### 2.4. Demand and innovation

Already Jakob Schmookler (1966) emphasized the role of demand as an innovation driver, pointing out a strong relationship between investment in capital good users industries and patent applications in the same industries. Other scholars have empirically revisited and re-examined Schmookler's hypothesis (see, among others, Scherer, 1982; Kleinknecht and Verspagen, 1990; Brouwer and Kleinknecht, 1999), producing some evidence which lends some support to the demand-pull determinants of innovation at the firm level.

Demand-pull arguments have been suggested both in favour and against the cyclical hypothesis. On the one hand, it has been argued that established firms might delay the introduction of innovations as it requires a diversion of resources from on-going activities because they prefer to exploit the value of their existing rents (Mensch, 1979). Given that the value of existing rents decreases in a recession, in that case firms might be encouraged to introduce new products and processes. On the other hand, two arguments based on the role of demand suggest that innovations are more likely to be introduced during business cycle upswings. The first claims that rising demand during a boom provides more favourable conditions to absorb new products than a recession. The second argument suggests that because firms have only a limited period of time to appropriate the returns from their innovations, they are more likely to introduce new products and processes in an expanding market regardless when they produce them (for a review on this issue, see Geroski and Walters, 1995). Geroski and Walters (1995) also show the presence of a long-run association between the level of demand and innovative activity, and they find that demand appears to Granger to cause innovation. In a recent empirical study at the firm level, Bogliacino and Pianta (2009, p. 28) conclude that demand side factors have a significant influence on the growth of profits and on the innovation-related turnover (see also Crespi and Pianta, 2008; Piva and Vivarelli, 2007).

Given the prominent role played by demand in the current economic downturn (OECD, 2009b; World Bank, 2010), the question addressed here is to which extent the macroeconomic environment, in terms of the drop in the demand is playing a role in firms' decisions about innovation investments. Two sources of demand are taken into account in the analysis: domestic demand and export.

## 3. Data and methodology

Our analysis is grounded on two Reports from the European Commission, the *Innobarometer 2009* and the *European Innovation Scoreboard 2008* (European Commission, 2009a,b). For another analysis of these data, see Kanerva and Hollanders, 2009). The first is a survey which was conducted during April 2009 in the 27 Member States of the EU, Norway and Switzerland, and it is now at its eighth wave. The *Innobarometer* placed the focus on innovation spending at firm-level, including the effects of the economic downturn. Overall, 5238 enterprises across Europe were interviewed according to three main criteria: country, company size (20–49, 50–249, 250+ employees) and activity sector. Both the *Innobarometer 2009* and the *European Innovation Scoreboard 2008* include the same countries and they are thereby suitable for a comparative cross-country analysis.

Regarding the *Innobarometer*, our analysis is based on the following two questions of the survey made on April 2009: (see Table A1 in the Appendix):

1. Question no. 1: "Compared to 2006, has the amount spent by your firm on all innovation activities in 2008 increased, decreased, or stayed approximately the same (adjust for inflation)?"
2. Question no. 2 "In the last six months has your company taken one of the following actions [increased, decreased or maintained the innovation spending] as a direct result of the economic downturn?"

The first question regards the three-year period 2006–2008, and the answers refer to trends of the European firms' innovation spending before the crisis. In turn, the second question aims at cap-

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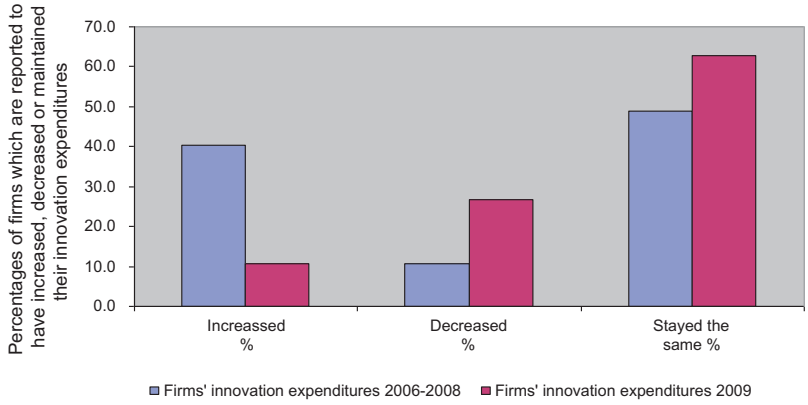


**Fig. 1.** Firms' innovation expenditures: comparison between the three years before the crisis and in response to the crisis.
*Source:* author's elaboration on the two questions of the *Innobarometer* (see Table A1 in the Appendix).

turing the direct effects of the current economic downturn on the firms' innovation investments.

Similarly to the Innobarometer, the *European Innovation Scoreboard* (EIS) is a Report of the European Commission – Directorate General Enterprises and Industry – carried out by the MERIT since 2001.[1] The EIS aims at measuring and comparing the innovation performance at country level using a synthetic composite indicator. For our analysis we will use the current EIS composite indicator (European Commission, 2009a), which is based on 29 indicators addressing several dimensions of a country's system of innovation (see Table A2 in the Appendix for a detailed list of the indicators).

In this paper, we will refer to the EIS composite indicator as *InnoStruct* to emphasize the fact that it provides a structural measure of innovation, in opposition to the *Innobarometer* which instead focuses on medium and short-term innovation investments. The *InnoStruct*, like many other composite indicators of technology indicators, has demonstrated to be a quite stable measure over time (for a review, see Archibugi et al., 2009). Accordingly, in this paper, we take the *InnoStruct* as a measure of the strength of each national system of innovation (Lundvall et al., 2002). The *InnoStruct* is a composite indicator normalised between 0 and 1.

We derived from *Innobarometer* the following two indicators:

1. The *Innovation Investments Indicator* relative to the period 2006–2008 ($InnoInv_{06-08}$), is based on the balance between the percentage of firms increasing and decreasing their innovation expenditures over the period 2006–2008 (see Table A1 in the Appendix). In this way, the $InnoInv_{06-08}$ represents for us a baseline in terms of firms' innovation investments *before* the crisis.
2. The *Innovation Investments Indicator* relative to 2009 ($InnoInv_{09}$), is instead based on the *Innobarometer* question relative to the direct impact of the economic downturn on firms' innovation spending in 2009 (see Table A1 in the Appendix). The $InnoInv_{09}$ is thereby a short-term indicator reflecting the firms' innovation performance *in response* to the crisis.

Similarly to the *InnoStruct* of the EIS, these two indicators are normalized ranging between 0 and 1.

## 4. The impact of the global economic turmoil and the uneven effects on European countries[2]

### 4.1. The effects of the recession on Europe

We explore, in this section, the direct effects of the global economic turmoil on the investments in innovation across European firms. Although our data do not allow us to provide a comprehensive analysis since they reflect the firms' behaviour at one point time only, they help identifying to what extent innovation investment was affected by the 2008 financial shock. In Fig. 1, we plot the average firms' answers relative to the first and second questions of the *Innobarometer*. The responses clearly show that the economic downturn is having a profound impact on the firms' innovation behaviour across Europe. The percentage of firms increasing their innovation expenditures drops dramatically as a direct effect of the crisis, from 40.2% to 10.6%. In turn, the percentage of firms decreasing their innovation spending surges from 10.8% up to 26.7%. However, the presence of a high number of firms which are expected to maintain their innovation spending at the same level, which has increased to more than 60% from about 50%, is also remarkable.

