Innovation Policy Analytics for Economic Crisis

Euripidis Loukis
Dept. Information & Communication Systems Engineering
University of Aegean
Karlovassi, Greece
e-mail: eloukis@aegean.gr

Spyros Arvanitis
KOF Swiss Economic Institute
ETH Zürich
Zürich, Switzerland
e-mail: arvanitis@kof.ethz.ch

Charalampos Alexopoulos
Dept. Information & Communication Systems Engineering
University of Aegean
Karlovassi, Greece
e-mail:alexop@aegean.gr

***Abstract*— Policy analytics is defined as the exploitation of existing data from government agencies, possibly in combination with data from private sector firms, and using advanced analytical techniques in order to support different stages of public policy making. It constitutes a highly ambitious new generation of electronic (digital) government, aiming to provide substantial support to higher government functions. However, the area of policy analytics is still in its infancy, so extensive further research is required in this area in order to develop effective methodologies for supporting various stages of policy-making in important domains of government intervention. This paper contributes to filling this research gap for a highly important domain of government intervention and policy, the promotion of firms' innovation activity, in difficult times of economic crisis. It presents a methodology for exploiting existing data from Taxation Authorities and Statistical Agencies in combination with data from private sector consulting and business information firms in order to identify characteristics of the firm and its external environment that affect its innovation behaviour (the extent of their product/service innovation reduction) during economic crises. Our methodology exploits findings of previous research in the areas of innovation and economic crises. It can generate valuable insights, which can support substantially the development of innovation policies in times of economic crisis. Furthermore, an application of this methodology is presented, using existing Greek firms' data from the Hellenic Statistical Authority, in combination with data from the business information and consulting firm ICAP, for the economic crisis period 2009 – 2014, which provides interesting insights.**

Keywords - Electronic Government; Digital Government; Policy Analytics; Policy Informatics; Innovation; Economic Crisis.

I. INTRODUCTION

Policy analytics (previously called also as policy informatics) is defined as the exploitation of existing data from government agencies, possibly in combination with data from private sector firms, and using advanced analytical techniques in order to support different stages of public policy making [1]. It constitutes a highly ambitious new generation of electronic (digital) government, aiming to provide substantial support to higher government functions. While the first generation of electronic (digital) government aimed to support government agencies' internal processes as well as their transactions with firms and citizens, and the second generation aimed to support communication and consultation with the society (with a special focus on the exploitation of the social media for this purpose), this new third generation aims to support and enhance the whole cycle of policy-making for addressing serious problems of modern societies [2][3].

Though there has been a long interest in providing support for the design and implementation of important public policies (due to their high importance for and impact on the society and also the large amounts of financial resources they consume), recently this has become much more intensive, leading to an exponential development of policy analytics, mainly for three reasons:

i) The development and success of the data science and business analytics in the private sector, which aims at the exploitation of the large quantities of data collected by firms in order to support decision making, strategy formulation, as well as development of new products and services [4][5].

ii) The increasing availability of data in government agencies, which can provide (after appropriate processing) significant support of policy and decision making. The main sources of these data are: the increasingly complex internal information systems (IS) of government agencies, as well as their electronic transactions and consultations IS; the growing use of social media by government agencies, which generates large quantities of textual data, containing valuable citizens' knowledge, experience, proposals, ideas, opinions and comments; and recently the development of the Internet of Things (IoT), especially in the context of modern cities [6][7].

iii) The increasing complexity and severity of the challenges, problems and needs of modern societies. The 'traditional' social problems that governments face have become more complex and severe, while at the same time new problems have appeared (e.g., due to the globalization of the economy, the climate change, the ageing population, the migration of massive populations from underdeveloped countries or areas facing serious conflicts, warfare or social unrest to the more developed countries) [6][7].

