Greece's AKIS: an evaluation of linkage mechanisms

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Abstract. The aim of this paper is to describe existing linkage mechanisms among the four main pillars (Education, Research, Consulting, and Private Companies) of the Agricultural Knowledge and Innovation System (AKIS) in Greece, in terms of implementation and strength level. Moreover, the study explores approaches to strengthening sustainable linkages. Data were collected from 38 AKIS actors using a structured questionnaire and indicate some interesting results: (a) strong links in most of the mechanisms between research and education; (b) Consultancy Agencies maintain stronger links with Research Organizations than other actors; (c) Private Companies maintain stronger links with Research (at lower levels); (d) there were significant differences in terms of the strength of linkage mechanisms between Educational Institutions and Consulting Agencies and (e) activities (workshops, research projects, consultancy projects), networks, and digital platforms were considered appropriate approaches for developing synergy, complementarity, and coordination among the AKIS actors. Results of this research may be used as a decision-making tool in identifying, designing, and implementing complementary interventions and institutional changes that seem likely to strengthen the AKIS in Greece and promote enhanced agricultural innovation and equitable development.

Keywords: Educational Institutions, Consulting Agencies, linkages mechanisms, Research Organizations, Private Companies.

Introduction

In the last decades, the agri-food sector has faced a significant challenge to boost production without exceeding the world's ecological boundaries resulting in an increasing number of demands and constraints being placed on it (Vuylsteke & Gijseghem 2012; Panneto et al. 2020). In the future, the agri-food sector is facing the big challenge of feeding almost 9 billion people by mid-century (De Amorim 2019) that may peak at more than 11 billion by the end of the century (FAO 2017), with continuous pressure on the Earth's natural resources, health, climate, and welfare for both humans and animals (EU SCAR AKIS 2019). These challenges make it imperative to expand the goals related to innovation across the agri-food sector (UNCTAD 2017). Historically, innovation has played an important role in keeping up with the challenges in agriculture (EU SCAR 2015). Innovation can be defined as the combination of 'software', 'hardware', and 'orgware', that have been implemented and brought into use to serve a specific public or private purpose (Smits 2002). In this view, innovations not only require new knowledge, processes, and new modes of thinking ('software'), but also new technologies or tools ('hardware'), and a reordering of institutions and organizations ('orgware') (Hermans et al. 2017). "Technological" innovation is claimed to provide solutions to produce more with less (land degradation, water, loss of food and inputs, loss of biodiversity), to halt the decline in food and agricultural prices, including the cost of nutritious food, and reduce the risks of epidemics and pandemics (FAO 2021). Innovation has a critical role to play in helping farmers and rural communities meet the challenges of today and tomorrow (EU SCAR 2019). Specifically, agricultural innovations lead to an expanded knowledge system without constraints, which includes a wide range of stakeholders that produce and use this knowledge (Knickel et al. 2009).

Recently, our understanding of agricultural knowledge has evolved from a transferable commodity to something that is diffused through technical and social interactions (Ingram & Maye 2020). This understanding supports the concept of Agricultural Knowledge and Innovation Systems (AKIS) and the processes of creation, exchange, and use of knowledge that works interactively among a diverse set of public, private, and civil society actors (Hall et al. 2003; Spielman et al. 2008; Klerkx et al. 2012; Hermans et al. 2017), either from within the agricultural sector or along an agricultural value chain (Knierim et al. 2015). Through this system, the actors are given the opportunity to collaborate, share their ideas, and turn existing knowledge and research results into innovative solutions that can be more easily implemented in practice (Feo et al. 2021), while at the same time strengthening their collective agency (Schut et al. 2014).

The concept of AKIS has grown within the last decade, with increased visibility and recognition, as it became clear that the linear research model was failing (IAASTD 2009). AKIS is a useful concept to 'describe a system of innovation, with emphasis on the organizations involved, the links and interactions, the supportive physical, financial and knowledge infrastructure with its incentives and budget mechanisms' (EU SCAR 2012; Turner et al. 2013; EU SCAR 2015). It is positioned as a central concept for framing innovation support policies, modernizing the agricultural sector, and ensuring sustainable management and use of natural resources in farming (Maye 2016). Literature asserts that AKIS is necessary to deal with the challenges taking place

more efficiently in agriculture by connecting science and practice better and boosting knowledge exchange and innovation for the benefit of farmers (EU SCAR AKIS 2019).