The impact of the economic downturn on firms' innovation spending is also more evident if we look at the data at the country level, reported in Fig. 2. Here we plot the difference between the percentage of firms increasing and decreasing their innovation spending relative to both periods 2006–2008 and 2009. The differences between the results relative to the two periods are striking. If we look along the *x*-axis, reflecting the innovation expenditures over the 2006–2008, all the countries show a positive balance, that is, the percentage of firms increasing their innovation spending is higher than firms decreasing them for *all* the considered countries. But if we turn to the *y*-axis, we see that only *four* countries are resisting above the dot line, which corresponds to a balance equal to zero in 2009. As a direct effect of the economic downturn, in Switzerland, Sweden, Austria and Finland only the percentage of firms declaring to increase their innovation spending is higher than the percentage of firms declaring they disinvest. Across all the other countries, the percentage of firms reducing investments in innovation is higher that those increasing their innovation expenditures. As a whole, the average balance across Europe passed from a 29.4% relative to 2006–2008 period to a −16% in 2009.

Overall, these results are consistent with another survey carried out at the fall of 2008 by the European Commission – Joint Research Centre: "The 2008 EU Survey on R&D Investment Business Trends" (European Commission, 2009c). The results are drawn from 130

[1] Both the Innobarometer and EIS reports can be found at: http://www.proinno-europe.eu/index.cfm?fuseaction=page.display%26topicID=51%26parentID=48.
[2] Both Cyprus and Malta have been excluded from the analysis.

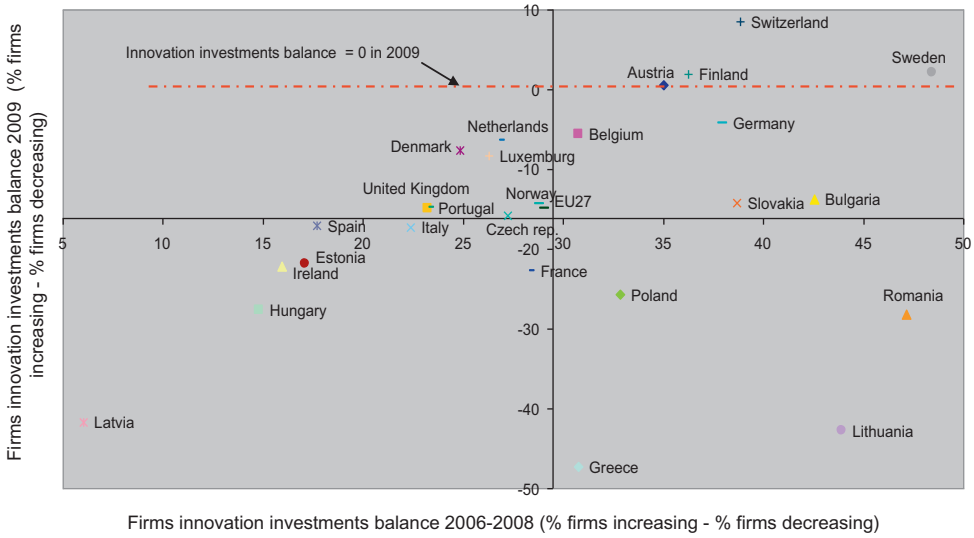


**Fig. 2.** The balances of firms investing and disinvesting in innovation before and after the crisis. *Note:* axis cross at average values. *Source:* as for Fig. 1.

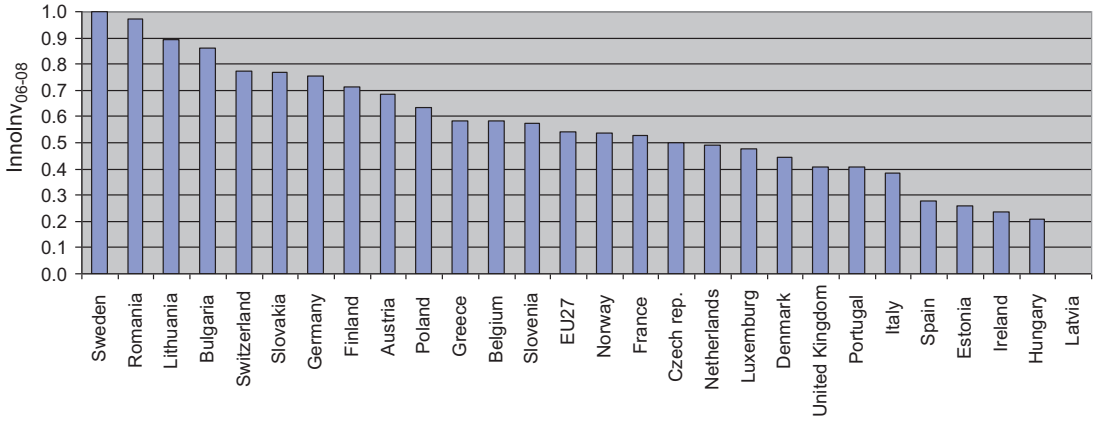


**Fig. 3.** Innovation performance over the period 2006–2008 ($InnoInv_{06-08}$). Calculated on the question no.1 of the Innobarometer:"*Compared to 2006, has the amount spent by your firm on all innovation activities in 2008 increased, decreased, or stayed approximately the same* (*adjust for inflation*)*?*" (see Table A1 in the Appendix). *Source:* author's elaboration on *Innobarometer* data.

responses from the 1000 EU-based companies listed in the 2007 EU Industrial R&D Investment Scoreboard, accounting for 30% of the total R&D investment by the EU Scoreboard companies. They find a significant reduction of expectations of R&D investment, well below these companies' average of the past three years, and relate this outcome (with some caution) to the impact of the economic crisis.

### 4.2. The uneven impact of the crisis across European countries

Fig. 3 shows the results of $InnoInv_{06-08}$ in reference to the situation three years ago. Two groups of countries appear to have further increased their innovative effort: those catching up and the traditional innovation champions. Among the former, we find EU New Member States such as Romania, Lithuania, Bulgaria, Slovakia, Poland and Slovenia, among the latter Sweden, Switzerland, Germany and Finland. Along the political and economic process of convergence undertaken by these countries, most of them have been also catching up in terms of firms' innovation spending with respect to the other Member States (for an assessment on the EU enlargement policies see Von Tunzelmann, 2004).

In Fig. 4, we bring the strength of each NSI on the *y*-axis through an index of structural innovative capacity such as the *InnoStruct* and on the *x*-axis the $InnoInv_{06-08}$ performance (see Section 3). On the grounds of a cluster analysis[3] using the two indexes as variables four groups have been identified:

1. The *Catching-up countries*: although they do not show a high strength of their national innovation system, they have been increasing their investments more than the average relative to the considered period. This group includes five New Member States.
2. The *Frontrunners*: this group consists of those countries which show both a consolidated structural leadership of their innovation performance, and at the same time, they keep increasing their investments in innovation.
3. The *Declining*: these countries which, despite having a strong national innovation system, have been relatively increasing their innovation expenditures less over the 2006–2008 period.
4. Finally, the *Lagging-behind*: is that group of countries characterized both by a low innovation performance at national level and a low performance in firms' innovation spending. Interestingly,

[3] A kmedians cluster analysis has been performed, using group medians from k partitions as a technique of agglomeration.

