POLICY ANALYTICS FOR IMPROVING FIRM BEHAVIOUR IN CRISIS

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ABSTRACT

Data science and business analytics have been initially developed in the private sector, and their success gives rise to the development of data science in the public sector as well, and the emergence of the 'policy analytics'. A new generation of the e-government domain is gradually emerging, referred to as 'e-government 3.0', which aims at the exploitation of the large quantities of data possessed by government agencies, possibly in combination with data from the private sector, using advanced modelling and analysis techniques, in order to support and improve policy making, and promote 'evidence-based policy' making. This paper makes a contribution towards the development of public sector data science and policy analytics, focusing on a highly important problem: the economic crises, which occur repeatedly in market-based economies. It presents a methodology for the exploitation of government data from Taxation Authorities and Statistical Agencies, in combination with data from the private sector (from business information and consulting firms), for the identification of firm's characteristics that affect behavior in the economic crisis, focusing on their investment related behavior (the extent of reduction of their investment). Our methodology aims to support the design of public policies for reducing the negative impact of economic crises on firms' investment, and improving firms' investment behavior during economic crises. An application of this methodology is presented, using data from Greek firms for the crisis period 2009 – 2014, which leads to interesting insights; four firms' characteristics have been identified that reduce the negative effects of the crisis on Greek firms' investment.

KEYWORDS

e-government, policy analytics, policy informatics, data science, economic crisis, investment

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1 Introduction

Data science and business analytics have been initially developed in the private sector, aiming at the exploitation of the large quantities of data collected by firms in order to support decision making and strategy formulation, and also develop new products and services [5,6]. Their success in many private sector firms, in combination with the growing availability of large quantities of data in government agencies, gives rise to the development of data science in the public sector and the emergence of the 'policy analytics' [28, 15, 4, 7, 10]. Policy analytics (previously termed also as policy informatics) is defined as the exploitation of existing data from government agencies, possibly in combination with data from private sector firms, using advanced analytical techniques, in order to support different stages of public policy making [10]. A new generation of the e-government domain is gradually emerging, referred to as 'e-government 3.0', which aims at the exploitation of the large quantities of data stored in government agencies internal information systems (IS), and also the textual data collected through their social media accounts, as well as the data collected through various novel Information and Communication Technologies (ICT) (such as the Internet of Things (IoT)), in order to support various stages of public policy making [14, 18]. While the previous generations of e-government aimed at the improvement of the efficiency of the internal operations of government agencies, and also of their transactions with citizens and firms (e-government 1.0), as well the enhancement of the dialogue and consultation with them (e-government 2.0), this new generation of e-government has far more ambitious objectives: to support the most sophisticated functions of government agencies, which concern the design of effective public policies for addressing the complex problems and needs of modern societies. The exploitation for these purposes of the enormous data resources of government agencies, using advanced modelling and analysis techniques, can radically transform and improve government policy making, and promote 'evidence-based' policy making, which can be highly beneficial for modern societies [15, 10]. However, though some first research has been conducted in this area (see section 2.1), it is still in its infancy, so much more research is required in order to develop a higher level of maturity of it, and provide substantial support for the design of public policies in critical domains.

This paper makes a contribution towards the development of public sector data science and policy analytics, focusing on a highly important problem: the economic crises, which repeatedly occur in