On a global level, the diffusion of innovation in an AKIS is determined by the links, the partnerships for transmission and absorption, and the linkage mechanisms used to achieve objectives related to agricultural sustainability (World Bank 2013). The concept of AKIS recognises the value in agricultural institutions actively promoting linkages, technology transfer, and information sharing (Rivera et al. 2005). The argument for linkages is that by working together, actors stand a better chance of establishing institutional relationships that can facilitate access to technology information, marketing arrangements, and capital, enabling farmers to be competitive (Kumar et al. 2001). According to Spielman et al. (2012), strengthening research and advisory service linkages promotes effective dissemination of innovation and information on both sides. In addition, the urgent need for a highly effective agricultural advisory service has attracted the attention of policymakers to make administrative adjustments in organisational structure, the functioning of technology transfer mechanisms, and resource management (Kassem et al. 2018).

A well-developed AKIS requires well-organized coordination mechanisms at multiple levels (Birke et al. 2022). According to Akinbile et al. (2002), innovation linkage mechanisms refer to the structured working relationship between two or more organizations, a regular information flow and feedback to common goals, and enhanced productivity. A careful adjustment of formal and informal mechanisms is a prerequisite for the diffusion and utilization of knowledge (World Bank 2013), and effective communication links between actors in agriculture and rural development are vital (Agbamu 2000). Collaboration and linkages may take different forms, including frequent exchange of information, joint priority setting for policies and programs, joint implementation of innovation projects (Ekboir & Rajalathi 2012), and joint planning (Rivera et al. 2005), while the lack of appropriate coordination and governance for agricultural innovation at the national level is a chronic problem in many countries (Diab 2015). The main linkage mechanisms fall into five categories: 1) planning and review, 2) program activities, 3) resource use, 4) information, and 5) training (Temel et al. 2002) (see Figure 1). According to Lemma and Tesfaye (2016), weaknesses in the management of linkage mechanisms, the choice of strategies to implement linkage policies, and the inappropriate institutional environment are the main factors that limit the effectiveness of linkages in AKIS. Furthermore, flaws in AKIS, such as missing linkage mechanisms between relevant stakeholders or ineffective knowledge transfer, may hinder farmers' ability to build their knowledge base (EU SCAR 2015).

In the last twenty-five years, the linkages between research-extension (Kumar et al. 2001; Rathore et al. 2008; Ogunremi et al. 2012; Kassem et al. 2018) and research-extension-education (Kumar et al. 2001; Eneyew 2013; Jaishi 2020) have been examined in the literature. Also, studies were conducted that evaluated the linkages of all actors in the AKIS (Koutsouris & Zarokosta 2021; Onumaha et al. 2021; Kassem et al. 2022;), as well as the linkage mechanisms of all actors in the AKIS (Azerbaijan; Egypt; the Kingdom of Saudi Arabia; Nigeria) (Temel et al. 2002; Temel et al. 2003; Temel 2004; Dimelu & Emodi 2012; Diab 2015). In Greece, most existing research on the AKIS has centred on the Farm Advisory services. The needs that have emerged from the lack of extension services in Greece and the serious deficiencies in professional training have been explored by several studies (Michailidis et al. 2010; Charatsari et al. 2012; Kaberis & Koutsouris 2012; Pappa & Koutsouris 2014; Brinia & Papavasileiou 2015). In the last decade, several papers in journals and international conferences pointed to the negative consequences in the Greek farming sector caused by the lack of an extension/advisory mechanism (Konstantidelli et al. 2018; Charatsari & Lioutas 2019; Lioutas et al. 2019; Koutsouris et al. 2020 Koutsouris & Zarokosta 2022). Furthermore, Koutsouris (2014b) and Koutsouris et al. (2020) studied the AKIS intending to assess advisory services, and they found that the Greek AKIS is highly fragmented and ineffective, and the inadequacy caused by a lack of coordination mechanisms between stakeholders have led, at best, to extremely weak linkages. Thus, based on the literature review the linkage mechanisms between the main pillars of AKIS (Education, Research, Consulting, and Private Companies) in Greece were not sufficiently developed. This study aims to fill this gap and investigate the strength of linkage mechanisms, their implementation levels, and how they can be enhanced in AKIS. Based on that, this study aims to: a) Examine the linkage mechanisms across the main actors in AKIS in Greece; and b) Determine the appropriate approaches to support cooperation among the actors from the point of view of respondents.