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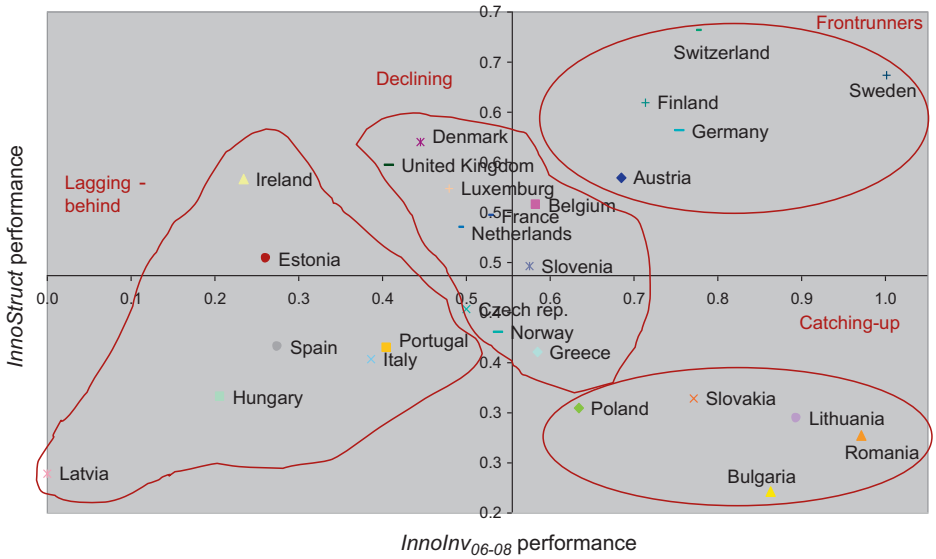


**Fig. 4.** Innovation performance ($InnoInv_{06-08}$) and national innovation system strength (*InnoStruct*). *Note*: axis cross at average values. *Source:* author's elaboration on *Innobarometer* data (as for Fig. 3), and on *EIS* data (see Table A2 in the Appendix).

this group includes both New Member States such as Hungary and Latvia, as well as large countries like Italy and Spain.

As predicted by Neo-Schumpeterian theories, catching-up processes do not occur automatically in response to mere technology gaps (Fagerberg, 1994). From Fig. 4, we observe that the there is a positive trend of alignment of the former socialist block, and now New Member Countries. Most of these countries are among the *Catching-up countries* group, except for Estonia, Latvia and Hungary. Second, the brilliant performance of the *Frontrunners* does not seem to be a hereditary privilege but rather it is the result of systematic efforts which allow their economies to keep on learning along cumulative patterns. While the innovative systems' strength is inherently a structural feature, at the end of the day it is the result of years of know-how accumulation (Pavitt, 1988). Finally, the *Lagging-behind* group includes those countries which are likely to widen their innovation delay in comparison to their direct competitors. To sum up, we do not observe a clear relationship between a structural measure of innovation, such as the strength of the innovation systems, and a measure of firms' innovation before the crisis. This is also confirmed by the low correlation rate between the *InnoStruct* and the $InnoInv_{06-08}$ which is equal to 0.14.

In Fig. 5, we plot on the *y*-axis the *InnoStruct* performance, while on the *x*-axis we report the $InnoInv_{09}$ indicator. In this way, it is possible to explore the effects of the downturn on the groups of countries. First, with respect to Fig. 4, countries belonging to the *Catching-up countries* such as Romania, Lithuania and Poland disappeared from the lower-right quadrant, while Bulgaria and Slovakia moved closer to the *y*-axis. Secondly, a different picture emerges as well in the upper-right quadrant. The five countries included in the *Frontrunners*, namely Sweden, Switzerland, Germany, Finland and Austria are all still there, but together with several other countries which have been moving towards them. Overall, Fig. 5 shows that

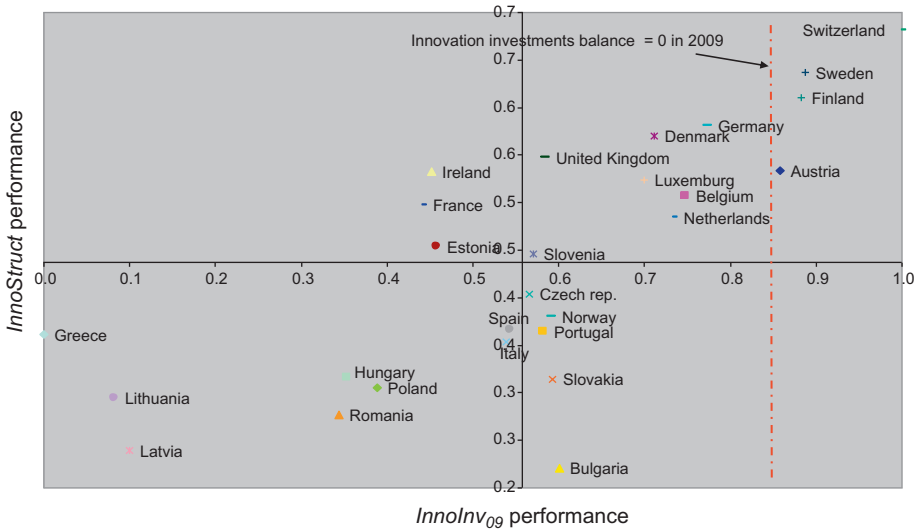


**Fig. 5.** Short-term firms' innovation performance ($InnoInv_{09}$), and national innovation system strength (*InnoStruct*). *Note*: axis cross at average values. *Source:* author's elaboration on question no. 2 of the *Innobarometer* data (see Table A1 in the Appendix), and on *EIS* data (see Table A2 in the Appendix).

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**Table 1**
Change in the behaviour of the firm related to its innovation investment as a response to the crisis vis-à-vis the period before the crisis.

| Variable | Value assumed by the variable | Behaviour of the firm |
|---|---|---|
| Change in innovation behaviour (INVchange) = [−(INVEST2 − INVEST1)] | =1 | Cyclical (e.g. firms which were increasing and pass to maintaining or decreasing in response to the crisis) |
| | =0 | Neutral (e.g. firms which were increasing and keep on increasing) |
| | =−1 | Counter-cyclical (e.g. firms which were decreasing and pass to increasing or maintain) |

*Note*: INVEST1 and INVEST2 relate respectively to the three-year period before the crisis and to the crisis. They are categorical variables which assume the following values: =1 if firm increases investment, =0 if firms maintain investment at the same level, and =−1 if decreases investment.

the relationship between the NSI strength and the firms' innovation behaviour in response to the crisis is much deeper than in Fig. 4. As a consequence of the crisis, the distance between the *Frontrunners* and the other countries is increasing.

To recap, the evidence of this first descriptive part of the paper suggests two major points:

- *The uneven effects of the crisis.* The impact of the current global economic downturn on firms' investment in innovative activities has not been of the same magnitude across European countries. On the contrary, the most struck have been those New Member States which were catching up over the years 2006–2008.
- *Structure matters:* considering the effects of the economic downturn on the firms' innovation behaviour, countries endowed with stronger national innovation systems are also those less affected, in relative terms, by the recession. This clearly emerges in opposition to the 2006–2008 period in which we do not observe a significant relationship between trends in firms' innovation investments and the strength of the NSI.

*Why have countries been affected differently by the crisis? And which characteristics of the NSI which are playing a role in making some countries relatively less affected by the crisis? How are these characteristics relevant vis-à-vis the role of demand?* The next section attempts to answer these questions.

## 5. The uneven effects of the crisis on innovation investment across countries: some explanations

We will now attempt to provide some explanations for the uneven effects of the crisis across countries. Two categories of explanations are addressed: (i) some structural characteristics of the NSI, and (ii) the drop in the domestic demand and export.

### 5.1. The variables

In order to carry out the analysis, a new variable has been developed merging the two main questions from the Innobarometer used in Section 2 (see Table 1). The new dependent variable – INVchange – reflects a change in the behaviour of the firm related to its innovation investment as a response to the crisis vis-à-vis the period before the crisis. Three different behaviours are then identified by juxtaposing firms' innovative behaviours before and in response to the recession: cyclical, neutral and counter-cyclical. Two reasons lead us to construct this new variable. First, it allows summarizing the different behaviours of the firms in the two different periods in one single variable with a relevant gain in the simplicity and robustness of the analysis, as well as in the interpretation of the results. Secondly, it allows looking at the very changes in firms' innovative behaviour in response to the crisis. For example, firms which were decreasing investment in the previous period and keep on decreasing them during the crisis are not considered as changing their behaviour. This allows us to identify the very effect of the crisis in changing the attitude of the firms: cyclical vs. counter-cyclical behaviours.