It is widely recognized that the potential of the above massive government data, especially if combined with related private sector data (e.g., from consulting and business information firms), towards the provision of valuable support of highly important public policies, is quite high. This

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potential can be exploited to a much greater extent if these data undergo advanced processing using various sophisticated analytical techniques from the areas of statistics, data mining, operational research, etc., such as regression analysis, clustering, association analysis, data segmentation, classification analysis, anomaly detection, social network analysis and computer simulation [1]. However, the area of policy analytics is still in its infancy, so extensive further research is required in this area in order to develop effective policy analytics methodologies for supporting various stages of policy-making in important domains of government intervention. Some useful knowledge has already been developed in the area of policy analytics, which includes methodologies for exploiting different sources of data, using advanced basic or more advanced analytical techniques in order to support some of the stages of the policy making cycle in some domains of government intervention, such as the environment [8], the energy provision [9], the justice [10] and the management of emergency crises (both natural disasters, such as earthquakes and hurricanes, and man-made crises, such as terrorism and ethnic violence) [11][12]. However, extensive additional research is required in this area in order to increase our knowledge concerning the exploitation of the large quantities of data available today in government, in combination with data from various private sector firms, and using advanced analytical techniques for supporting all the stages of public policies' development and implementation, in various important domains. It is necessary to experiment with exploiting a variety policy-related public and private sector datasets, using various analytical techniques, from 'traditional' statistical analysis to advanced data mining and artificial intelligent ones, in order to extract from them insights and knowledge that can be useful for policy making.

This paper contributes in this direction towards filling the abovementioned research gaps, dealing with a highly important domain of government intervention and policy: the promotion of firms' innovation. We focus on periods, in which this is more difficult and at the same time more useful for the economy and the society: on periods of economic crisis. It is widely recognized that innovation has become an important element of the modern economy, of critical importance for the competitiveness and growth of firms, sectors and countries [6][7][13]. It involves development of new products and services (or substantial improvement of existing ones) in order to adapt to evolving needs and preferences of customers, development of new markets or market segments, and exploitation of new technologies that have emerged. Governments of various layers (central, regional and municipal governments) of most countries exhibit active interest in promoting innovation, and design and implement policies for this purpose that take the form of financial support through grants, subsidies and tax credits, but also the form of relevant laws and regulations. Government initiatives become much more difficult, but at the same time much more necessary and important in periods of economic crisis, which are an inevitable trait of market-based economies [14][15]. Economic crises are repeatedly occurring with varying intensities and durations in market-based economies, with quite negative consequences for the economy and the society in general. One of the most important (however less observable and debated) negative consequences is the reduction of firms' product/service innovation activities, which has quite negative impact on their medium- and long-term competitiveness. So, during periods of economic crisis it is even more important than in the 'normal' periods to design and implement policies for mitigating this reduction of firms' innovation activities and promoting product/service innovation that can contribute to overcoming the crisis. However, this necessitates a sound evidence-base, which will allow achieving higher levels of effectiveness and maturity of these critical policies.

In this direction this paper presents a methodology for exploiting existing data from Taxation Authorities and Statistical Agencies, in combination with data from private sector consulting and business information firms, in order to identify characteristics of the firm and its external environment that affect its innovation behaviour (the extent of their product/service innovation reduction) during economic crises. Our methodology is based on and leverages findings of previous research in the areas of innovation and economic crises. It can generate valuable insights, as to the types of firms exhibiting higher or lower sensitivity to the crisis with respect to innovation activity, which can support substantially the development of innovation policies in periods of economic crisis. Furthermore, an application of this methodology is presented, using Greek firms' data from the Hellenic Statistical Authority, in combination with data from the business information and consulting firm ICAP, for the economic crisis period 2009 – 2014; it has revealed interesting characteristics of firms and their external environment affecting innovation behaviour during the Greek crisis.

The paper is organized in five sections. The following section II outlines the conceptual background of our study. Section III describes the proposed methodology of innovation policy analytics for economic crisis periods, while Section IV presents the abovementioned application. Finally, Section V summarizes the conclusions and proposes future research directions.

