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Qualitative and quantitative methodological approach for evaluating public R&D funding

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Qualitative and quantitative methodological approach for evaluating public R&D funding

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Abstract

This paper presents and demonstrates a qualitative and quantitative methodological approach to the evaluation of public Research and Development (R&D) funding. This approach aims to support rather than replace traditional evaluation approaches, by focusing on the input, output and behavioural effects of public R&D funding. This study employs as an evaluation model an adapted impact analysis model of the Finnish Funding Agency for Technology and Innovation (TEKES), including additionality theory and other evaluation methods. In addition, an evaluation tool is proposed in which R&D indicators are arranged in portfolios. Furthermore, a data repository mechanism is designed, and a computational tool for computing and displaying evaluation results is employed - a customised web-based application centred by an ontological evaluation model. The methodological approach is articulated, explained, illustrated and discussed by employing R&D programmes granted by the Greek funding agency. The

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results display both a standardised approach that can be applied to R&D funding evaluation, as well as a flexible and modular approach that can be adapted according to the objectives and policies of funding agency.
The main benefits of this methodology are the ease of decoding quantitative and qualitative evaluation attributes in an automated way with low cost; and the ability to evaluate results objectively, in addition to producing outcomes in a broad and comparative manner. The challenge in this methodological approach is focused on three key areas: the exploitation of new evaluation tools, the elevation of hidden information, and the formulation of appropriate questions beneficial to revealing the effectiveness of government R&D funding mechanism

Key words: R&D evaluation, methodological approach, qualitative and quantitative, evaluation ontology model.

1. Introduction

In recent years the need for public investment in research, development, and innovation has become urgent. Funding research and development programmes with an aim to create innovative results is a powerful tool in public policy (Carnegie Commission, 1992; Ruegg & Feller, 2003; European Court of Auditors, 2007; Hyvärinen, 2009). These programmes, which are designed to address the needs of national policies, usually concern the private sector and social institutions such as universities and research centres. The immediate, mid-term and long-term evaluation results of such funded programmes and projects are crucial not only for further strategy development and policy production, but also for capturing the added value of new knowledge, new technologies and innovation output (Georghiou, 1998; Ebersberger, 2005; EC, 2008a).

Such an evaluation, by funding agencies and other interested parties, is undoubtedly a complex process (Bachtler et al., 2009; Aiginger, Falk & Reinstaller, 2009; Edler et al., 2010). It aims to both identify the most appropriate applied solutions for an optimal allocation of resources in parallel efforts; and assess the participants in a research consortium by measuring productivity, collaboration, expenditure management, and monitoring project's completion time (Chatelin & Arvanitis, 1989; Braun et al., 2009; EC, 2008b).

The evaluation of public funding R&D is a frequently debated topic in literature. Quantitative approaches have been proposed for more objective evaluation results, based on the inputs and outputs of R&D funding (Agarwala-Rodgers, 1977; Block & Krull, 1990). Some of these approaches use technical methods to determine the significance of findings such as cost – benefit analysis, econometrics, organisation rules, and workflow (González Jaumandreu & Pazó 2005; Kudyba & Diwan, 2002). The qualitative approach, in contrast, focuses more on the efficiency, effectiveness and the added value of public intervention (Donovan, 2007; Autio, Kanninen &

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Gustafsson, 2008; Cerulli & Potì, 2010). Therefore, qualitative methods are likely to lead to perspectives such as those relating to human initiative, sustainable changes, acceptance of innovation, and the relative differences between firms with and without public intervention (Eilat, Golany & Shtub, 2008; Edler et al., 2010, Georghiou & Clarysse, 2006; EC 2008b; Tuzi, 2005).

In fact, the practice of evaluation typically generates more data than the actual data for project management; and funding agencies collect vast and complex amount of structured and unstructured data in order to monitor programme objectives and project goals. These data should be gathered and recorded from the beginning of the of the programme execution life cycle. Additionally, the growth of such evaluation data streams from monitoring projects and data analysis processes should be taken into attention during evaluation. The objective is then to render these data beneficial to the exercise of evaluation. One way this could be done is by converting them into a flexible data structure model (Brass, 2008). Although, there is an overhead of indexing and categorising structured and unstructured information, such easy access to substantial primary information is crucial to evaluation processes.

The goal of this study is to present a qualitative and quantitative methodological approach for evaluating public R&D funding. Contents of the methodological framework comprise an evaluation model, a mechanism, and computational tools to exercise the evaluation practice. The evaluation model employed in this study is called Grid Structure Causality Evaluation (GSCE) model. In our study, a grid structure causality evaluation model adapted according to the impact analysis model of TEKES (discussed by Hyvärinen and Rautiainen (2007)) was applied along with additionality theory. Consequently, the paper addresses indicators grouped in portfolios as a computational tool for supporting the evaluation approach. These are related to the model and incorporated in each component of GSCE to measure the qualitative and quantitative aspects of programmes and projects. Furthermore, an Evaluation Project Data Table (EPDT) is introduced in place of information warehouse, where structured and unstructured data are organised in a classified and taxonomic scheme for the evaluation practice. The instrument to embrace the model, the indicators and the data is a web-based application where the knowledge is stored, in an ontology model, as a knowledge base in the methodological framework. Additionally, the proposed methodological framework is applied to the R&D of the Greek Regional Operational Programmes of twenty-six projects in total funded by the General Secretariat for Research and

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Technology (GSRT), which is the Greek R&D funding agency. The aim of the illustration is not to re-evaluate the programmes but to show the value of the approach and to highlight the importance of measuring input, output and behavioural additionality from public R&D funding. The proposed portfolios and indicators, which were developed specifically for the case study demonstration, fulfill to a degree evaluation questions; since similar evaluation questions have been approached by the academic literature, in addition to funding agencies and government policy makers that have the responsibility to address the right questions to the matters of concern. The effectiveness and efficiency of the proposed methodology could help the interested parties in the evaluation to more easily customise the parameters of the indicators according to their evaluation objectives and requirements. This methodology could also be used as an instrument for policy makers to express qualitative evaluation results in quantitative terms.

2. Methodological Framework

2.1 Evaluation Model

The evaluation model, the content of the methodological approach, is based on a grid structure causality evaluation model. This model is a combination of an adapted impact analysis model of TEKES (as presented by Hyvärinen and Rautiainen (2007)), additionality theory (Georghiou Rigby & Hugh, 2002; Gök, 2010) and supplementary methods such as bibliometric evaluation (Donovan & Butler, 2007; Geisler, 2005; Kostoff, Shlesinger & Malpohl, 2004), network analysis (Lee & Bozeman, 2005; Ahuja, Galleta & Carley, 2003), spillover effects (Guellec & van Pottelsberghe de la Potterie, 2003), ex-post evaluation (Rietschel et.al., 2009; Nanda et al., 2000), case studies (Corley, 2007; Lööf & Hesmati, 2005), and bench marking (Hauser & Zettelmeyer, 1997).