market-based economies [16, 17]. Economic crises of varying intensities and durations often appear in the market-based economies, being an inevitable trait of them, and have serious consequences, both short-term as well as medium-term and long-term ones, affecting negatively the lives of millions of citizens. The short-term consequences include contraction of economic activity, reduction of firms' sales revenue, production activity and personnel employment, leading to increase of unemployment and poverty. The medium-term and long-term consequences of economic crises are less visible and publicly debated, but equally important: reduction of firms' investment, which has quite negative impact on their medium and long term productivity and competitiveness. A recent report of the PricewaterhouseCoopers consulting firm on the long crisis that Greece experiences since 2010 concludes that one of its most negative consequences is the reduction of Greek firms' investment, which has increased further their technological and competitiveness hysteresis, and constitutes a major barrier to recovering from the crisis [25]. Therefore, governments have to design and implement policies for reducing these serious short-term as well as the medium-term and long-term negative consequences of economic crises. The development of policy analytics methodologies for supporting the design of such policies is of vital importance. In this direction our paper presents a policy analytics methodology, which aims to support the design of public policies for improving firms' behavior during economic crises, focusing on their investment related behavior, in order to reduce the negative impact of economic crises on firms' investment. It exploits existing data from various government sources (e.g. Taxation Authorities, Statistical Agencies, etc.), in combination with data from the private sector (e.g. from business information firms, consulting firms, etc.), for the identification of firm's characteristics that affect positively or negatively the extent of investment reduction due to the economic crisis. However, our methodology can be used for gaining similar insights concerning any other aspect of firms' behavior during economic crises. As economic crises of varying intensities and durations occur repeatedly in different geographic regions, we expect that our methodology can have a wide usefulness for government agencies responsible for economic policies, as well as for consulting firms active in this domain. Furthermore, a first application of the proposed methodology is presented, using data from Greek firms for the crisis period 2009 – 2014, which leads to interesting insights.

This paper consists of five sections. The following section 2 outlines the background of our study, while in section 3 the proposed policy analytics methodology is described. Then in section 4 the above application of it is presented. In the final section 5 the conclusions are summarized, and future research directions are proposed.

2 Background

2.1 Policy Analytics

Though policy analytics, and the development of data science in the context of public sector in general, is a relatively new area, some knowledge has already been developed about approaches, frameworks and methodologies for exploiting existing government data, in combination with private sector data, using advanced analytical techniques, in order to support different stages of the policy making cycle in some important domains of government activity and policy, such as the environment [8], the energy provision [3], the justice [29] and the management of emergency crises (both natural disasters (e.g. earthquakes and hurricanes) and man-made crises (e.g. terrorism and ethnic violence)) [13, 23]. Also [10] examines the main analytical techniques used in policy analytics, and concludes that the most widely used ones are: statistical techniques, such as association analysis, data segmentation, clustering, classification and regression analysis, anomaly detection, etc., machine learning, social network analysis, geographic information systems, simulation and computer simulation. Furthermore, the growing amount of textual data collected by government agencies through social media, which includes valuable citizens' knowledge, ideas and opinions that can be quite useful for policy making, gives rise to the development of methods for exploiting in this direction these massive textual data, which are based on advanced text and opinion mining as well as sentiment analysis techniques [20].

However, the area of policy analytics is still in its infancy, so extensive research is required in order to advance it to higher levels of maturity. Substantial research is required in this area in order to increase our knowledge concerning the exploitation of the exponentially increasing quantities of data available in government, in combination with data from private sector firms as well, using various types of analytical techniques, for supporting all the stages of public policies' development and implementation: agenda setting, policy analysis, policy formulation, policy implementation and policy monitoring and evaluation [4, 28]. It is necessary to develop policy analytics' approaches, frameworks and methodologies in a wide range of thematic policy domains, with main emphasis on policies concerning the most serious challenges and problems our societies and economies face.

2.2 Economic Crises

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 [16, 17]. They are significant contractions of economic activity, due to 'business cycles', which are the fluctuations that economic activity usually exhibits, or other economic and political events (such as the oil crisis in the early 1970, or banking crises) [17].