II. BACKGROUND

In this section we briefly present the background of the proposed methodology concerning innovation and economic crise.s

A. Innovation

The 'Oslo Manual 2018' [13] defines product/service innovation as 'a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced in the market'. Innovation is more than simply a new idea or an invention: it includes implementation, diffusion and active use by other parties, such as individuals, firms or public organisations. It is the wide diffusion of an innovation that can actually generate economic and social positive impact and value. However, beyond the above positive value, innovative products and services might replace some existing ones, and this can cause problems to firms producing the latter (e.g., reduction of

sales, profitability and personnel employment), and in general lead to significant disruptions; however, in the long-term innovation leads to economic growth. The main theoretical foundations of innovation have been developed in the beginning of the 20th century by the Austrian economist J. Schumpeter, who created theories on how firms search for new opportunities and competitive advantage over current or potential competitors [16]. He also introduced the concept of "creative destruction" to describe the disruption of existing economic activity that can be caused by innovations creating new ways of producing goods or services, or even entirely new industries.

In the modern economy innovation is highly important for firms' competitiveness, or even survival [6][7]. As new technologies are continuously emerging, firms have to develop new or substantially improved products and services that incorporate and exploit these technologies, acting either as 'first movers' (i.e., before their competitors) - leaders, or as 'late movers' (i.e., after some of their competitors have taken action) – followers. Furthermore, customers' needs and preferences are evolving, and also markets are changing (e.g., new competitors, substitutes or suppliers appear), and firms have to respond by introducing new or substantially improved products and services.

Innovation is a highly knowledge-intensive activity; it requires the use and combination of both internal and external knowledge, which necessitates significant human capital (human competences and skills) as well as organizational capital (appropriate practices and processes). In particular, innovation requires absorbing relevant knowledge from their external environment (e.g., from universities, research centres, suppliers, customers, partners, etc.), combining it with internal knowledge they possess, and then exploiting this combined knowledge for making product/service innovations [17]-[19]. So, modern firms in order to be innovative need to possess high levels of knowledge 'absorptive capacity', which has four main components: a) acquisition capacity (ability to locate, identify, value and acquire external knowledge that is related to firm's products and services); b) assimilation capacity (ability to analyse, process, interpret, understand, internalize and classify the acquired external knowledge); c) trans-formation capacity (ability to associate and combine the existing knowledge base of the firm with the newly acquired knowledge); d) application or exploitation capacity (ability to incorporate acquired, assimilated and transformed knowledge into new or significantly improved products and services) [18].

Due to the high importance of innovation for firms, sectors and countries considerable research has been conducted for the identification of factors that influence firm's innovation activity, termed as 'innovation determinants'; reviews of this research are provided in [13][20][21][22]. This research has revealed characteristics of the firm and its external environment that affect its innovation activity; the most important of them are size, human capital, adoption of 'organic' non-hierarchical forms of workplace organisation (such as teamwork, decentralisation of decision making and job rotation), technological capabilities, financial resources, creativity and innovation culture, as well as demand prospects and competition, which impact positively firm's innovation activity. A more recent relevant research stream has focused on and revealed the strong positive impact that information and communication technologies (ICT) can have on both the 'process' of innovation (i.e., the design and implementation of it) as well as its 'outcomes' (i.e., the resulting ICT-enabled innovative products and services) [6][7][13][23][24][25][26]. In [25] are identified three main channels through which the use of ICT impacts positively firms' innovation activities. The first channel is the support and improvement of the management of the knowledge (internal or external) required for the innovation process. ICT enables an efficient storage, accessibility and exchange of this knowledge throughout the firm. Internal networks, e-mail systems, and electronic databases all facilitate the transfer of knowledge and the communication between innovation participants. Second, ICT enables a more efficient cooperation for innovation with external partners, which has become even more important in the last twenty years, with the wide adoption of 'open innovation' models [23]. Third, ICT enable new products and services, and also the variety and personalization of existing products and services, which were not operationally and economically feasible before without ICT [24]. Furthermore, some specific kinds of information systems (IS) have been identified, such as enterprise resource planning (ERP), customer relationship management (CRM), business intelligence/analytics (BI/BA) and e-business ones, as well as social media, which can substantially improve firm's absorptive capacity and finally ability for innovation, by enabling the collection and processing of data that can be quite useful for firms' innovation activity [27][28]. Also, the use of cloud computing can provide rapid and low-cost electronic support of product/process innovations, so it can positively impact firms' innovation activity [29][30].