The model is shown in Figure 1, which illustrates the four key components: investments, results, direct effects, and impacts on regional and national economy and society. One of the main challenges of R&D funding evaluation is to measure and show the effects of public R&D funding, by plotting the input, output and behavioural additionality (Georghiou & Clarysse, 2006; Hyvärinen & Rautiainen, 2007).

Figure 1: Grid structure causality evaluation (GSCE) model adapted according to the impact model of TEKES as presented by Hyvärinen and Rautiainen (2007). The four components of the grid, the corresponding evaluation methods and the different effects of additionality concepts are introduced.

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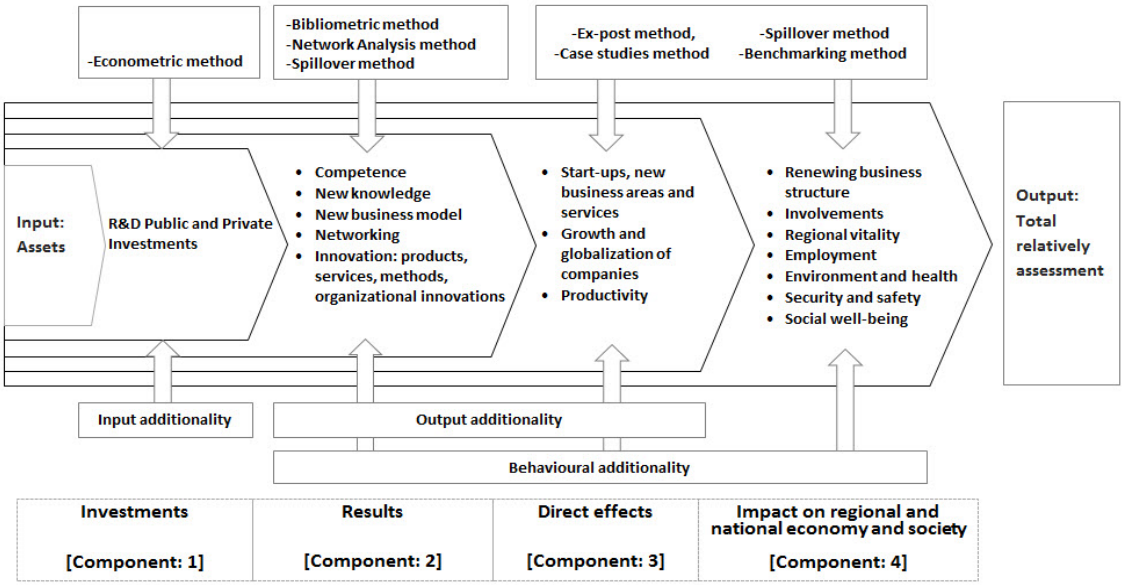

2.2 Proposed indicators

In order to determine R&D indicators as a tool for evaluating public R&D funding, an important parameter is to compose the appropriate questions concerning programme objectives and government policy (Braun et al., 2009; Arnold et al., 2009). Evaluation practices can be significantly improved by the creation and practice of quantitative and qualitative R&D indicators. In the present study, the proposed evaluation indicators focused on input, output and behavioural additionality by codifying administrative, financial, scientific and technical data. This data came from contracts, documents, reports, deliverables, publications, conference presentations and patents, as well as from unstructured and semi-structured interviews. All the information was accessed after projects' completion.

In our methodological approach we proposed two series of indicators:

- Indicators of structured data, derived from data elaboration of identifiable structure from classified and organised repositories.
- Indicators of unstructured data, derived from data elaboration of semi-structured and no identifiable structure resources.

2.3 Description of data and web-based ontology model application

A data warehouse is an additional content in our methodological framework where structured and unstructured evaluation data should be collected, organised and categorised. In this study, a mechanism of a prototype spreadsheet table schema is employed. The data collected derive from different dimensions or sections of the evaluation process reflected in the complete project's

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cycle. In our study, the data warehouse is called Evaluation Project Data Table (EPDT), and it is designed to store all information from numerous latitudes of programmes and to integrate all the evaluation components in a uniform manner. All the data in EPDT table come from heterogeneous data bases, spreadsheets, reports and deliverables from scientific and technological results from the participants, the external evaluators, and the funding agencies. The classification and the taxonomy of the assembled material into entities and fields in the EPDT table remains a product of subjective reorganisation of the available data sources. The structure of the EPDT table is planned to comprise information of R&D projects organised and classified into a number of entities, and each entity is composed by a number of fields which depends on and varies according to the needs and requirements of the agency. For example, some of these entities provide information about the programme, the call, the participants, the participant's activity in the project, the work packages (WP), the deliverables (D), and others. It is worthy of note that the amount and type of fields must be predetermined from the beginning by the R&D funding agency relative to its policy and programme objectives.

A web-based ontology application was operated to import project and programme data in a knowledge warehouse structure. An acquisition of knowledge was obtained by modelling this information into an ontology schema, where the user can access the project's data and evaluation indicators by operating the application. In general, an ontology formally describes a domain of discourse (Antoniou & Harmelen, 2008). Ontologies can be used from domain experts, data bases and applications whenever there is necessary information to be shared relative to a subject or a domain. The criteria for designing, and the principles for creating the evaluation ontology, are clarity and objectivity, coherence, extendibility, inferencing, inheritance, and inverse relations. Developing an ontology model for evaluation practice embraces hierarchical classes in a taxonomy schema, defining and describing permissible values for the properties, and finally loading values. A technical paper describing the web-based application and the ontology model is currently being elaborated.

3. Case study Results

The proposed evaluation methodological approach is prototypical, generic and flexible. In order to demonstrate the feasibility of the evaluation approach, Greek R&D funding programmes were employed to participate. The regions of implemented programmes chosen were roughly

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similar to the regional dimension of the European Research policy, and the thematic areas concerning the projects were similar to those supported in the R&D priorities of the European Research Area.

In the case study, twenty-six (26) projects contributed from several thematic areas of national policy and from six Regional Operational Programmes of the Third Community Support Framework in Greece during the period 2006-2009. These projects were supervised by GSRT and were implemented by consortia from the private sector and academia. In each cooperation project, at least one firm and one university or research centre cooperated. The criteria for selecting the projects were geographical distribution, which took into account the six regions' socio-economic disparities, and the projects'' completion in terms of administrative, financial, scientific and technical requirements. Table 1 presents both the Greek regions as well as the thematic areas of participant projects in the study.