Economic crises have quite negative short medium and long term consequences for the economy and the society. They give rise to reductions of the demand for most goods and services, resulting in decrease of firms' sales, production and profits, which leads to reductions in personnel employment, materials' procurement, while some weaker firms go bankrupt. These increase un-employment, especially among some disadvantaged groups, such as the young people, the low-skilled, the immigrants and the temporary workers, leading to serious and extensive social problems [16]. Furthermore, during economic crises firms usually reduce investment, both basic investment (e.g. in production

equipment, buildings, etc.) and innovation – related investment (e.g. in R&D, products and services innovations, internal processes innovations, etc.), due to the abovementioned reduction of the demand for their products and services, which makes such investment more risky, and at the same time decrease the available financial resources for investment [16, 17]. This has quite negative impact on firms' medium and long term productivity and competitiveness, and constitutes one of the worst consequence of the economic crises. However, in some cases firms can exhibit the opposite investment behavior: during economic crises increase some types of investment, such as the R&D and innovation ones, in order to take advantage of the reductions in the prices of the required inputs (such as specialized personnel and equipment) caused by such crises [1-2].

The above negative consequences of the economic crises on firms are not the same for all firms; some firms are more efficient than the others, offer higher value-for-money products and services, and also make appropriate adaptations to the crisis (e.g. in their products and services, as well as in their prices, distribution, etc., or even enter new markets), so they have less negative consequences than others. So, it is important to identify firms' characteristics that affect positively or negatively their sensitivity to economic crises, in order to design policies for supporting the most vulnerable firms, learning from the less vulnerable ones (e.g. by identifying characteristics and practices of them that reduce their vulnerability to the crisis).

3 A Policy Analytics Methodology for Improving Firms' Investment Behavior in Crisis

In this direction we have developed a methodology of policy analytics, using both public and private sector data, as well as regression analysis, aiming to support the design of public policies for reducing the negative impact of economic crises on firms' investment, and improving firms' investment behavior during economic crises.

For this purpose, the proposed methodology uses existing data from the public sector, concerning firms' investment during the economic crises, possessed by Taxation Authorities (Ministry of Finance) and Statistical Agencies; and also, data from the private sector, concerning various characteristics of firms, possessed by Statistical Agencies as well as business information firms and consulting firms. These data are used for the estimation of investment reduction regression models from them, having as dependent variables various measures of the reduction of firm's investments due to the economic crisis, and as independent variables various firm's characteristics. These models allow the identification of firm's characteristics that affect the extnent of its investment reduction due to the economic crisis.

In order to have a theoretical foundation for the selection of firm's characteristics to be used as independent variables in the above models we reviewed existing frameworks that define the main components of a firm [9, 19, 22, 24, 26]. We finally selected the extended Leavitt's Diamond framework [26], since it has a wider perspective than the other frameworks (e.g. the one described in [9] focuses on structural components, and the one described in [24] focuses on activity components). It is an extension of the basic Leavitt's Diamond framework [19], and defines five main components of a firm: strategy, processes, people, technology and structure. For each of these components we can select specific relevant firm's characteristics (e.g. strategy characteristics, processes characteristics, etc.), which are available in the existing data, and are expected to affect firm's investment behavior during the crisis.

In particular, using these existing data are estimated a series of regression models (using ordinary least squares, probit, logit, ordered probit, ordered logit, or multinomial logit estimation techniques, according to the type of the dependent variable – see [12]) having the following form:

$$\mathrm{INV_{RED}} = \mathrm{bo} + \mathrm{b1} * \mathrm{fch1} + \mathrm{b2} * \mathrm{fch2} + \ldots . + \mathrm{bn} * \mathrm{fchn} + \mathrm{bn+1} * \mathrm{d\_sz} + \mathrm{bn+2} * \mathrm{d\_sec} \quad (1)$$

Their dependent variables (INV_RED) can be various measures of the reduction of firm's investment due to the economic crisis; they might concern reduction of firm's total investment, or specific types of investment (e.g. in equipment, buildings, R&D, etc.). Their independent variables will be firm characteristics (fchi) belonging to the following six categories:

I) Strategy characteristics: characteristics concerning the strategic orientations of the firm; they can include the extent of adopting an innovation strategy, or an export strategy, etc.