The hypotheses of our research are as follows:

1. There is no statistically significant difference between Research Organizations and Consulting Agencies concerning the strength of the linkage mechanisms (Kassem et al. 2018).

2. There is no statistically significant difference between Research Organizations and Educational Institutions regarding the strength of the linkage mechanisms.
3. There is no statistically significant difference between Research Organizations and Private Enterprises regarding the strength of the linkage mechanisms.
4. There is no statistically significant difference between Educational Institutions and Consulting Agencies regarding the strength of the linkage mechanisms.
5. There is no statistically significant difference between Educational Institutions and Private Enterprises regarding the strength of the linkage mechanisms.
6. There is no statistically significant difference between Consulting Agencies and Private Enterprises regarding the strength of linkage mechanisms.

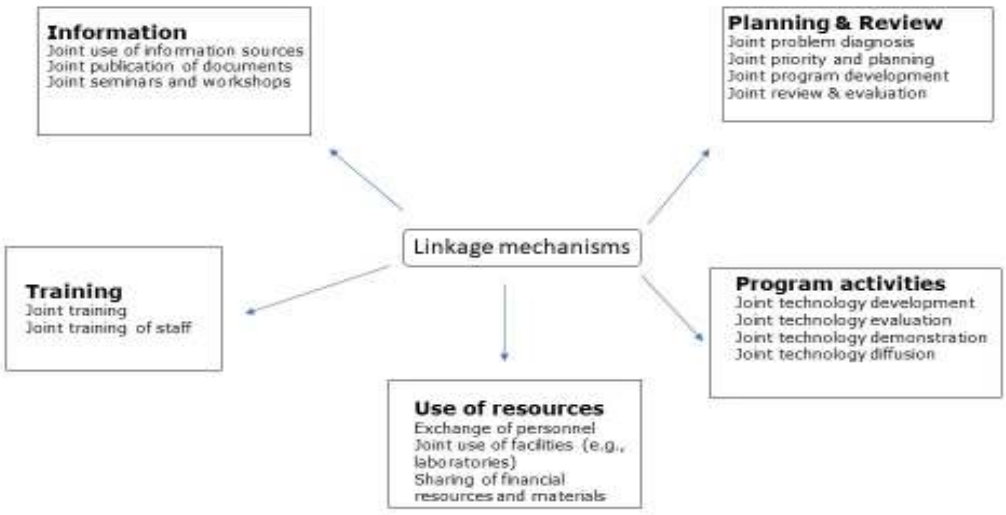
The paper is organised as follows: the first section introduces the background of the topic, the second section provides a description of the methods used, the third section presents results and discussion, and the paper concludes with the main insights on the potential empowerment of AKIS in Greece.