Table 1: Presentation of Greek regions, R&D thematic areas, their abbreviations and the number of participated projects in our case study respectively.

Greek regions	**Abbreviation**	**No Projects**
East Macedonia and Thrace	EMT	4
Attica	ATT	5
North Aegean	NAG	3
West Greece	WGR	5
Ionian Islands	INI	3
Crete	CRT	6
R&D thematic areas	**Abbreviation**	**No Projects**
Renewable Sources of Energy and Energy Saving	TA1	1
Culture - Sustainable Tourism	TA2	5
Food – Agricultural Development and Aquaculture	TA3	2
Health - Biomedicine, Diagnostic and Therapeutic Methods	TA4	4
Structural Environment and Earthquake protection management	TA5	3
Natural Environment και Sustainable Development	TA6	1
Textiles and Advanced technology procedures	TA7	2
New forms of Business Management, Labour and Training	TA8	4
Information Technology, Action in ICT (Information and Communications Technology)	TA9	4

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3.1 Evaluation Project Data Table - EPDT

In the case study, a data repository was designed as a prototype spreadsheet data table and the structure of this evaluation project data table consisted of 119 fields classified into 13 entities as presented in Table 2.

Table 2: Evaluation Project Data Table (EPDT): 119 fields classified in 13 entities.

1	**Programme**	41	Certified (final) public cost	80	Name
1	Axis	42	Status national identity code	81	Unit
2	Measure	**5**	**Participant's activity in the project**	82	Approved value
3	Action	43	Activity identity code	83	Checked value from external evaluation
4	Type	44	Activity name (1=basic R&D development, 2=applied R&D development , 3=demonstration activity)	84	Certified value
2	**Call**	45	Participant identity code	85	Value of new indicators trough D.
5	Call identifier	46	Approved budget of public funding	**10**	**Personnel status vs cost**
6	Initial Budget of Public funding	47	Approved budget of private funding	86	Participant identity code
7	Initial Total Budget (public and requested private contribution)	48	Total approved budget	87	Personnel type (A=senior experienced researchers, B=junior researchers, C=support personnel)
8	Call deadline	**6**	**Work Package (WP)**	88	Personnel status (1= existing, 2= new hired for the project need)
9	Approved budget of public funding	49	WP number	89	Approved number of personnel
10	Total approved budget	50	WP title	90	Approved number of personnel
11	Number of submitted proposals	51	Lead participant identity code	91	Certified cost personnel
12	Number of successful granted proposals (collaborative projects)	52	Activity identify code	92	Certified person months - Full time equivalent (FTE) in person-months
3	**Collaborative Project**	53	Approved budget	**11**	**Personnel type vs cost**
13	Project title	54	Person months - Full time equivalent (FTE) in person-months	93	Participant identity code
14	Code project	55	Contribution weighting factor to the project	94	Personnel type (A=senior experienced researchers, B=junior researchers, C=support personnel)
15	Project coordinator (short name)	56	Approved start date	95	Initial number of personnel
16	Project coordinator (full legal name)	57	Approved end date	96	Initial person months - Full time equivalent (FTE) in person-months
17	Project thematic area code	58	Certified start date	97	Initial total budget
18	Directorate Unit of project monitoring	59	Certified end date	98	Approved number of personnel
19	Key words	60	Certified completion (percentage)	99	Approved person months - Full time equivalent (FTE) in person-months
20	Initial start date	**7**	**Deliverables (D)**	100	Approved total budget for personnel
21	Approved start date	61	D number	101	Certified number of personnel
22	Certified implementation day	62	D title	102	Certified person months - Full time equivalent (FTE) in person-months
23	Duration in months	63	D nature (report-1, prototype -2, final product-3, other-4)	103	Certified total budget for personnel
24	Approved budget of public funding	64	WP number related to D	**12**	**Budget vs Cost per expenditure category**
25	Approved budget of private funding	65	Lead participant identity code	104	Participant identity code
26	Approved total budget	66	Involved participant identity code	105	Expenditure category identity code
27	Certified final total cost	67	Total approved budget	106	National accounting code
28	Certified final public cost	68	Approved Delivery Date	107	Sort description
29	Independent experts' comments from external valuation	69	Certified delivery date	108	Initial total budget
4	**Participants**	70	Approved completion (Y/N)	109	Initial budget of public funding
30	Participant identity code	71	Certified completion (Y/N)	110	Approved total cost
31	Full legal name	72	Independent experts' comments from external valuation	111	Approved total public cost
32	Sort name	73	Quantitative scoring about D (0= absent, 1=not acceptable, 2=acceptable, 3=satisfied, 4=good, 5=excellent).	112	Certified total cost
33	Involvement in the project (coordinator, partner, sub-contractor)	**8**	**Participant vs Work Packages and contribution activity**	113	Certified public cost
34	Region	74	Participant identity code	**13**	**Final payment details**
35	County	75	WP number	114	Date signed of final payment (completion of physical and financial scope of the

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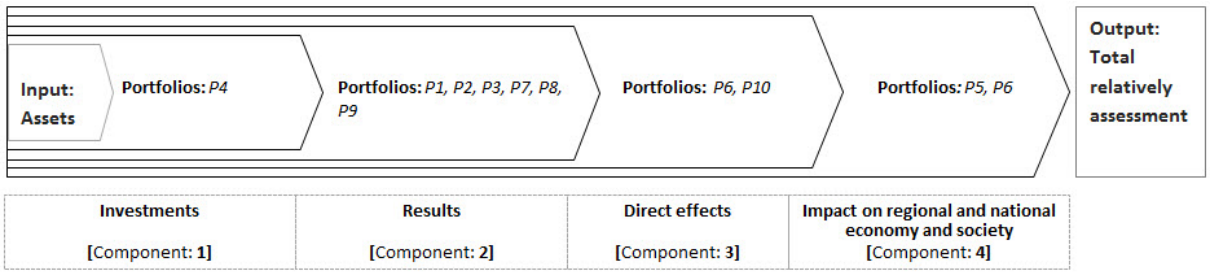
					project)
36	Type of legal entity (Public body, university, research institute, large scale firm, small and medium firm, broader public sector)	76	Activity identify code	115	Participant identity code
37	Approved budget of public funding	77	Approved total budget	116	Approved budget of public funding
38	Approved budget of private contribution	78	Approved budget of public funding	117	Certified cost of public funding
39	Approved total budget	**9**	**Success Indicators – Project goals from the public agency**	118	Partially paid of public funding
40	Certified (final) total cost	79	Indicator identity code	119	Public funding final repayment or participant return unduly paid

3.2 Project Evaluation Indicators

The evaluation indicators employed in this study were categorised into ten (10) portfolios from P1 to P10. Each portfolio accommodated a number of indicators (thirty three in total) from i1 to i33. Nine of the portfolios consisted of new proposed indicators from structured and unstructured data while one portfolio (P10) consisted of mandatory indicators pre-established by the funding agency. Furthermore, in computing values for indicators in portfolios P1, P2, P3, P5 and P7, records were derived from unstructured data while in portfolios P4, P6, P8, P9 and P10, records were derived from structured data. A general note is that particular portfolios or indicators in our study could be omitted and integrated into others as one; however, for reasons such as distribution structure, dissimilar statistical methods, and illustrating different access through different data in separate portfolios, the analytical style was followed. Our intention was to reveal the framework's ability to allow interested parties to select the approach and the style of result presentation during evaluation.