II) Processes characteristics: characteristics concerning firm's business processes, such as their complexity, efficiency, formality, flexibility, etc.

III) Personnel skills characteristics: characteristics concerning the level of general skills possessed by firm's personnel (e.g. the share of employees with tertiary-level education), or some important specific skills (such ICT-related skills, e.g. share of employees who can use ICT, share of ICT-specialized personnel).

IV) Technology characteristics: characteristics concerning the technologies used by the firm; they can include the extent of use of various established as well emerging ICT, such as internal operations' support information systems (IS) (e.g. ERP, CRM, SCM), internal decision support IS (e.g. business analytics (BA) ones), external transaction IS (e.g. e-sales and e-procurement ones), IS for external communication and interaction with customers or potential customers (e.g. various social media platforms), cloud computing, etc.;

V) Structural characteristics: characteristics concerning firm's structure: organization in departments, and communication and coordination between them. They can also include the use of 'organic' structural forms, in addition to their hierarchical structures, such as teamwork, de-centralization and job rotation, which according to previous research can enhance organizational agility (e.g. see [27]); so they can improve firm's capacity to adapt to the changes that occur in its external environment due to the crisis (e.g. in customers' needs, suppliers' offerings and prices, competitors' actions), and therefore reduce its negative consequences, and finally have more financial resources available for investment.

VI) Size and sector control variables: it is also necessary to include firm size and sector control independent variables (d-sz and d-sec), in order to examine the effects of firm size and sector on investment reduction due to the crisis.

In general, we expect that the extent of firm's investment reduction due to the economic crisis will be shaped by: (a) its general efficiency level, that enables the firm to offer products and services of high value-for-money; (b) its capacity to sense and understand in depth the specific changes caused by the crisis in firm's activities and external environment, and then make appropriate adaptations, e.g. in its products/services, or even development of new/products/services (e.g. simpler and lower cost ones), entry in new markets, changes in internal processes and organization, etc. These are expected to determine the extent of the negative consequences of the crisis on the firm, and therefore the availability of financial resources for investment. As both (a) and (b) are affected to a significant extent by firm's characteristics (especially concerning its strategy, processes, people, technology and structure), we expect that the latter will have significant impact on the extent of firm's investment reduction due to the crisis.

4 Application

The policy analytics methodology described in the previous section 3 has been applied for the identification of characteristics of Greek firms that affect their investment reduction due to the long and intensive economic crisis that Greece experienced from 2009 until to-day [11]. For this purpose, we have used Greek firm's data for the period 2009-2014 from two sources: i) the Greek Statistical Agency (data concerning the extent of firms' investment reduction in the period 2009-2014); and ii) ICAP S.A., a well-known business information and consulting firm (data concerning firms' characteristics and practices). In particular, we have used data from 363 Greek firms, coming from the most technologically advanced manufacturing and modern services sectors of the Greek economy, as they constitute the main priority of public policies for overcoming economic crises (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 investment reduction regression model was estimated.

Our dependent variable was calculated as the average of seven 5-levels ordinal variables measuring the extent of reduction of five types of firm's investment concerning production equipment, buildings, personnel training, advertisement/marketing, R&D, product/services innovations and process innovations. So it is a measure of firm's overall investment related behavior during economic crisis. The independent variables were:

- for strategy: adoption of an innovation strategy (INN) (quantified through the percentage of sales revenue of the last three years coming from new products/services), adoption of an export strategy (EXP) (binary variable);
- for personnel: number of employees with tertiary-level education as percentage of the total number of firm's employees (TERT), number of ICT-specialized personnel as percentage of the total number of firm's employees (ICTP);
- for technology: use of internal operations' support IS (INT-IS = average of three 5-levels ordinal variables assessing the extent of using an ERP, a CRM and a SCM system respectively), use of internal decision support IS (BA-IS = extent of using a business analytics (BA) system), use of e-sales IS (ES-IS – binary variable), use of social media (SM – binary variable) and use of cloud computing (CLO - binary variable);
- for structure: use of 'organic' structural forms, such as teamwork, decentralization and job rotation (ORG – binary variable);
- 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 firms, and 0 for service firms).