Materials and Methods

Firstly, a literature review was carried out aiming to determine possible linkage mechanisms between all the actors in AKIS. A structured questionnaire was designed to obtain responses to the study's questions. Data were collected through a survey addressed to 38 expert representatives (mainly senior managers) from the four main pillars of AKIS. From the Educational Institutions, seven professors at Agricultural Universities, the Director of the General Directorate of Agricultural Education of Hellenic Agricultural Organization Dimitra (ELGO-DIMITRA), and three Directors of Agricultural Schools participated. From the Research Institutes, two researchers from the Institutes of ELGO-DIMITRA and the Director of the General Directorate of Agricultural Research; two researchers from the National Center for Research and Technological Development (Hellas-CEARTH); one researcher from the Technology and Research Foundation (FORTH); and the Director of the American College of Agriculture. Subsequently, 12 Consultative Agencies participated, of which two were Development Companies and one Local Action Group. Finally, only eight of the private companies responded (seven input providers and one manufacturing company) based in different regions of the country. Possible linkage mechanisms were first presented and evaluated by Temel et al. (2002) (Figure 1). Data were collected during December 2022 and March 2023 using an online survey tool after an initial phone communication. The instrument for data collection was divided into three sections. In the first section, the respondents indicated for which Research Organization, Educational Institution, Consulting Agency, or Private Company they worked as well as the title they held. In the second section, respondents were asked to indicate their linkages with each of the other participating actors within the AKIS. If their answer was positive: yes (1), the respondents were asked to clarify the strength of the linkage mechanisms (extent and quality) by identifying (i) the level of linkage: strong (3), moderate (2), weak (1), and (ii) the type of linkage: formal (3), mixed (2), and informal (1). The level of implementation of each linkage was calculated by collecting a score of the strength of linkage and the type of linkage, with a maximum score of (6) points for each mechanism (Kassem et al. 2018). In the third section, the respondents were asked to evaluate the level of importance of potential types of linkages that can support the coordination and cooperation among actors of the AKIS according to Zahran et al. 2020: (1) not important, (2) slightly important, (3) moderately important, (4) important, and (5) very important.

The collected data were coded and analysed using descriptive and statistical tools. Frequency, percentages, means and standard errors were used for the descriptive analysis of the different variables. In addition, a t-test was used to answer the research hypotheses.

Figure1: Linkage mechanisms



Source: Temel et al. 2002

Results and discussion

Descriptive statistics

In the survey, 38 representatives from Research Organizations, Educational Institutions, Consulting Agencies, and Private Enterprises (providing inputs and manufacturing) participated (Table 1).

Table 1: Distribution of respondents

Categories	N	%
Research Organizations	7	19
Educational Institutions	11	29
Consulting Agencies	12	32
Private Enterprises	8	21
Total	**38**	**100**

Linkages(interactions)

Table (2a, b) shows the linkages (interactions) between the four participating actors: (I) Research Organizations; (E) Educational Institutions; (C) Consulting Agencies, and (K) Private Enterprises. Specifically, the first row and first column included linkages of component (I). The terms (IE) in the cell of the first row and the second column of AKIS indicate the interaction of component (I) with component (E), where (I) is the initiator of this interaction. Similarly, the first column and second row show the interaction of (E) with (I) with (E) as an initiator. Finally, the diagonal line shows the four participating actors.

Table 2a: Linkage matrix

I	IE	IC	IK
EI	E	EC	EK
CI	CE	C	CK
KI	KE	KC	K

(I) Research Organizations; (E) Educational Institutions; (C) Consulting Agencies, & (K) Private Enterprises

Table 2b: The coded linkage matrix

I	1	1	1
1	E	0	1
1	1	C	1
1	1	1	K

(1) There is a connection, (0) It does not exist, or it is at negligible levels

Linkage Research Organizations - Consulting Agencies

The data presented in Table 3 describes the implementation and strength of linkages between Research Organizations and Consulting Agencies, according to their representatives' point of view. The overall average of 50% for Consulting Agencies regarding the implementation level of linkages was realized, whereas it reached 34% for Research Institutions. Researchers and advisors perceived low to medium linkages among each other in most mechanics explored. A study conducted by Kassem et al. (2018) in the Kingdom of Saudi Arabia determined that linkages between researchers and extensionists were low to medium. The representatives of the Research Institutions declare a low to medium application of the mechanisms, whereas the representatives of the Consulting Organizations claim to have more than one-half of linkage mechanisms, application levels ≥50% (joint problem diagnosis, joint priority setting and planning, joint program planning, joint technology development, joint technology evaluation, joint technology demonstration, joint technology diffusion, and joint publication of documents).