B. Economic Crises

One of the most important problems that governments face, and have to address through appropriate policies, are the economic crises of varying intensities and durations that repeatedly occur in market-based economies [14][15]. They can be defined as significant contractions of economic activity, which can be due to 'business cycles' (i.e., the fluctuations that economic activity usually exhibits, with periods of expansion followed by periods of contraction) or other events that happen in the society or economy (such as the oil crisis in the early 1970, or banking crises) [15].

Economic crises have quite negative both short-term as well as medium- and long-term consequences for the economy and the society. The short-term consequences (which are much more 'observable' and widely debated by the society, as they directly affect large number of citizens) include reductions of the demand for many goods and services, resulting in serious decrease of firms' sales, production and profits, leading to reductions in personnel employment and materials' procurement (and through this mechanism the crisis propagates further towards the

suppliers, etc.). For the above reasons economic crises increase unemployment, especially among some disadvantaged groups, such as the young people, the low-skilled, the immigrants and the temporary workers [14]. This causes big social problems, increasing the number of citizens living in poverty and social exclusion; furthermore, it increases the required government spending for unemployment benefits, as well as for other types of social welfare and assistance for the unemployed (e.g., further training), while at the same time during these economic crises government income from taxation decreases due to lower firms' profitability and individuals' income.

Another highly important (however much less debated) negative consequence is that during economic crises firms usually reduce investment in fixed assets (e.g., in production equipment, ICT, buildings, etc.) and also in innovations, due to the reduction on one hand of the external demand for products and services, which makes such investment more risky, and on the other hand of the available financial resources for investment [14][15][31][32]. This is called 'pro-cyclical' behaviour' (i.e., investment follows the ups and down of the business cycle), having quite negative impact on firms medium- and long-term competitiveness. Especially the reduction of firms' innovation activities during economic crises decreases the degree of renewal of their products and services, exploitation of emerging new technologies, and adaptation to changing needs and preferences of customers, and results finally in lower competitiveness. However, for some innovation investments has been observed the opposite behaviour by some firms during economic crises: increase, in order to take advantage of lower prices of some required inputs (such as specialized personnel and equipment) [33]; this is called 'anti-cyclical' or 'counter-cyclical' investment behaviour'.

The above negative consequences of the economic crises are not the same for all firms: some firms are more efficient than the others, offer higher value-for-money products and services, so they have weaker negative consequences on their sales revenue, and therefore on employment and investment, including investment in innovation. Therefore, it is important to identify characteristics of the firm and its external environment that affect positively or negatively its sensitivity to economic crises, especially with respect to innovation activity. In this paper we present an innovation policy analytics methodology for this purpose (described in the following section III). This can be quite useful for government agencies in order to develop effective and focused policies for reducing the negative consequences of economic crises on firms' innovation activity. It allows identifying characteristics (with respect to strategy, organization, human resources, use of ICT, external environment) of firms exhibiting lower sensitivity to the crisis with respect to innovation (i.e., lower or even no product/service innovation reduction due to the crisis), and therefore learning from them (which strategies, forms of organization, human resources, kinds of ICT reduce a firm's innovation sensitivity to the crisis). It further allows identifying characteristics of firms exhibiting higher sensitivity to the crisis with respect to innovation (i.e., higher product/service innovation reduction due to the crisis), in order to design effective policies for assisting and supporting them (e.g., financial support of innovation activities, relevant laws and regulations).