As shown in Figure 2, the proposed portfolios were integrated and correlated with each component of the GSCE model. Figure 2 shows this interaction.

Figure 2: Portfolios in interaction with the components of GSCE model.



As an example of the proposed methodological approach, a project from the case study is illustrated and discussed. This project comes from the region of Crete and the thematic area of

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"Health - Biomedicine, Diagnostic and Therapeutic Methods". The results of the project automatically generated by the web-based ontology application were knowledge from the GSCE model, data of EPDT table, and associated portfolios. The main benefit employing such knowledge technology application in the evaluation practice is the flexibility of adjusting evaluation parameters according to the programme aim and policy. The project's indicators are presented in a numeric and diagrammatic manner. Table 3 presents indicators values for a project (denoted as Pcre) implemented in region Crete.

Table 3: Indicator values of Pcre project as classified in ten proposed portfolios.

Symbol	Values	Symbol	Values	Symbol	Values
P1		**P5**		i21	Figure 4
i1	5	i11	no data	i22	Figure 4
i2	5	i12	no data	**P9**	
P2		i13	no data	i23	0.91
i3	0	**P6**		i24	a= 1.00; b= 1.00; c= 0.76; d= 0.99
i4	1	i14	2	**P10**	
i5	0	i15	no data	i25	2
i6	4	**P7**		i26	1
P3		i16	Figure 3	i27	0.75
i7	59	i17	Figure 3	i28	1
P4		i18	Figure 3	i29	1
i8	61%	**P8**		i30	9
i9	38%	i19	1,08	i31	1
i10	1.63	i20	Figure 4	i32	1.48
				i33	Figure 5

Following is a brief presentation and discussion of the above results for each portfolio and its corresponding indicators.

Portfolio P1 corresponds to scientific knowledge and holds two indicators: conference presentations (i1) and publications (i2). These indicators are based on bibliometric methods and indicate the scientific and technological work produced by the participants in the consortium after the project's completion. The higher the value of P1, the greater scientific knowledge capacity the project shows. It is important to note that average scientific knowledge in different areas of sciences or between basic and applied research could not be directly compared. In these cases, relative criteria had to be assumed.

Portfolio P2 describes technological innovation and refers to four individual indicators. Patents (i3), new products or services (i4), improved products or services (i5), and

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methodologies (i6) including new methods, new techniques, and new algorithms. The mission of this portfolio is to determine the success of project in innovation development.

Portfolio P3 demonstrates knowledge and innovation by combining portfolios P1 and P2. This portfolio consists of one indicator (i7), which indicatively shows the output additionality in terms of both new knowledge and innovation. Operationally, i7 is the sum of each indicator of P1 and P2 where each indicator is multiplied by a weighting factor (a dimensionless multiplicative factor). This factor is defined by the evaluators or by the funding agency based on the policy and the rational expectations of the programme, by taking into account the background and the experience of the participants. P3 is also an indicative measurement of the behavioural additionality as a change of firm behaviour from public R&D funding.

In our study, a reference value was defined as equal to eleven (11) for all the projects. The assumption for this reference came from the following reasoning. After project completion, it is expected that at least one improved product or service (weighting factor=6), at least one publication (weighting factor=4), and at least one presentation in an international or large-scale national conference (weight factor=1) are accomplished. It was also taken into consideration that a consortium includes at least one firm and one university and/or research institution. In fact, P1 and P2 portfolios could be omitted and integrated into P3 as one portfolio, but for the reasons previously explained, they are demonstrated separately.

Portfolio P4 corresponds to R&D investments and refers to three individual indicators: the percentage of public R&D funding (i8), the percentage of firm R&D investment (i9), and the overall additionality of public R&D funding (i10). This portfolio determines the magnitude of input additionality, and measures the success of the firm's R&D investment vis a vis the public R&D support. Indicator i10 reflects the sum of one unit of currency in public R&D funding and the matching amount of currency in firm R&D investment. In this particular project the overall input additionality is 1.63. It has previously been noted (Georgiou 2002) that it would be more efficient for input additionality if for every euro of public R&D funding is met by at least by one more euro from private R&D investment.

Portfolio P5 shows output sustainability in a five year period. This portfolio is composed of three indicators: number of sustainable products or services (i11), number of products or services coming from knowledge (i12), and percentage of income growth by region and by thematic area (i13). It is basically a portfolio corresponding to an ex-post evaluation approach, which estimates

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the additional long-term contribution of the project to research, technology and production. It is assumed that the greater the number of sustainable products or services that remain "live" over time, the greater the impact on gross domestic product (GDP) growth in the region for each thematic area. In our case, portfolio P5 has no values, because the indicators are related to a long-term evaluation, which is beyond the scope of this study.

Portfolio P6 concerns collaborations between the participants (firms and academia) during and after project completion. This portfolio consists of two indicators: the number of collaborations during project implementation (i14), and the number of collaborations after project implementation over a five years period (i15). P6 shows behavioural additionality, by presenting collaboration and cooperation networks expressed as the number of new created knowledge and technological networks from public intervention. A reference value for i14 in this study was determined based on the number of firms in the consortium. The minimum number of collaborations suggested was the total number of participants in the consortium divided by two. In this example, two collaborations succeed between the four participants during project implementation, which is equal to the reference value; and there is no data for the number of collaborations after project implementation over a five year period, since once more, this is beyond the scope of this study.

Portfolio P7 demonstrates project quality management as a result of all project deliverables. P7 consists of three indicators: highest quality grade (i16) on a scale of one to five for each deliverable, normalised to one; final normalised quality grade (i17) rated by external evaluators; and third, a diagrammatic indicator (i18), which is a graphical representation of i16 and i17.

Figure 3 shows indicator i18 which demonstrates that none of the project deliverables reach the highest quality grade. It would be interesting to also compare the proposed approved cost for each deliverable relative to its certified final cost.

Figure 3: Portfolio P7, project quality management, shows quality performance of each project deliverable as rated by external evaluators normalised to one, the highest quality rate.