Table 3: Differences between Research Organizations and Consulting Agencies depending on the strength of linkages

	Implementation Level %		**Strength of Linkages***					
	R.O.	**C.A.**	**R.O.**		**C.A.**			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Joint technology evaluation	29	55	0.71	0.29	1.50	0.34	-1.59	0.06
Joint technology demonstration	29	54	0.71	0.29	1.50	0.31	-1.68	0.06
Joint technology development	31	56	0.86	0.34	1.58	0.36	-1.35	0.10
Sharing of financial resources and materials	29	50	0.71	0.29	1.25	0.28	-1.26	0.11
Exchange of personnel	26	44	0.57	0.20	0.92	0.19	-1.16	0.13
Joint publication of documents	38	51	1.00	0.44	1.58	0.40	-0.94	0.18
Joint seminars and workshops	33	45	0.71	0.29	1.08	0.26	-0.91	0.19
Joint problem diagnosis	40	56	1.14	0.40	1.58	0.31	-0.86	0.20
Joint technology diffusion	38	57	1.29	0.47	1.67	0.35	-0.65	0.26
Joint program development	40	53	1.14	0.40	1.42	0.34	-0.51	0.31
Joint use of information sources (e.g. lib., Internet)	38	46	1.00	0.31	1.25	0.33	-0.51	0.31
Joint training of staff	31	44	0.86	0.34	1.11	0.31	-0.49	0.32
Joint training	43	43	1.00	0.31	1.17	0.30	-0.36	0.36
Joint use of facilities (e.g. laboratories)	29	39	0.71	0.29	0.83	0.21	-0.34	0.37
Joint review and evaluation	43	50	1.29	0.42	1.25	0.28	0.07	0.47
Joint priority setting and planning	21	53	0.71	0.47	1.42	0.29	-1.35	0.97
Overall Average	**34**	**50**	**0.90**	**0.35**	**1.32**	**0.30**	**-0.87**	**0.27**

Research Organizations (R.O.) and Consulting Agencies (C.A.)
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

However, in addition to identifying the existing linkage mechanisms, we also examined the strength of these mechanisms (Table 3). There are no strong linkages (mean >2.30) in any mechanism on both sides.

Finally, according to the t-test, there is no statistically significant difference between the Research and Consulting Organizations regarding the strength of the connection mechanisms between them (p >0.05). In the study of Kassem et al. (2022), significant differences were found when they jointly developed technologies and determined the needs of the stakeholders in the association.

Findings in Table 3 lead to the conclusion that there is a need for closer collaboration between researchers and advisors to strengthen and improve the linkages. Consulting Agencies and advisors should serve as the main source of research to develop an orientation and maintain awareness of actual farmers' problems. However, the advisory services focus on users' acceptance and adoption of those technologies, while the research services focus on the technical aspects of generating useful technologies. The advisor services need the backing of strong applied agricultural research institutions to effectively serve the farming communities, and applied research institutions need strong advisor services to work in a field-problem-oriented mode (FAO 2005; SWG SCAR- AKIS 2017).

Linkage Research Organizations- Education Institutions

Table 4 presents the levels of implementation and the strength of interactions in the examined linkage mechanisms between Research Organizations and Educational Institutions, according to their representatives' points of view. Findings revealed that Educational Institutions in all mechanisms apply implementation levels >50%, except for training of staff (47%), whereas they received one in four linkage mechanics (implementation level >50) from the other body. As seen in Table 4, they agreed that the most common mechanisms utilized to establish linkages include joint priority setting and planning; joint technology evaluation; joint technology diffusion, and joint publication of documents.

Table 4: Differences between Research Organizations and Educational Institutions depending on the strength of linkages