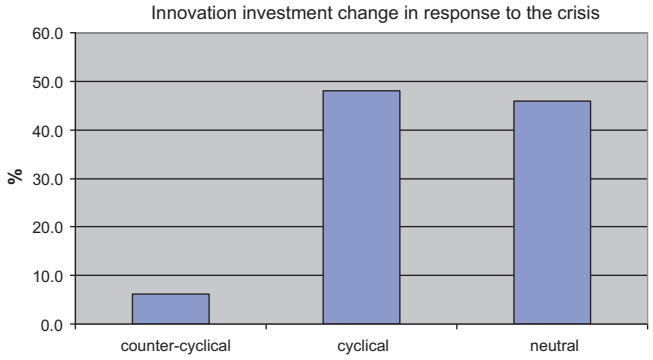


**Fig. 6.** Firms' innovation investment behaviour in response to the crisis. *Source:* author's elaboration on *Innobarometer* data (as for Fig. 1).

In Fig. 6, the INVchange variable is plotted. What emerges clearly is the prominence of the cyclical behaviour of the firms. Nearly fifty per cent of the firms in the sample exhibit a cyclical behaviour, and forty per cent of firms are instead neutral. Finally, only six per cent of the firms in the sample seem inclined to exploit the current situation by investing more in innovation, while in the previous period they were either maintaining or decreasing innovation expenditures. From the operational standpoint, in what follows we try to point out those country-specific features which have a role in offsetting the cyclical behaviour of the firms, and therefore that have a positive influence on persistency of innovation investment. The following different characteristics of the NSI have been derived from the EIS: (i) the stock of knowledge; (ii) the quality of the human resources; (iii) the depth of the financial and credit system; (iv) the specialization of the country (see Table 2; see also Table A3 for the construction of the composite variables "knowledge" and "human resources").

In order to capture the role played by the short-term macroeconomic environment, we build two different variables. The first – domestic demand drop – reflects the drop in the domestic demand of the country and is calculated as the percentage variation between the third term 2009 and the first term 2008. The second – export drop – reflects the drop in the exports of the country and is calculated in the same way over the same period of time. In this way we seek to gage the drop of the demand during the crisis distinguishing among domestic and external demand. In Fig. 7, we report these variables for the countries considered. While the drop in export has been remarkable for nearly every country, there is a good deal of variance in the drop in domestic demand. New Member States, and to a lesser extent Sweden, Ireland and the UK, are facing the larger drops in domestic demand.

Please cite this article in press as: Filippetti, A., Archibugi, D., Innovation in times of crisis: National Systems of Innovation, structure, and demand. Res. Policy (2010), doi:10.1016/j.respol.2010.09.001

**Table 2**
Characteristics of the NSI included in the analysis.

| NIS characteristics | Variable | Indicator |
|---|---|---|
| Stock of knowledge | Business R&D | Business R&D expenditures (% of GDP) |
| | Public R&D | Public R&D expenditures (% of GDP) |
| | Non-R&D expenditure | Non-R&D innovation expenditures (% of turnover) |
| | EPO patents | EPO patents per million population |
| | IT expenditures | IT expenditures (% of GDP) |
| Human resources | S&E and SSH graduates | S&E and SSH graduates per 1000 population aged 20–29 (first stage of tertiary education) |
| | S&E and SSH doctorate graduates | S&E and SSH doctorate graduates per 1000 population aged 25–34 (second stage of tertiary education) |
| | Tertiary education | Population with tertiary education per 100 population aged 25–64 |
| | Life-long learning | Participation in life-long learning per 100 population aged 25–64 |
| | Youth education | Youth education attainment level |
| Credit system | Venture capital | Venture capital (% of GDP) |
| | Private credit | Private credit (% of GDP) |
| Industrial Specialization | Employment in medium-high and high-tech manufacturing | Employment in medium-high and high-tech manufacturing (% of work-force) |
| | Employment in knowledge-intensive services | Employment in knowledge intensive services (% of workforce) |

*Source*: (European Commission, 2009b).

### 5.2. The results

Table 3 presents the "robust" estimates of an ordered logit model in which the dependent variable is INVchange (positive values of the independent variable reflect *cyclical* behaviours of the firm, thus a negative coefficient signals those country-effects which offset cyclical behaviour). Three sets of independent variables are included (correlation rates are reported in Table A4). The first reflects the magnitude of the drops in the domestic demand and export. The second group includes the variables accounting for the characteristics of the NIS. The third group includes the interaction effects between demand effects and NIS effects. Finally, as already stated in the Introduction, both firm-specific and industry-specific factors can play a role in affecting innovation behaviour of the firm during recessions. Accordingly, a set of variables controlling for the individual characteristics of the firms is included. Specifically, we introduce three binary variables at the firm level – i.e. size, innovation intensity and internationalisation – in order to control for firm idiosyncratic effects, together with industry dummies.

In the first model, only the demand effects are included, together with the control variables. Both domestic demand and export are statistically significant and positive. In the first place, this seems to suggest that the drop in demand played a substantial role in explaining the cyclical behaviour of the firms. When in the second model the NSI effects are added, both private credit and technological manufacturing specialization are negative and significant. That is, these are the country characteristics of the NSI which tend to

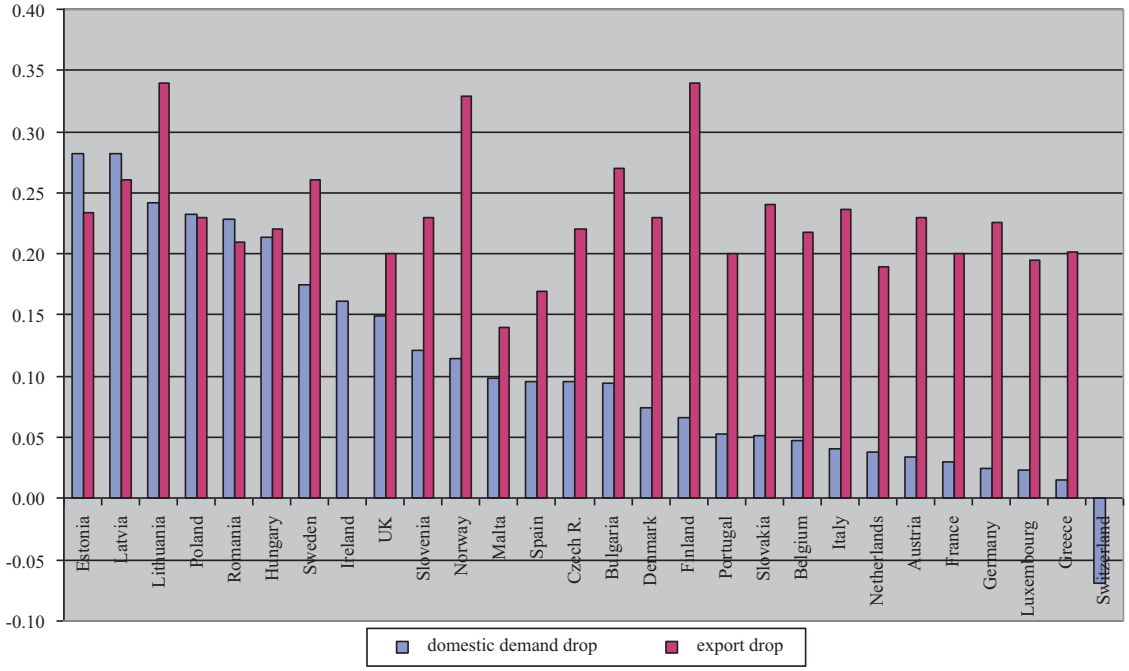


**Fig. 7.** The drops in the domestic demand and export, 1st term 2008–3rd term 2009.
*Source*: author's elaboration on Eurostat data "Euro-indicators".