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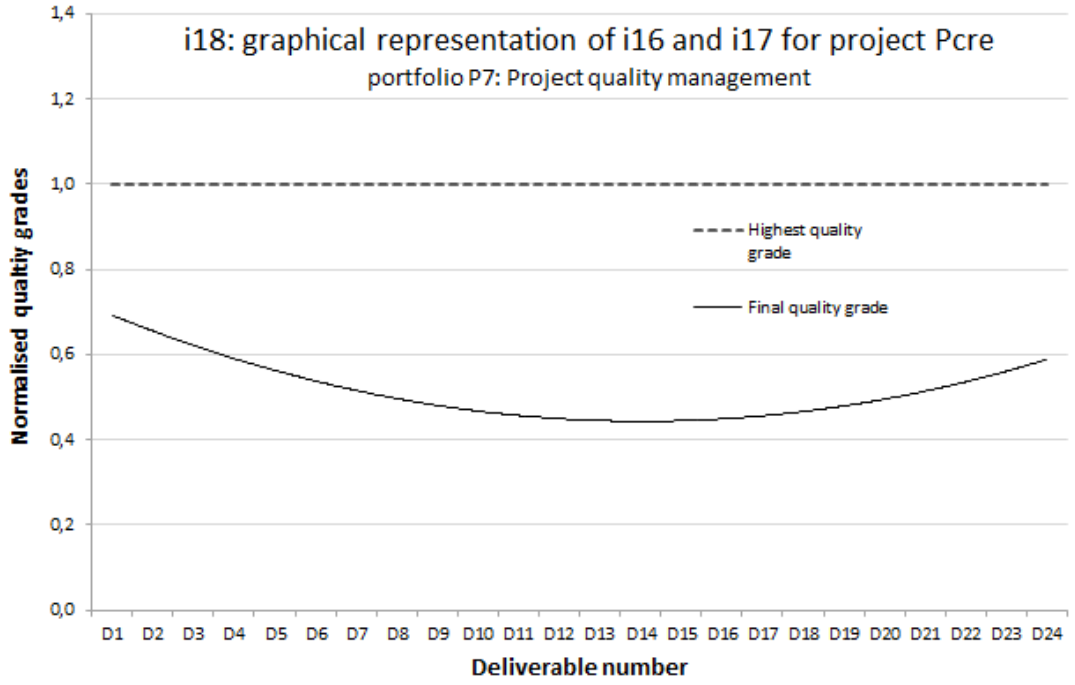

Portfolio P8 displays time management, by referring to project duration and deliverables' time completion. P8 comprises four indicators: divergence of project duration from the approved duration (i19), which is expressed as the ratio of the certified to the approved project duration; approved duration of each deliverable (i20); certified duration of each deliverable (i21); and a diagrammatic indicator (i22) of i20 and i21. Portfolio P8 reflects the degree of time management and planning capability in the project, and reveals the divergence from the scheduled time. Regarding the project, the ideal value for indicator i19 is one and any deviations from this value must be closely examined during the evaluation.

Figure 4 shows the diagrammatic indicator i22. This indicator shows deviation of project deliverables from the scheduled delivery. Observation of the results allows a general comment about the importance of interim evaluations to prevent divergence from the final project's objectives.

Figure 4: Indicator i22 from portfolio P8, project time management, shows approved duration time compared to certified duration time for each project deliverable in relation to total project duration.

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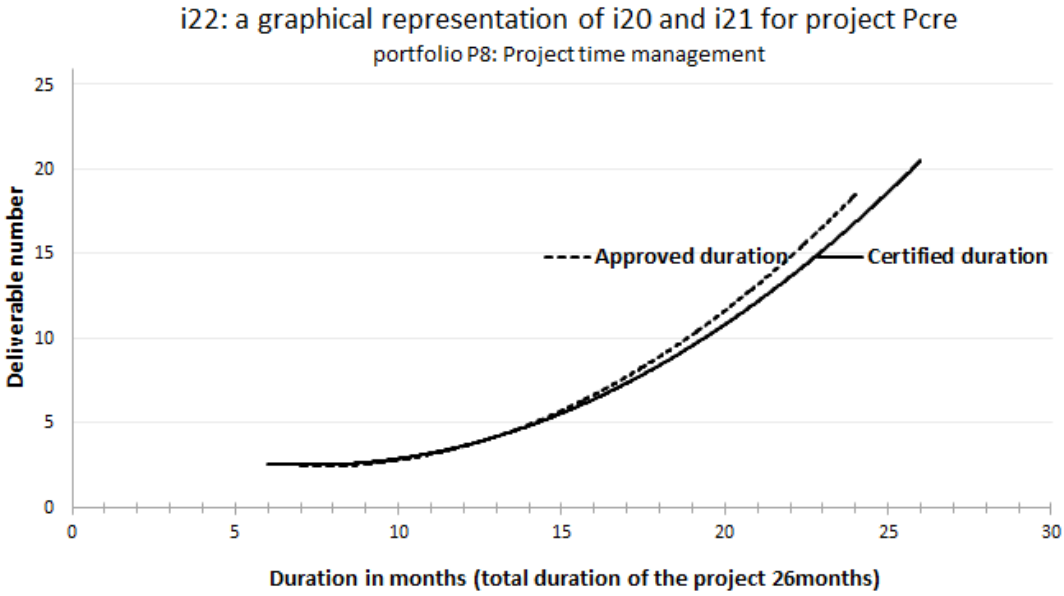

Portfolio P9 demonstrates project cost management, focusing on the total cost of the project and the individual total cost of each participant. P9 comprises two indicators: project cost divergence from the approved project budget (i23), which is expressed as the ratio of the certified total cost to the total approved budget; and participant cost divergence from the approved budget (i24), which is expressed as the ratio of certified participant total cost to approved participant budget for each participant (a, b, c, and d). For positive evaluation, indicators i23 and i24 should be close to one. In this study, a value of one (1) is defined as a successful reference value and 0.85 is the threshold below which the project needs special attention. In the project under examination, there are four participants in the consortium, two firms (c and d), a university (a) and a research institution (b). Again, the importance of interim evaluation should be emphasised, to impose corrective actions if necessary. Furthermore, firm involvement in R&D programmes should ensure the experience and appropriate infrastructure for accomplishing project objectives.