III. PROPOSED METHODOLOGY

As mentioned above, the proposed innovation policy analytics methodology aims to identify characteristics of the firm and its external environment that affect its innovation behaviour (the extent of product/service innovation reduction) during economic crises. It exploits findings of previous research in the areas of innovation (concerning innovation determinants, briefly reviewed in the last paragraph of section II.A) and economic crises (see section II.B). In particular, our methodology uses two main data sources:

i) existing public sector data concerning firms' innovation behaviour (i.e., extent of product/service innovation reduction) during economic crises, possessed by Taxation Authorities and Statistical Agencies,

ii) existing public and the private sector data concerning various characteristics of firms (e.g., concerning strategy, organization, human resources, use of ICT) and their external environment, possessed by Statistical Agencies, and also business information firms and consulting firms.

These data are used for the estimation of innovation reduction regression models, having as dependent variables various measures of the reduction of different kinds of firm product/process innovation (e.g., incremental, radical, etc.) due to the economic crisis (INN_RED), and as independent variables various characteristics of the firm and its external environment (fch_k, k = 1,.. ,n):

$$INN\_RED_i = b_0 + b_1 * fch_{1i} + b_2 * fch_{2i} + \ldots + b_n fch_{ni} + b_{n+1} * d\_size_i + b_{n+2} * d\_sector_i \text{ , for firm } i \quad (1)$$

where: d_size are dummy variables for firm size, and d_sector are dummy variables for firm sector affiliation.

These regression models allow the identification of independent variables having statistically significant regression coefficients, which reveal characteristics of the firm and its external environment that affect the extent of innovation reduction due to economic crisis.

In these innovation reduction regression models we can include as independent variables:

a) Firm characteristics that can influence the extent of reduction of sales revenue due to the economic crisis, which is the main determinant of the financial resources available for investments in innovation. For instance, the extent of adopting an export strategy to countries not facing economic crisis can reduce the negative impact of a domestic economic crisis on firm's sales revenue and therefore increase the availability of financial resources for innovation investments.

b) Characteristics of the firm and its external environment that can influence its innovation activity. According to previous research on innovation determinants (briefly reviewed in the last paragraph of section II.A) the most important of them are:

- size (with larger firms in general having more financial

resources for innovation investments, and also more opportunities for bank loans);
- human capital (employing personnel of higher educational levels, competences and skills can increase firms' capacity to perform the extensive and complex knowledge related activities required for making product/service innovations [34] - see third paragraph of section II.A);
- adoption of 'organic' non-hierarchical forms of workplace organisation, such as teamwork, decentralisation of decision making and job rotation (they facilitate the exchange and combination of knowledge of firms' employees from different functions and background, which is of critical importance for innovation [26]);
- financial resources and technological capabilities (for financing projects of product/service innovation, and for producing innovative products/services respectively);
- creativity and innovation culture;
- use of ICT (which as mentioned in II.A can significantly support and enhance both the 'process' and the 'outcome' of innovation [6][7][26], and especially use of some specific kinds of IS that can substantially increase firm's knowledge absorptive capacity and therefore ability for innovation, such as ERP, CRM, BI/BA, e-business, social media and cloud computing [27][28][29][30];
and also some characteristics of firm's external environment that according to previous innovation determinants' research (see section II.A) affect innovation activity, such as:
- demand prospects (larger demand potential increases firm's incentives for fostering product/service innovations);
- competition conditions (higher competitive pressures also increase firm's incentives for product/service innovation).
The above provide useful guidelines for specifying the innovation reduction regression models for the practical application of this methodology.