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**Table 3**
Ordered logit model, robust estimates (dependent variable: INVchange).

| | Model no. 1 | Model no. 2 | Model no. 3 |
|---|---|---|---|
| Demand effects | | | |
| Domestic demand drop | 1.26*** | 0.52 | 0.72 |
| Export drop | 1.72*** | −0.60 | −0.43 |
| National Innovation System effects | | | |
| Knowledge | | 0.07 | 1.82 |
| Human Resources | | −0.13 | 4.77** |
| Venture capital | | −0.02 | −0.15 |
| Private credit | | −0.41*** | −0.54*** |
| High-tech manufacturing specialization | | −0.73*** | −3.33*** |
| Knowledge intensive service specialization | | 0.29 | −2.25** |
| Interaction effects | | | |
| Demand* knowledge | | | 0.19 |
| Demand* human resources | | | −4.81** |
| Demand* high-tech specialization | | | 1.35 |
| Demand* KIS service specialization | | | 2.45** |
| Export* knowledge | | | −1.57 |
| Export* human resources | | | −4.75** |
| Export* high-tech specialization | | | 2.72*** |
| Export* KIS service specialization | | | 3.46** |
| Firm level control variables | | | |
| Medium and large firms | 0.24*** | 0.22*** | 0.22*** |
| Highly innovative firms | 0.78*** | 0.79*** | 0.82*** |
| Internationalised firms | 0.06 | 0.13 | 0.13 |
| Industry dummies | Included | Included | Included |
| Observations | 3072 | 3072 | 3072 |

Robust standard errors in parentheses (country clustered errors provide the same results).
Reference control variables: small firms; low innovative firms.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

offset the cyclical behaviour of firms. In this model demand effects no longer show up as significant.

The third model is a multiplicative interaction model. These models are common in the quantitative political science literature in which it is frequently implied that the relationship between political inputs and outcomes varies depending on the institutional context. It has been acknowledged that the intuition behind the relevance of context, or "context conditionality", is captured quite well by multiplicative interaction models (Friedrich, 1982; Aiken and West, 1991). In interaction models the interaction variables are added to the independent variables – the constitutive variables – which thus take the following form:

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 XZ + \varepsilon \quad (1)$$

In these models usually $Z$ is a binary variable in order to make the results easier to interpret. It should be kept in mind that $\beta_1$ must not be interpreted as the average effect of a change in $X$ on $Y$ as it can in a linear-additive regression model. Rather, $\beta_1$ captures the effect of a one-unit change in $X$ on $Y$ when condition $Z$ is absent. When condition $Z$ is present ($Z = 1$), Eq. (1) becomes:

$$Y = (\beta_0 + \beta_2) + (\beta_1 + \beta_3)X + \varepsilon \quad (2)$$

Hence, the effects of the constitutive variable $X$ is $(\beta_1 + \beta_3)$. Our model includes two sets of constitutive variables, the NIS variables and the demand ones. In this way, we are able to explore the interaction effects of the two different dimensions of a country which, as a matter of fact, interact in reality. Both the drop in demand and export have been transformed into binary variables taking value equal to 1 whether the drop in domestic demand (or export) is higher than the average and 0 if lower.[4]

The results of the third model are shown in Table 3. If we consider the overall effects of the NIS variables (by adding all the related coefficients, see Eq. (2)) the variables offsetting the cyclical behaviour of firms are human resources, private credit and high-tech manufacturing sectors, similarly to the previous model (apart from the human resources coefficient). The only coefficient predicting the overall cyclical behaviour of the firm is the specialization in knowledge-intensive service. By looking at the interaction effects, one can observe the remarkable role played by the presence of qualified human resources in contrasting the cyclical behaviour of the firms in countries characterized by both a large drop in domestic demand and export. On the contrary, in those countries the specialization in knowledge-intensive service sectors predicts cyclical behaviour. As far as the manufacturing sector is concerned, specialization in high-technology is associated to cyclical behaviour of firms in the case of a large drop in exports.

## 6. Discussion and policy implications

### 6.1. Is innovation cyclical or persistent?

One of the most significant results of our analysis is that about 65 per cent of the firms declare to have kept their innovation investment unchanged in spite of the crisis. This somehow confirms the importance of technological accumulation (stressed, among others, by Nelson and Winter (1982), Grandstrand et al. (1997), Patel and Pavitt (1997)), and lends substantial support to the persistency of innovative activities over time (Geroski et al., 1997; Cefis and Orsenigo, 2001). But accumulation and persistency do not explain all firms' behaviour: we also observe a good deal of cyclical innovative behaviours across firms. Significantly, firms which exhibit a cyclical behaviour are the major innovators. In fact, firms which are more likely to reduce investment in response to the crisis are characterized by: (i) larger innovation intensity (in terms of share of turnover invested in innovation); (ii) larger size (see Table 3).

[4] We also tried to take 1 whether the drop in domestic demand or export is higher than the third quartile but we prefer the current choice because it allows us to include more countries.

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We can speculate that firms are maintaining innovation activities related to on-going projects which are often characterized by some degree of rigidity and consistent sunk costs, but appear less willing to start new innovation projects.

### 6.2. The uneven effects of the crisis and the role of National Systems of Innovation

It has clearly emerged that the crisis has not been of the same magnitude across all European countries. On the contrary, we have shown that the most negatively affected by the downturn are those EU New Member States which were catching up over the 2006–2008 period. Countries endowed with stronger NSI are, on the contrary, less affected and are better able to respond, at least in relative terms, to the recession. And this should be contrasted with the previous period of moderate economic expansion (2006–2008), when firms were expanding their investment in innovation in most countries and regardless of the strength of their NSI.

We have attempted to explain this evidence on the ground of the structural characteristics of the NSI and the role played by domestic demand and export. The structural characteristics of the NSI seem to play a more relevant role than demand. Hence, the hypothesis that the characteristics of the NSI can affect the way firms react to an external shock as the actual global turmoil is confirmed by the results. Specifically, the presence of qualified human resources plays a crucial role in cushioning the effects of a downswing in innovation in frontrunner countries. This seems to be less the case in catching-up countries; this result reflects mostly the ex-Socialist nations, the largest group of catching-up countries considered here. Apparently, the high level of human resources in the previously planned economies have not yet been fully incorporated into the new competitive economy and therefore do not have the "braking" effect in terms of reduction of investment in innovation. When the interaction with demand is also included, the availability of human resources becomes the most important factor in contrasting a reduction of firms' innovation expenditures. Firms are very reluctant to fire qualified workers even when facing a drop in their demand.[5]

Our results show that the decision to invest in innovation relative to the knowledge intensive sector is particularly sensitive to the domestic demand. This can be explained by the fact that this sector includes both the financial intermediation industry and the real estate industry which have been severely hit by the crisis. That decisions to invest in innovation are particularly sensitive to exports in both the high-tech manufacturing and knowledge intensive sector comes as no surprise: firms' internationalization and their innovative activities go hand in hand (Filippetti et al., 2009; Frenz and Ietto-Gillies, 2009; Frenz et al., 2005). The "depth" of the financial system, in terms of the dimension of private credit, seems to play an important role in counteracting the effect of the crisis on firms' innovation expenditures. In general, this finding reinforces the importance of the financial sector for innovation, not only as an engine in times of growth, but also as a buffer during a downswing. This is particularly important for the EU New Members Countries which have not developed a sufficiently robust domestic financial market. The substantial withdrawal of foreign capital which occurred quickly as the crisis burst out, coupled with an insufficient supply of domestic credit, is very likely to have played a substantial role in the reduction of innovation investment of firms.