Portfolio P10 demonstrates the mandatory indicators of GSRT, which are designed by the agency to demonstrate and measure programme objectives. In this study, these indicators are normalised and classified into three categories. The first category is called structure and networking (P10a), and is composed of two indicators: new female personnel involved in the project (i25) and participants' collaboration (i26). The second category is called effects (P10b) and consists of three indicators: dissemination and publicity activities (i27), number of firms

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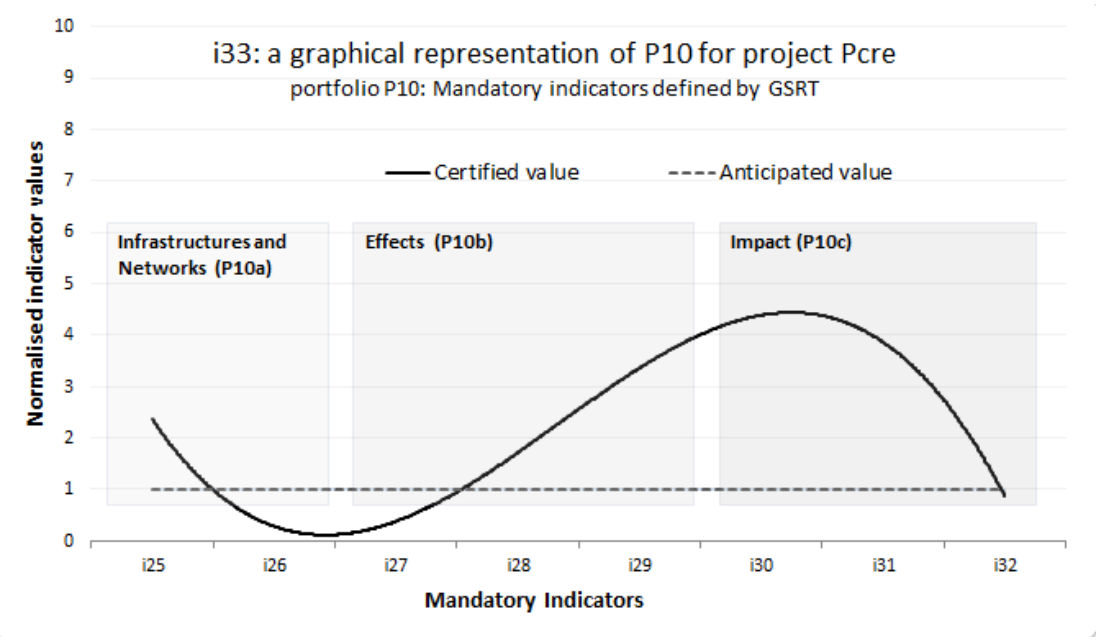
affected by the public funding (i28), and number of research organisations and universities affected by the public funding (i29). The third category is called impact (P10c) and consists of three indicators: publications and conferences by the participants (i30); new full time jobs created immediately after project implementation (i31); and new full time jobs created during project implementation (i32). Finally, there is a diagrammatic indicator (i33), which graphically presents the divergence of all the portfolios' indicators from the reference value.

The indicators equal or greater to one are those that reached or exceeded the goal. Figure 5 shows the three categories in portfolio P10, for which the project Pcre indicates an overall positive impact factor.

Figure 5: Portfolio P10, mandatory indicators of GSRT, shows final certified normalised values compared to anticipated values of each indicator which are approved by GSRT.



3.3 Programme Evaluation Indicators

The proposed methodological approach similarly offers integrated information about programmes in a direct manner by selecting the way results are presented depending on the requirements, purpose, and policy of the evaluation practice. Consequently, an interesting attribute of this methodological approach is the ability to easily switch focus from project to programme, and to perform benchmarking on programme objectives. However, benchmarking approaches require extra attention to more consultative attitudes rather than to doctrinal observations. The prototype web-based ontology application can present cumulative portfolio

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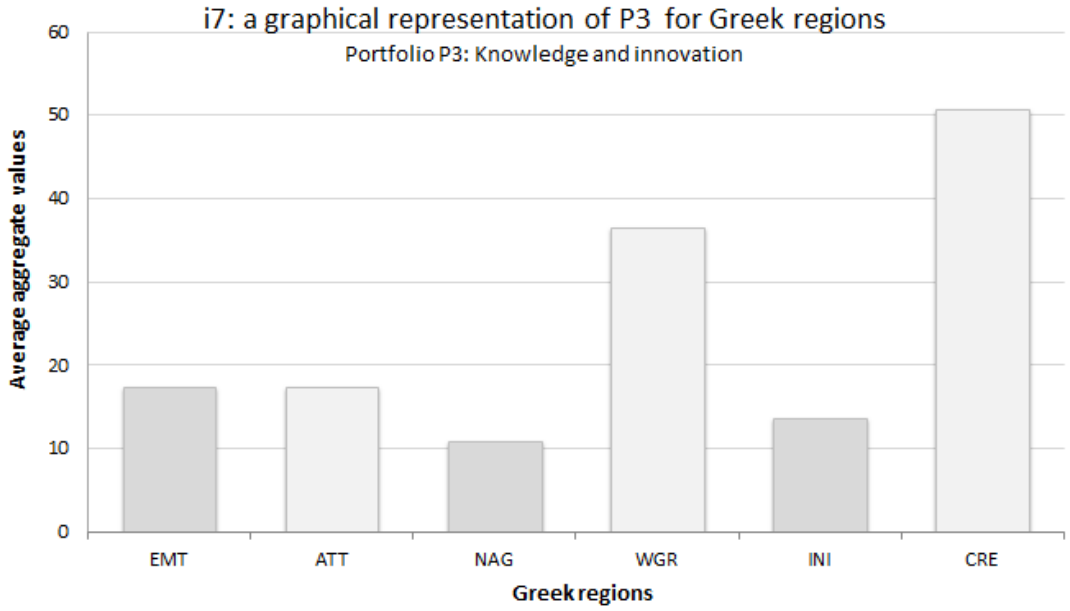
results in a numeric and diagrammatic representation. The following presents some average aggregate indicators for the six Greek Regional Operation Programmes per region and thematic area. Some general comments are presented, not to judge or evaluate the programmes, but rather to show the capabilities of the methodological approach.

With regard to portfolio P4, the overall additionality of public R&D funding, our study shows that for each euro of public R&D funding, the private sector increases R&D investments by between 0.46 and 1.03 euro, which is a typical input additionality value by national Greek standards. Figure 6 shows indicator i7 from portfolio P3 diagrammatically. This demonstrates the average aggregate values of knowledge and innovation for each region as revealed by the methodology approach applied in Greek programs.

Figure 6: Portfolio P3, knowledge and innovation, shows average aggregate values per Greek region from case study.



The column chart shows that regions West Greece (WGR) and Crete (CRE) revealed intensive knowledge and innovation, while regions North Aegean (NAG) and Ionian Island (INI) reached only the minimum threshold value of 11 determined earlier in the project evaluation indicators. Obviously, the interpretation of these results could be different under another point of view. For example, the size, the impact and the degree of excellence of the research institutions participating in the various consortiums could be correlated to project results per region.