IV. APPLICATION

The innovation policy analytics methodology described in the previous section III has been applied for the identification of characteristics of Greek firms and their external environment that affect the extent of their product/service innovation reduction due to the long and intensive economic crisis that Greece experienced from 2009 until today. For this purpose, we have used existing Greek firm's data for the period 2009-2014 from two sources: i) the Hellenic Statistical Authority (data concerning the extent of firms' innovation reduction in the period 2009-2014); and ii) ICAP S.A., a well-known business information and consulting firm (data concerning characteristics of firms and their external environment). In particular, we have used data from these two sources for 363 Greek firms, which belong to the most technologically developed manufacturing and services sectors of the Greek economy; 40.2% of them were from manufacturing sectors, 9.4% from constructions, and 50.4% from services sectors; 52.6% of them were small, 36.1% medium and 11.3% large ones. From these data an innovation reduction regression model was estimated.

Our dependent variable is the extent of reduction of firm's product/service innovation due to the crisis, which is assessed in a 5-point Likert scale ("negligible, "small", "moderate", "large", "very large"). In Table 1 we can see the relative frequencies of these values.

TABLE 1. RELATIVE FREQUENCIES FOR EXTENT OF INNOVATION REDUCTION

Negligible	small	moderate	Large	very large
30.5%	21.1%	25.5%	16.4%	6.6%

We can see that more than half (51.6%) of the firms of our sample (coming from the most technologically developed manufacturing and services sectors of the Greek economy, as mentioned above) had negligible or small extent of innovation reduction due to the crisis, while about one quarter (25.5%) had moderate extent of reduction, and less than one quarter of them (23%) had a large or very large extent of innovation reduction.

The independent variables were:
- characteristics of firm: adoption of export strategy (EXP - binary variable); use of 'organic' forms of workplace organization, such as teamwork, decentralization and job rotation (ORG – binary variable); human capital (HC – percentage of firm's employees having tertiary-level education);
- ICT use: extent of use of customer relationship management, business intelligence/analytics and collaboration support systems (CRM, BI/BA, CS – ordinal variables measured on a 5-point Likert scale: "not at all", "to a small extent", "to a moderate extent", "to a large extent", "to a very large extent"); use of social media and cloud computing (SM and CLO – binary variables);
- characteristics of a firm's external environment: decrease of demand in the last three years (DEMDEC – ordinal variable measured in a 5-point Likert scale: "increased strongly", "increased", "remained the same", "decreased", "decreased strongly"); intensity of price competition and intensity of non-price competition (PRCOMP and NPRCOMP - ordinal variables measured in a 5-point Likert scale: "very weak", "weak", "moderate", "strong", "very strong").
- size and sector control variables: two control variables for size: D-L (taking value 1 for large firms having more than 250 employees and 0 for all other firms) and D-M (taking value 1 for medium-size firms having 50 - 250 employees and 0 for all other firms); and one control variable for sector: D-SE (taking value 1 for manufacturing or construction sectors' firms, and 0 for service sectors' firms).

In Table 2 we can see the innovation reduction model we estimated from the above data through ordinal regression estimation (since the dependent variable is a five-level ordinal variable) and using negative log-log link function (as the lower categories of the dependent variable are more probable); the statistically significant coefficients at levels of 1%, 5% and 10% are shown with ***, ** and * respectively.

This model reveals two ICTs that have statistically significant negative effects on the extent of Greek firms' innovation reduction due to the crisis (i.e., reduce the negative effects of the crisis on firms' product/service innovation): the cloud computing and the BI/BA. The use of cloud computing can provide rapid and low-cost electronic support of firm's activities and processes, improving their

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efficiency, and this can make the firm more resistant to the crisis and reduce the negative impact of economic crisis on its sales revenue. This increases the availability of financial resources for innovation projects. Also, cloud computing can provide rapid and low-cost electronic support of firm's product/service innovations, and this has positive influence on its innovation activity. The use of BI/BA allows extracting useful insights from the data stored in a firm's IS (concerning sales, production, procurement, expenses, etc.), which can lead to efficiency improvements, making the firm more resistant to the crisis, reducing the negative impact of economic crisis on sales revenue, and therefore increasing the availability of financial resources for innovation projects. Furthermore, the use of BI/BA enables gaining valuable insights from firm's sales data, which allow identifying opportunities for making product/service innovations.