[5] This point suggests that there can be differences across the countries depending on the different structure and organization of the labour market, but this topic is out of the scope of this paper (see however Lorenz and Lundvall, 2006; Filippetti and Guy, 2010).

### 6.3. Which policies in times of crisis?

On the grounds of our results, what will the economic crisis bring in terms of innovative capabilities across Europe? And what can we learn to inspire policy analysis? There is evidence that the crisis is hitting countries with a less developed NSI, namely the New Member States. This will lead to an increase in their technological gap which, especially for ex-Socialist economies, is still huge. It will not be easy to recycle the skills and the human resources available into a competitive economy. There is the risk that the effects of the downturn will turn out to be structural, and as a result of the crisis at least some of the New Member States will be no longer able to sustain the catching-up process they started before the recession (for an assessment of the impact of the crisis from a European policy perspective see Archibugi and Filippetti, 2011).

It remains to be seen how these countries will be able to react since competences, skills and knowledge are not an ephemeral phenomena, but are rather embedded in organizations' routines, firms' capabilities, workers' skills and capital goods (Lall, 1992; Evangelista, 1999; Massini et al., 2002). Will the structural components of competence and skills prevail over the adverse short-term economic environment? And how will the new economic environment be transformed by the crisis? There is no guarantee that after the turmoil the *loci* of the competitive advantage will remain the same. New sectors can emerge as a result of new technological opportunities as well as of substantial public policies that governments are enacting to hamper the effects of the crisis. A case in point is the "green industry", which is believed to represent a fundamental source of innovation and growth for the coming future (OECD, 2009a).

Periods of technological breakthroughs can represent a crucial "window of opportunity" for lagging behind countries to catch up (Perez and Soete, 1988). However, catching-up processes based on the adoption of technology require a reliable base of internal knowledge, human resources and infrastructures. Winners and losers are not easily identifiable when the game is still ongoing. But the winners are more likely to be those countries which are equipped with both strong innovative infrastructures and domestic knowledge base. On the other hand, the capacity of the *catching-up countries* to recover their previous catching-up patterns cannot be taken for granted. This will crucially depend on their capacity to maintain their acquired knowledge, skills, competences and human resources in their business sector and *within their borders*.

The empirical analysis has shown the crucial role played by qualified human resources in reducing the effects of the crisis. In some countries, the crisis is already leading to the emigration of skilled workers, budget cuts to the R&D public spending and to the educational system, as well as the weakening of the credit system and infrastructures. If these factors are not properly counter-acted by public and business policies, there is the risk that NSI will be substantially weakened and that the potential for growth in the coming years will be undermined. The large public expenditures programmes put forward by most of the States in response to the crisis do represent crucial means to sustain current innovation capabilities. The choice of sectors and the design of public procurement policies can provide new opportunities and it is very likely that those that manage to capture them will be the winners and those who do not will become the losers.

As argued by the technological accumulation hypothesis, technological discontinuities do not necessarily imply new and different competences and skills (Pavitt, 1988; Patel and Pavitt, 1994). Continuing investment in knowledge, human resources and structures is the best way to cope with (uncertain) scientific and technological evolution. New sectors and technological opportunities will emerge after the crisis and a process of *re-specialization* is expected to be crucial for recovery (Perez, 2009b). Those countries which

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maintain their innovation capabilities will be more likely to be ready to exploit the recovery and expansion of the market in the new emerging sectors. This will be key for creating new job opportunities along with the phase of recovery. In a recent study from the OECD (2009b), paradigmatic examples of counter-cyclical policies carried out during recent periods of recession in Finland and Korea are reported. In line with our argument they claim that policies aimed at supporting business and public R&D (the latter was *increased* during the recession by these Governments), as well as policies directed at stimulating job opportunities for skilled labour were very important in putting these economies on a stronger and more knowledge-intensive growth path (OECD, 2009b).

### 6.4. Limitations of the current analysis and prospects for future research

We are well aware of the limitations of our data. As often stated, the responses collected by the *Innobarometer* refer to firms' perceptions in a period of time. Time series data would be able to provide much better information on the effects of the crisis, and the next surveys will certainly shed light on this. Further research must be carried out when more accurate data is available. This will make it possible to investigate more in depth the dynamics of the micro behaviours and macro-aggregates. Moreover the data considered here provide information on innovating firms that are already in business now, but do not take into account the role of new firms. They cannot tell us if in an unknown garage the Bill Gates or Steve Jobs of the future is already at work. Both Gates and Jobs founded *Microsoft* and *Apple* respectively in the 1970s, when everyone was playing the "The Dying Swan" of the international economy. In short, these data cannot tell us how *creative* the *destruction* process of the economic downturn actually is. However, we have taken into account the freshest dataset available at the micro level. Thanks to the particular nature of the survey it was possible to compare the firms' innovation behaviour before and in response to the crisis.

We also had to limit our analysis to European countries only. Unfortunately, we do not have similar data regarding non-EU countries such as United States, Japan, or emerging economies such as China and India. A European would naturally wonder: what if these countries are not reacting like the European countries vis-à-vis the current recession? What if their firms are not decreasing their innovation investments–or are decreasing them to a considerably lesser extent? We have learnt from the past that the way firms and countries react to the global turmoil will likely decide who will hold the technological leadership of the global economy in the coming future.

## 7. Conclusions

This paper represents an attempt to explore empirically the effects of the current economic crisis on innovation across the European countries, and to propose some explanations for it. A substantial amount of firms have managed to maintain their investment for innovation, but the number of firms able to expand it has dramatically dropped, and the firms that have decreased them have also substantially raised. This trend is not distributed uniformly across the European economic space. The most affected have been the European catching-up countries, namely the New Member Countries of Central and Eastern Europe.

A possible explanation for these patterns that has not taken into consideration here is the role played by Multinational Corporations (MNCs) and by international division of labour. Several manufacturing and service firms in the New Member Countries are suppliers to core companies placed in advanced countries. Hence, it is likely that these firms are those suffering larger cuts with compared with the strategically more important nodes placed in other countries. This trend is confirmed by the results from the *2008 EU Survey on R&D Investment Business Trends* (European Commission, 2009c), where one can read that in the economic downturn, outside MNCs subsidiaries may face the strongest cuts in R&D. The crisis has, so far, stopped a tiring process in which these countries were trying to increase their efforts also as a consequence of joining the EU market.[6]

We have also seen that the countries that were relatively less affected are those with a stronger NSI. Switzerland, Sweden, Finland, Germany and Austria will emerge from this crisis with a relatively stronger innovative capacity, while the United Kingdom and France, and to a larger extent, the Southern European countries, are likely to lose additional relative positions. Within a perspective of increasing integration, this calls for a stronger and cooperative innovation policy at European level not only in good times but especially in bad times.

Sever recessions are prominently characterized by a major fall in demand. While scholars agree that negative demand shocks affect investment, the ultimate effect on innovation investment can differ across countries. This emerges from the descriptive analysis, and this is what we seek to explain relying on the NSI literature. This literature claims that economic and institutional structure differs between countries and this would be a major factor in determining the direction of learning and innovation. We showed that this also plays a role in affecting the innovation behaviour of firms during major recessions. Particularly, competences and quality of human resources, the specialization in the high-technology sector, along with the development of the credit system, seem to be the structural factors which are able to mitigate the effects of the economic downturn on innovation investments of firms across Europe. The fact that some structural characteristics of the NSI explain persistency of innovation in response to major exogenous shocks is an important finding. It sheds some light on the behaviour of firms during crisis, and represents a step forward in terms of understanding the mechanisms underlying the relationship between macro- and micro-determinants of innovation which lie at the heart of the NSI theory.

## Appendix A.

See Tables A1, A2, A3 and A4.