In Table 1 we can see the investment reduction model using the above data through ordinary least squares estimation (for each independent variable is shown its standardized regression coefficient, with the statistically significant ones at the test levels of 1%, 5% and 10% shown with ***, ** and * respectively). This model reveals four characteristics of a firm that have statistically significant negative effects on its investment reduction due to the crisis (i.e. reduce the negative effects of the crisis on firm's investment): the adoption of an export strategy (EXP), which has the strongest negative effect (standardized coefficient -0.178), the use of 'organic' structural forms (such as teamwork, decentralization and job rotation) (ORG) (standardized coefficient -0.104), the use of cloud computing (CLO) (standardized coefficient -0.041) and the size of the firm (D-L) (with large firms exhibiting lower extent of investment reduction - standardized coefficient -0.100).

Independent variable	Standardized Coefficient
INN	0.024
EXP	- 0.178***
TERT	-0.018
ICTP	0.011
INT-IS	0.054
BA-IS	-0.099
ES-IS	0.091
SM	0.011
CLO	-0.041**
ORG	-0.104*
D-L	-0.100*
D-M	-0.004
D-SE	0.028
Dependent variable = DEC_INV N= 314 $R^2 = 0.125$	

Table 1: Estimated investment reduction model

The adoption of an export strategy reduces the reliance of firm's sales revenue on its domestic market, as part of this revenue comes from markets of other countries; so if there is an economic crisis in

the home country on one hand the sales revenue from the domestic market is reduced, but on the other hand 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 firm's home country on overall firm's sales revenue is finally weaker. This results in higher availability of financial resources to be used for investment.

Furthermore, the use of 'organic' structural forms, such as teamwork and job rotation, facilitates the exchange of knowledge among firm's employees about the complex and multi-dimensional changes that occur in firm's external environment due to the crisis (e.g. in customers' needs, suppliers' offerings and prices, competitors' actions), and also about possible actions for managing them successfully; also teamwork facilitates as the co-operation of employees from different functions (e.g. sales, marketing, production, procurement, finance) for the design and implementation of specific responses to these changes. Also, the economic crisis increases the complexity of firms' external environment and therefore the quantity of the external knowledge that has to be acquired and processed by them, so this cannot be done exclusively at the higher hierarchical levels; therefore de-centralization of such tasks towards lower hierarchical levels can be quite beneficial, enabling more effective acquisition and processing of this extensive crisis-related external knowledge by a larger number of individuals. Previous literature has found that the use of these 'organic' structural forms increases organizational agility [27]. This increased capacity for firm's adaptation to the new realities brought by the crisis can reduce the negative consequences of it for the firm, and for this reason increase the available financial resources for investment.

Finally, the use of cloud computing allows the rapid and low-cost provision of electronic support of a) existing firm's activities and processes, in order to improve their efficiency, and b) firm's responses to the crisis (e.g. changes in existing products and services, as well as in their prices, distribution, etc., new products and services, or even entries in new markets). So, the use of cloud computing can enhance firm's efficiency, and also its capacity for adaptations to the new realities brought by the crisis, so it can reduce the negative consequences of the crisis for the firm, and therefore increase the available financial resources for investment.

Also, firm size affects the extent of investment reduction during economic crisis, as larger firms have in general more financial resources, and also banks are more willing to finance them, so they can make more investments in crisis periods.

On the contrary none of the examined personnel-related variables (neither the share of tertiary education graduates nor the share of ICT-specialized personnel) has statistically significant effect on firm's investment reduction due to the crisis. This indicates that the acquisition of highly skilled human resources is not enough for increasing firm's capacity to cope with the crisis and reduce its negative impact. It is necessary to adopt appropriate forms of organization of these human resources, such as teamwork, job rotation and decentralization, which facilitate exchange of knowledge and co-operation for managing the crisis.