TABLE 2. ESTIMATED INNOVATION REDUCTION MODEL

Independent variable	Coefficient	Independent variable	Coefficient
EXP	-0.275**	***CLO***	-0.348**
ORG	-0.073	***DEMDEC***	0.218***
HC	-0.298	***PRCOMP***	0.108
CRM	0.040	***NPRCOMP***	0.084
BI/BA	-0.094*	***D-L***	-0.375
CS	0.033	***D-M***	-0.053
SM	-0.151	***D-SE***	-0.100
Nagelkehre Pseudo $R^2 = 0.125$			

Also, the estimates in Table 2 indicate that the adoption of export strategy has statistically significant negative effect on the extent of Greek firms' innovation reduction due to the crisis (i.e. reduces the negative effects of the crisis on firm's product/service innovation). The adoption of export strategy reduces the reliance of firm's sales revenue on its domestic market. So if there is an economic crisis in the home country of the firm the sales revenue from the domestic market is reduced, but this does not happen with the sales revenue from the markets of the other foreign countries, in which the firm is present (if in these countries there is not economic crisis, or at least it is less severe, which is the case for Greece). Therefore, the negative impact of an economic crisis in a firm's home country on overall firm's sales revenue is finally weaker. This results in higher availability of financial resources that can be used for product/service innovation. Finally, our model indicates that the extent of demand decrease that the firm experienced during the last three years due to the Greek economic crisis has statistically significant positive effect on the extent of innovation reduction due to the crisis (i.e., increases the negative effects of the crisis on firm's product/service innovation). If the firm belongs to a sector that experienced higher demand decrease during the crisis then the decrease of its sale revenue will be stronger, reducing the financial resources for innovation.

Furthermore, interesting and useful insights can be gained also from the independent variables that do not have statistically significant effects on the extent of firm's innovation reduction due to the crisis. They indicate that Greek firms do not exploit their human capital, their organic forms of workplace organization (such as teams, decentralisation of decision making and job rotation) and their collaboration support systems for coping better with the crisis and for promoting product/service innovation. The same holds for their CRM systems and social media. Also, they do not react to competition pressures during the economic pressure with product/service innovation.

Our conclusions indicate that the design and implementation of public policies for promoting and facilitating export activities of Greek firms, and also the use of cloud computing and BI/BA, especially for sectors experiencing higher demand decrease during the economic crisis, would contribute to the reduction of the negative consequences of the economic crisis on their innovation activity, and therefore on their medium- and long-term competitiveness.

V. CONCLUSIONS

In the previous sections has been presented a methodology of innovation policy analytics, for the difficult periods of economic crises that market-based economies repeatedly face. It exploits and combines existing data from Taxation Authorities and Statistical Agencies, and also from private sector consulting and business information firms, and performs advanced processing of them (based on regression modelling), in order to identify characteristics of the firm and its external environment that affect its innovation behaviour (the extent of their product/service innovation reduction) during economic crises. Our methodology is based on and leverages findings of previous research on innovation determinants and economic crises. A first validation of this methodology was made through an application of it in the context of Greece, which provided some first evidence concerning the capabilities and usefulness of it. This application enabled the identification of some characteristics of Greek firms and their external environment that affect their innovation behaviour during economic crisis, which provide a useful base for innovation policy making.

However, our study has some limitations. The proposed methodology is based on the estimation of regression models, so it would be interesting to extend it with estimations of other kinds of models as well, e.g., from the areas of data mining and artificial intelligence (such as various classifiers). Also, the first application of the methodology was based on a cross-sectoral sample of Greek firms, so it would be interesting to proceed to more applications of it, in various other national contexts, and also in specific sectors, for different kinds of firm product/process innovation (e.g., incremental, radical, etc.), and using wider sets of characteristics of firms and their external environments as independent variables.

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