*Methodology: the two indicators*

1. The $InnoInv_{06–08}$ Indicator: is based on following *Innobarometer 2009* question: "*Compared to 2006, has the amount spent by your firm on all innovation activities in 2008 increased, decreased, or stayed approximately the same* (*adjust for inflation*)?"

$$InnoInv_{06-08\text{country-i}} = \frac{(X_{\text{country-i}} - X_{\text{country-min}})}{(X_{\text{country-max}} - X_{\text{country-min}})}$$

where $X_{\text{country-i}}$ = (% firms increasing – % firms decreasing) – see Table A1.

The $InnoInv_{09}$ Indicator is based on following *Innobarometer 2009* question: "*In the last six months has your company taken one of the following actions* [*increased, decreased or maintain the innovation*

[6] We are grateful to two anomynous referees for this point.

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**Table A1**
Results from the two questions[a] from the *Innobarometer 2009*[b].

| Country | Question no. 1 (2006–2008) | | | | Quesiton no. 2 (2009) | | | |
|---|---|---|---|---|---|---|---|---|
| | Increased % | Decreased % | Stayed the same % | Total | Increased % | Decreased % | Stayed the same % | Total |
| Austria | 40.8 | 5.8 | 53.4 | 100 | 11.2 | 10.7 | 78.1 | 100 |
| Belgium | 40.1 | 9.4 | 50.5 | 100 | 12.0 | 17.6 | 70.5 | 100 |
| Bulgaria | 52.6 | 10.1 | 37.3 | 100 | 11.9 | 25.7 | 62.3 | 100 |
| Czech rep. | 40.3 | 13.1 | 46.6 | 100 | 13.8 | 29.6 | 56.5 | 100 |
| Denmark | 35.2 | 10.4 | 54.4 | 100 | 17.2 | 24.9 | 57.9 | 100 |
| Estonia | 32.0 | 14.9 | 53.1 | 100 | 7.9 | 29.6 | 62.5 | 100 |
| Finland | 42.7 | 6.4 | 50.9 | 100 | 16.7 | 14.8 | 68.5 | 100 |
| France | 35.3 | 7.0 | 57.7 | 100 | 7.0 | 29.7 | 63.2 | 100 |
| Germany | 43.2 | 5.2 | 51.5 | 100 | 10.3 | 14.4 | 75.3 | 100 |
| Greece | 45.8 | 15.0 | 39.2 | 100 | 2.0 | 49.3 | 48.7 | 100 |
| Hungary | 36.0 | 21.3 | 42.7 | 100 | 4.6 | 32.2 | 63.2 | 100 |
| Ireland | 30.8 | 14.9 | 54.3 | 100 | 9.9 | 32.1 | 58.0 | 100 |
| Italy | 35.8 | 13.4 | 50.8 | 100 | 8.9 | 26.1 | 65.0 | 100 |
| Latvia | 27.3 | 21.2 | 51.5 | 100 | 9.2 | 51.0 | 39.8 | 100 |
| Lithuania | 54.9 | 11.0 | 34.2 | 100 | 6.3 | 49.1 | 44.6 | 100 |
| Luxemburg | 31.9 | 5.6 | 62.5 | 100 | 8.6 | 16.9 | 74.5 | 100 |
| Netherlands | 35.6 | 8.7 | 55.7 | 100 | 10.4 | 16.8 | 72.8 | 100 |
| Norway | 35.8 | 6.9 | 57.3 | 100 | 12.9 | 27.2 | 59.8 | 100 |
| Poland | 46.1 | 13.3 | 40.6 | 100 | 8.2 | 33.8 | 58.0 | 100 |
| Portugal | 37.2 | 14.0 | 48.8 | 100 | 13.4 | 28.2 | 58.4 | 100 |
| Romania | 56.4 | 9.2 | 34.4 | 100 | 10.7 | 38.8 | 50.5 | 100 |
| Slovakia | 48.6 | 9.9 | 41.5 | 100 | 16.5 | 30.7 | 52.7 | 100 |
| Slovenia | 39.5 | 9.1 | 51.3 | 100 | 5.1 | 20.6 | 74.2 | 100 |
| Spain | 28.8 | 11.2 | 60.0 | 100 | 10.1 | 27.2 | 62.7 | 100 |
| Sweden | 54.2 | 5.8 | 40.0 | 100 | 14.8 | 12.6 | 72.6 | 100 |
| Switzerland | 47.8 | 8.9 | 43.4 | 100 | 17.5 | 9.0 | 73.5 | 100 |
| United Kingdom | 32.9 | 9.6 | 57.5 | 100 | 8.5 | 23.2 | 68.4 | 100 |

*Source*: author's elaboration on *Innobarometer 2009* (European Commission, 2009b).

[a] *Question no. 1*: "*Compared to 2006, has the amount spent by your firm on all innovation activities in 2008 increased, decreased, or stayed approximately the same* (*adjust for inflation*)?". *Question no. 2*: "*In the last six months has your company taken one of the following actions* [increased, decreased or maintain the innovation spending] *as a direct result of the economic downturn?*" (question made on April 2009).

[b] With respect to the *Innobarometer 2009*, the results are been re-scaled to make them comparable across countries.

**Table A2**
Indicators for the *InnoStruct* of the European *Innovation Scoreboard 2008*.

| Dimension | Indicators |
|---|---|
| Human resources | S&E and SSH graduates per 1000 population aged 20–29 (first stage of tertiary education) |
| | S&E and SSH doctorate graduates per 1000 population aged 25–34 (second stage of tertiary education) |
| | Population with tertiary education per 100 population aged 25–64 |
| | Participation in life-long learning per 100 population aged 25–64 |
| | Youth education attainment level |
| Finance and support | Public R&D expenditures (% of GDP) |
| | Venture capital (% of GDP) |
| | Private credit (relative to GDP) |
| | Broadband access by firms (% of firms) |
| Firm investments | Business R&D expenditures (% of GDP) |
| | IT expenditures (% of GDP) |
| | Non-R&D innovation expenditures (% of turnover) |
| Linkages and entrepreneurship | |
| | SMEs innovating in-house (% of SMEs) |
| | Innovative SMEs collaborating with others (% of SMEs) |
| | Firm renewal (SME entries plus exits) (% of SMEs) |
| | Public-private co-publications per million population |
| Throughputs | EPO patents per million population |
| | Community trademarks per million population |
| | Community designs per million population |
| | Technology Balance of Payments flows (% of GDP) |
| Innovators | SMEs introducing product or process innovations (% of SMEs) |
| | SMEs introducing marketing or organisational innovations (% of SMEs) |
| | Share of innovators where innovation has significantly reduced labour costs (% of firms) |
| | Share of innovators where innovation has significantly reduced the use of materials and energy (% of firms) |
| Economic effects | Employment in medium-high & high-tech manufacturing (% of workforce) |
| | Employment in knowledge-intensive services (% of workforce) |
| | Medium and high-tech manufacturing exports (% of total exports) |
| | Knowledge-intensive services exports (% of total services exports) |
| | New-to-market sales (% of turnover) |
| | New-to-firm sales (% of turnover) |

*Source*: *European Innovation Scoreboard 2008* (European Commission, 2009b).