We remark that four out of the five technology-related variables, which concern the use of internal operations' support IS (INT-IS), e-sales IS (ES-IS), business analytics IS (BA-IS) and social media (SM), do not have statistically significant effects on firm's investment reduction due to the crisis (though previous literature has found that the use of ICT can increase organizational agility [27]). These probably indicate that sample firms do not exploit sufficiently their internal operations' support IS, e-sales IS, business analytics IS and social media for understanding better the specific consequences of the crisis for the firm, coping with the crisis and reducing its negative impacts (e.g. for understanding the crisis-induced changes in the needs and preferences of the customers, for supporting the design and production of new simpler and lower cost products and services, for the expansion of sales to new markets, customer groups and geo-graphic regions, etc.).

Summarizing, from the above first application of the proposed policy analytics methodology it has been concluded that Greek firms making exports, using 'organic' structural forms, such as teamwork, de-centralization and job rotation, and cloud computing, had less negative impacts of the crisis on their investment; also larger firms had less investment reduction in the crisis. Therefore, government, in order to contribute to the reduction of the negative consequences of the economic crisis on firms' investment, should design and implement public policies, programs and training for promoting, facilitating and supporting:

- the export activities of firms,
- the use of cloud computing
- the adoption and effective application of 'organic' structural forms (e.g. teamwork, de-centralization and job rotation),

especially for the small and medium firms.

5 Conclusions

In the previous sections of this paper has been presented a policy analytics methodology, which aims to support the design of public policies for improving firms' behavior during economic crises, focusing on their investment-related behavior (extent of reduction of their investment). It uses existing data from various government sources (e.g. from Taxation Authorities, Statistical Agencies, etc.), and combines them with existing data from the private sector (e.g. business information firms, consulting firms, etc.), for the identification of firm's characteristics that affect positively or negatively the extent of reduction of their investment due to the economic crisis. Our methodology has a much wider applicability: it can be used for identifying firms' characteristics affecting any other aspect of their behavior during economic crises. As economic crises of varying intensities and durations occur repeatedly in different geographic regions, being an inevitable trait of market-based economies, we expect that our methodology can be broadly useful to government agencies responsible for economic policies, as well as for consulting firms active in this domain. A first application of the proposed methodology has been presented, using Greek firms' data from Greek Statistical Agency and also a private

sector business information and consulting firm for the crisis period 2009 – 2014, which provides some first evidence of its usefulness: it has led to the identification of four characteristics of Greek firms that affect negatively the reduction of investment due to the crisis; these findings provide a basis for the development of public policies for reducing the negative impact of the crisis on Greek firms' investment.

However, our research has four limitations. The first limitation is that the presented application of the proposed methodology is based on the estimation of a linear regression model, so it would be interesting to investigate the estimation of non-linear models (such as ordered probit model), or the construction of decision trees or other classifiers, using various machine learning techniques, with the same dependent and independent variables. The second limitation is that due to the cross-section character of the data strictly speaking only conditional correlation and not causal inferences can be made. The third limitation is that the proposed policy analytics methodology supports mainly the first two stages (agenda setting and policy analysis) of public policies for reduction of the negative consequences of crises on firms). So further research is required for the development of policy analytics methodologies for supporting the next stages of these policies (policy formulation, policy implementation and policy monitoring and evaluation). A fourth limitation, which concerns the application of the proposed methodology described in section 4, is that it has used as independent variables a limited set of firm characteristics that were available in the data we used; also, many of them were measured through binary (Yes/No) variables. So further application of the proposed methodology would be interesting, using a wider set of firm characteristics as independent variables, and detailed measurements of them (e.g. through ordinal or even interval or ratio variables instead of binary ones), in several different national contexts, experiencing different kinds of economic crises (with respect to intensity, duration and causes-generation mechanisms).

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