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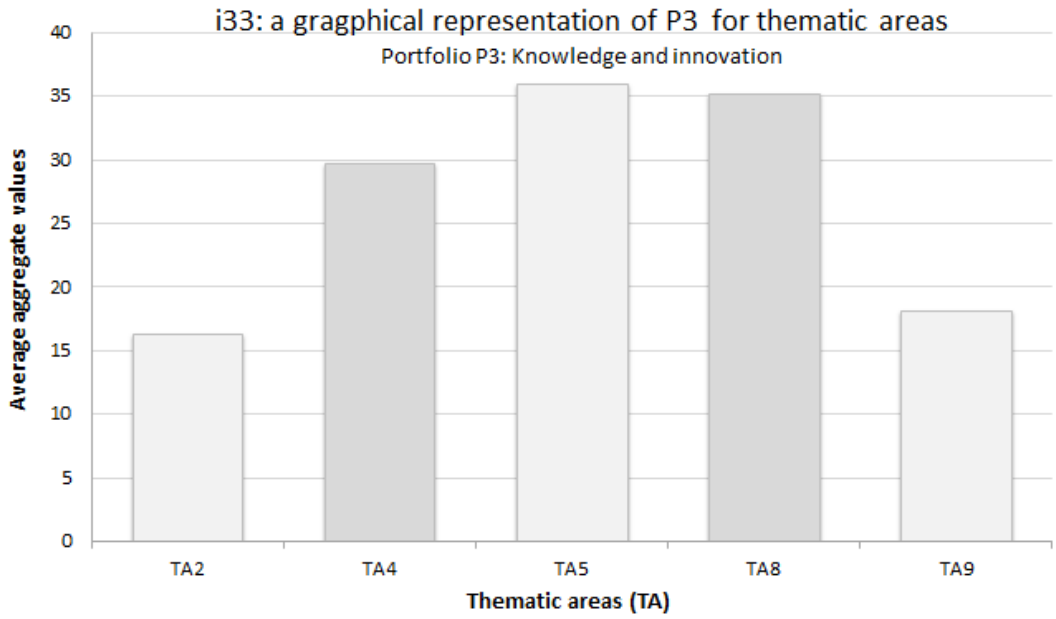
Additionally, firms' previous experience in collaboration schemas, involvement in R&D projects and other comparable criteria could be considered in the evaluation practice.

Similarly, indicator i7 diagrammatically shows average aggregate values of knowledge and innovation for several thematic areas, as displayed in Figure 7.

Figure 7: Portfolio P3, knowledge and innovation, shows average aggregate values per thematic area from case study.



As the figure shows, new knowledge and innovation performance appear in the thematic areas related to health, environment and new forms of business organisation. The evaluation practice should additionally consider supplementary relevant parameters, such as the impact factor of journals, number of publications, weight of conferences, and conference presentations, all of which are relative to the thematic areas and fields of knowledge under consideration. For example, the IT sector shows on average fewer publications in basic research than applied research in the health sector.

The methodological approach provides the appropriate tools for the funding agency to easily discover divergences in goals and objectives during and after programmes' implementation. Figures 8 and 9 show the diagrammatic indicator i33 that demonstrates the mandatory indicators of the GSRT per region and thematic area.

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Observing the relative positions of the average aggregate indicator values of portfolio P10 in relation to the reference value one in Figure 8, it appears that the initial predefined goals from the participants were achieved in only one region.

Figure 8: Portfolio P10, mandatory indicators of GSRT, shows final certified average aggregate normalised values compared to anticipated values, which are approved by GSRT, for each indicator per Greek region.

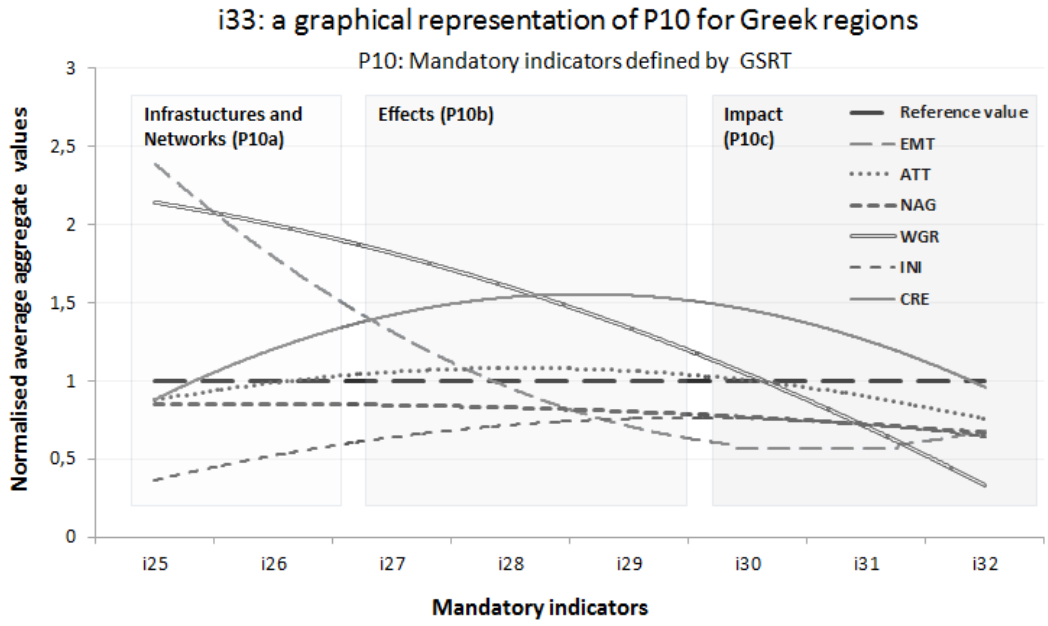

Figure 9 similarly shows the relative positions of the average aggregate indicator values of portfolio P10 in relation to the reference value one, and in this case, the initial predefined goals from the participants are achieved by only one thematic area.

Figure 9: Portfolio P10, mandatory indicators of GSRT, shows final certified average aggregate normalised values compared to anticipated values, which are approved by GSRT, for each indicator per thematic area.