Please cite this article in press as: Filippetti, A., Archibugi, D., Innovation in times of crisis: National Systems of Innovation, structure, and demand. Res. Policy (2010), doi:10.1016/j.respol.2010.09.001

**Table A3**
The construction of the variables "human resources" and "knowledge" from the EIS.

| Country | Innostruct | (1) S&E graduates | (2) S&E doctoral | (3) Tertiary education | (4) Life-long learning | (5) Youth education | (6) Human resources | (7) Business R&D | (8) Public R&D | (9) Non-R&D expenditure | (10) Patent | (11) IT expenditure | (12) Knowledge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 0.53 | 21.60 | 1.72 | 17.60 | 12.80 | 84.10 | 0.42 | 1.81 | 0.75 | – | 183.10 | 2.80 | 0.63 |
| Belgium | 0.51 | 33.10 | 0.94 | 32.10 | 7.20 | 82.60 | 0.46 | 1.30 | 0.57 | 0.73 | 129.10 | 2.80 | 0.46 |
| Bulgaria | 0.22 | 31.50 | 0.36 | 22.40 | 1.30 | 83.30 | 0.31 | 0.15 | 0.33 | 0.79 | 1.40 | 2.00 | 0.17 |
| Czech rep. | 0.40 | 25.80 | 0.86 | 13.70 | 5.70 | 91.80 | 0.33 | 0.98 | 0.55 | 0.88 | 7.30 | 3.20 | 0.39 |
| Denmark | 0.57 | 46.80 | 0.93 | 32.20 | 29.20 | 70.80 | 0.59 | 1.65 | 0.88 | 0.51 | 174.60 | 3.20 | 0.58 |
| Estonia | 0.45 | 38.20 | 0.57 | 33.30 | 7.00 | 80.90 | 0.45 | 0.54 | 0.58 | 3.36 | 5.60 | 2.90 | 0.47 |
| Finland | 0.61 | 38.30 | 2.17 | 36.40 | 23.40 | 86.50 | 0.72 | 2.51 | 0.94 | – | 267.60 | 3.20 | 0.82 |
| France | 0.50 | 62.00 | 1.13 | 26.80 | 7.40 | 82.40 | 0.55 | 1.31 | 0.74 | 0.33 | 119.20 | 3.10 | 0.48 |
| Germany | 0.58 | 25.90 | 1.56 | 24.30 | 7.80 | 72.50 | 0.38 | 1.77 | 0.76 | 1.07 | 275.00 | 2.90 | 0.63 |
| Greece | 0.36 | 25.30 | 0.58 | 22.00 | 2.10 | 82.10 | 0.30 | 0.15 | 0.41 | 0.74 | 6.50 | 1.20 | 0.13 |
| Hungary | 0.32 | 30.20 | 0.42 | 18.00 | 3.60 | 84.00 | 0.30 | 0.49 | 0.46 | 0.72 | 7.80 | 2.50 | 0.27 |
| Ireland | 0.53 | 62.10 | 1.11 | 32.20 | 7.60 | 86.70 | 0.61 | 0.88 | 0.44 | 0.96 | 64.10 | 1.50 | 0.29 |
| Italy | 0.35 | 32.10 | 0.89 | 13.60 | 6.20 | 76.30 | 0.29 | 0.55 | 0.52 | 1.10 | 76.10 | 1.70 | 0.32 |
| Latvia | 0.24 | 56.40 | 0.24 | 22.60 | 7.10 | 80.20 | 0.42 | 0.21 | 0.42 | – | 5.70 | 2.30 | 0.21 |
| Lithuania | 0.29 | 60.30 | 0.61 | 28.90 | 5.30 | 89.00 | 0.54 | 0.23 | 0.58 | 0.64 | 1.30 | 1.80 | 0.20 |
| Luxemburg | 0.52 | – | – | 26.50 | 7.00 | 70.90 | 0.39 | 1.36 | 0.27 | 0.90 | 194.90 | – | 0.40 |
| Netherlands | 0.48 | 36.00 | 0.87 | 30.80 | 16.60 | 76.20 | 0.49 | 1.03 | 0.67 | 0.29 | 173.30 | 3.30 | 0.48 |
| Norway | 0.38 | 29.40 | 0.94 | 34.40 | 18.00 | 93.30 | 0.58 | 0.81 | 0.77 | 0.17 | 95.50 | 2.40 | 0.37 |
| Poland | 0.31 | 52.90 | 0.86 | 18.70 | 5.10 | 91.60 | 0.47 | 0.18 | 0.38 | 1.03 | 3.00 | 2.60 | 0.26 |
| Portugal | 0.36 | 30.60 | 2.75 | 13.70 | 4.40 | 53.40 | 0.31 | 0.61 | 0.46 | 0.95 | 7.40 | 1.80 | 0.25 |
| Romania | 0.28 | 40.90 | 0.48 | 12.00 | 1.30 | 77.40 | 0.26 | 0.22 | 0.31 | 1.08 | 0.70 | 2.10 | 0.20 |
| Slovakia | 0.31 | 24.40 | 0.89 | 14.40 | 3.90 | 91.30 | 0.32 | 0.18 | 0.27 | 1.51 | 5.80 | 2.50 | 0.28 |
| Slovenia | 0.45 | 41.00 | 0.96 | 22.20 | 14.80 | 91.50 | 0.51 | 0.94 | 0.60 | 1.12 | 32.20 | 2.20 | 0.38 |
| Spain | 0.37 | 27.30 | 0.67 | 29.00 | 10.40 | 61.10 | 0.32 | 0.66 | 0.55 | 0.49 | 29.30 | 1.40 | 0.22 |
| Sweden | 0.64 | 29.70 | 2.25 | 31.30 | 32.00 | 87.20 | 0.72 | 2.64 | 0.99 | 0.66 | 184.80 | 3.80 | 0.74 |
| Switzerland | 0.68 | 48.50 | 2.33 | 31.30 | 22.50 | 78.10 | 0.69 | 2.14 | 0.69 | 0.92 | 411.10 | 3.70 | 0.72 |
| UK | 0.55 | 52.00 | 1.61 | 31.90 | 26.60 | 78.10 | 0.68 | 1.08 | 0.64 | – | 91.40 | 3.50 | 0.55 |

*Source*: *European Innovation Scoreboard 2008* (European Commission, 2009b).
*Note*: the variable "human resources" is derived aggregating the variables in the first five columns, while the variable "knowledge" is derived aggregating the other five variables from the seventh to the eleventh column (see Table A2 for the description of the variables). Both the variables have been normalized between 0 and 1 (see methodological appendix for the normalization procedure).

**Table A4**
The correlation rates between the independent variables.

| | Demand drop | Export drop | Knowledge | Human res. | Venture cap. | Private cred. | High-tech man | KIS service |
|---|---|---|---|---|---|---|---|---|
| Demand drop | 1.00 | | | | | | | |
| Export drop | 0.09 | 1.00 | | | | | | |
| Knowledge | −0.29 | 0.21 | 1.00 | | | | | |
| Human res. | 0.07 | 0.12 | 0.69 | 1.00 | | | | |
| Venture cap. | 0.06 | 0.07 | 0.55 | 0.66 | 1.00 | | | |
| Private cred. | −0.31 | −0.58 | 0.28 | 0.38 | 0.53 | 1.00 | | |
| High-tech man | −0.28 | 0.02 | 0.33 | −0.07 | −0.32 | −0.29 | 1.00 | |
| KIS service | −0.44 | −0.19 | 0.69 | 0.60 | 0.67 | 0.67 | 0.05 | 1.00 |

*spending*] *as a direct result of the economic downturn?*"

$$InnoInv_{09\text{country-i}} = \frac{(X_{\text{country-i}} - X_{\text{country-min}})}{(X_{\text{country-max}} - X_{\text{country-min}})}$$

where $X_{\text{country-i}}$ = (% firms increasing − % firms decreasing) – see Table A1.

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Please cite this article in press as: Filippetti, A., Archibugi, D., Innovation in times of crisis: National Systems of Innovation, structure, and demand. Res. Policy (2010), doi:10.1016/j.respol.2010.09.001

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Please cite this article in press as: Filippetti, A., Archibugi, D., Innovation in times of crisis: National Systems of Innovation, structure, and demand. Res. Policy (2010), doi:10.1016/j.respol.2010.09.001