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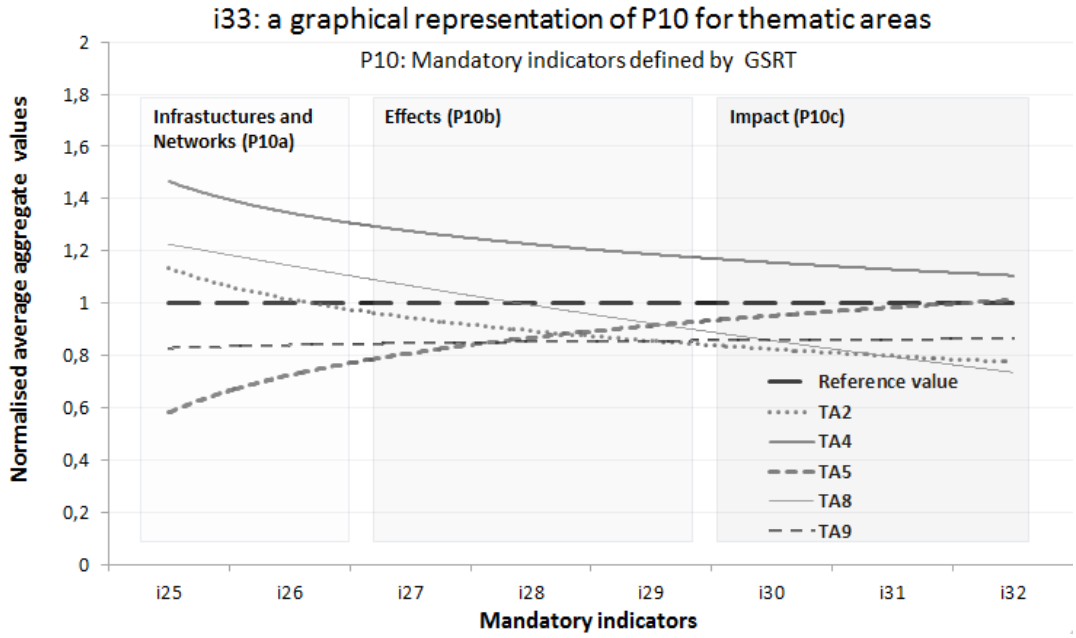

4. Discussion

The challenge of exploring the framework for Greek programmes was to show, briefly but comprehensively, the operability of the methodology and to demonstrate that interested parties in evaluation can obtain evaluation results from different approaches and angles by employing the proposed approach.

An attempt was made to collect sufficient evaluation information and to build a number of appropriate indicators. The suggested indicators in this paper are clearly subjective and comments following the results are of general and comparative nature. The reference values, thresholds and weighting factors are subjective and the responsibility of the funding agency and evaluation policy. In the present study, the proposed weighting factors proposed for indicators were a product of authors' assessments, personal experience and programme objectives. As an example, the impact of information technology on the health services of a remote geographic region could be positively evaluated if the only desideratum was user familiarity with this technology. On the other hand, in a tertiary-care hospital, the basis for positive impact would be the existence or absence of high-level electronic health services.

In addition, it is worth mentioning that indicators are not always "a panacea" and should be established at the stage of programme call. The reference indicator values should take into account the peculiarities of each national geographic region and the nature of the partners in the

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consortium, in addition to programme objectives. What is stressed here is that the same indicator in the evaluation practice can be weighted positively for a weak geographic region or for a newly established organisation and firm with low innovative performance; and be weighted negatively for other geographic regions or well established organisations and firms whose innovation performance is above the national or even the European average.

Data employed in the methodology from the Greek case study were classified, standardised and codified in an evaluation project data table. The effects of the applied taxonomy in the prototype table acted as catalyst to conceptually improve the classification of the indicators and clarify the terms of the evaluation entities. Ultimately, data definition of classes and formation of relationships arose, and the creation of ontology schema resulted via ontology technology. Additionally, the introduction of the proposed indicators in scientific knowledge, technological innovation and economic dimensions was important to evaluation and the diagrammatic indicators proved to be very helpful. For example, matters such as quality of the project with respect to its deliverables, time divergence from actual completion date, structures, networks, effects and impact vis-à-vis predetermined objectives at the beginning of the project were easily identified. In summary, the participation of the indicators highlighted a way for the funding agency to determine additionality effects of the public intervention, taking into consideration R&D policy strategies.

5. Conclusion

The proposed methodological approach comprises four contents: an evaluation model, a tool for measuring and presenting evaluation effects, a data repository, and a computational tool to support and create outcomes. It is worth noting that the above framework components are independent and can be replaced by others as required by programme objectives and the evaluation policy, which demonstrates the flexibility and modularity of the proposed evaluation framework. A qualitative and quantitative methodological approach has been presented, illustrated and discussed for supporting and not replacing traditional evaluation approaches, by focusing on input, output and behavioural effects of public R&D funding. The advantages of the proposed methodological approach are flexibility, sustainability, adaptability, speediness and expandability on R&D public intervention evaluation practice. Likewise, the benefits are increased by introducing and applying into the methodological framework the concept of

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ontology as a tool to codify evaluation knowledge and to compile a comprehensive taxonomy of data. It is recognised that the ontology model promotes shared understanding and enables better access to information which normally resides in several isolated separate evaluation components. The method to explore the proposed methodological approach was a case study of Greek government funded programmes, which were examined by the proposed qualitative and quantitative approach. The aim was not to re-evaluate the programmes or review already evaluated funded projects, but to examine the proposed evaluation methodological framework as a comprehensive approach with a view to exploring extra functions and new possibilities of evaluation practice.

The main benefits of this methodology are the ability to decode quantitatively the qualitative attributes of a project or programme in an automated way with low cost. The web-based evaluation ontology application is an effective knowledge tool for reducing the cost and management time of evaluations. Furthermore, benefits from the evaluation practice of the approach are consistency and objectivity in drawing conclusions about the course of a project or programme based on actual data. Moreover, by employing this approach, "hidden" relationships between projects or programmes from previous and on-going subsidies become visible. The challenge of public R&D funding is to discover the effects of the intervention as well as to define which of them need to be measured and capture the outputs of the applied strategy. Therefore, the methodological model is an important parameter in the evaluation practice. Through a model, the funding agency may express the basic values and the specific objectives of funding programmes which are aligned with the R&D policy. In a context of quality and reliable evaluation, weighting factors, indicators and other evaluation parameters are subjects to be determined wisely by the funding agency, according to the research and development policy.

In addition, a rational extension of this work would be the further development of ideas and refinements of the developed computational tools. Moreover, follow-up work for application to other programmes will explore strengths and limitations of the proposed approach. An in depth analysis and study of the effect of the public R&D funding mechanism is mandatory by policy makers. By attempting to measure additionality effects, answers will be given to how government policy influences firms and academia. Another challenge to the proposed methodological framework is to attempt different evaluation model implementations, such as employing the meta-logic model analysis of TEKES as demonstrated by Hyvärinen (2011).

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Although a lot of research has been conducted on the design of inquisitive questions in the context of comprehensive evaluation, this exercise is always vital; since based on deliberate questions, evaluation practice only has benefits, for funding agencies as well as policy makers.

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