	Implementation Level %		Strength of Linkages*					
	R.O.	E.I.	R.O.		E.I.			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Joint program development	43	64	1.14	0.43	2.00	0.27	-1.73	0.06
Joint use of facilities (e.g., laboratories)	29	52	0.71	0.36	1.64	0.36	-1.71	0.06
Sharing of financial resources and materials	36	52	0.71	0.29	1.36	0.31	-1.44	0.08
Joint publication of documents	55	67	1.43	0.48	2.18	0.32	-1.35	0.10
Joint problem diagnosis	45	62	1.29	0.47	1.91	0.25	-1.16	0.14
Joint review and evaluation	50	58	1.14	0.40	1.64	0.24	-1.11	0.14
Joint use of information sources (e.g. lib. Internet)	50	58	1.14	0.40	1.73	0.33	-1.11	0.14
Joint seminars and workshops	40	56	1.00	0.44	1.55	0.28	-1.10	0.14
Exchange of personnel	38	52	0.86	0.40	1.36	0.28	-1.07	0.15
Joint training	48	55	1.00	0.38	1.45	0.25	-1.05	0.15
Joint technology development	48	55	1.00	0.44	1.55	0.34	-0.99	0.17
Joint technology demonstration	43	56	1.14	0.51	1.64	0.31	-0.88	0.19
Joint technology diffusion	52	56	1.29	0.42	1.64	0.31	-0.68	0.25
Joint priority setting and planning	55	59	1.43	0.43	1.73	0.24	-0.66	0.26
Joint technology evaluation	55	58	1.43	0.48	1.73	0.36	-0.51	0.31
Joint training of staff	29	47	1.14	0.51	1.27	0.27	-0.25	0.40
Overall Average	**45**	**56**	**1.12**	**0.43**	**1.65**	**0.30**	**-1.05**	**0.17**

Research Organizations (R.O.) and Educational Institutions (E.I.).
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

A study by Kassem et al. (2022) showed that the mechanisms of linkages between Education and Research are: information sharing; use of facilities; workshops and seminars; participation in research projects; use of information sources; technology development, and publication of documents.

Additionally, the study provides information on the mechanisms implemented by both categories of low to moderate strength. Exceptions are the exchange of personnel, the sharing of facilities and laboratories, and the sharing of financial and material resources that have magically weak power with the initiators of the interaction, the Research Organizations, while the joint publication of work with the initiators, the Educational Institutions, is a mechanism of moderate to strong power.

Finally, according to the t-test, there is no statistically significant difference between Research and Education regarding the strength of the applied mechanisms of connection between them *(p* >0.05).

Linkage Research Organizations- Private Companies

Table 5 presents the levels of implementation and the strength of interactions in the examined linkage mechanisms between Research Organizations and Private Enterprises, according to their representatives' points of view. Research Organizations claim that half of the linkage mechanisms had implementation levels of 50% or higher in terms of planning and review, and program activities. The overall average of 43% for researchers regarding the implementation level of linkages was realized, whereas it reached 30% for private companies. As seen in Table 5, they didn't agree on common mechanisms utilized to establish. Kassem et al. (2022) reported similar results in their study.

Table 5: Differences between Research Organizations and Private Enterprises depending on the strength of linkages

	Implementation Level %		Strength of Linkages*					
	R.O.	P.E.	R.O.		P.E.			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Joint technology demonstration	55	35	1.71	0.36	1.00	0.33	1.47	0.08
Joint training of staff	50	23	1.71	0.36	1.00	0.42	1.27	0.11
Joint use of facilities (e.g., laboratories)	36	17	1.00	0.38	0.50	0.33	1.01	0.16
Joint problem diagnosis	52	40	1.57	0.37	1.13	0.29	0.96	0.18
Joint technology evaluation	52	40	1.57	0.37	1.13	0.29	0.96	0.18
Joint review and evaluation	50	40	1.43	0.37	1.13	0.29	0.65	0.26
Joint technology development	50	40	1.43	0.37	1.13	0.29	0.65	0.26
Joint publication of documents	43	25	1.29	0.42	0.88	0.48	0.63	0.27
Joint training	38	21	1.14	0.40	0.75	0.49	0.61	0.28
Joint priority setting and planning	48	46	1.29	0.29	1.50	0.42	-0.41	0.34
Joint seminars and workshops	31	21	1.00	0.38	0.75	0.49	0.39	0.35
Joint program development	50	42	1.43	0.30	1.25	0.37	0.37	0.36
Joint technology diffusion	50	40	1.43	0.37	1.25	0.45	0.30	0.38
Sharing of financial resources and materials	29	21	0.71	0.29	0.63	0.32	0.20	0.42
Exchange of personnel	31	19	0.71	0.29	0.63	0.42	0.17	0.43
Joint use of information sources (e.g. lib., Internet)	24	17	0.71	0.36	0.75	0.37	-0.07	0.47
Overall Average	**43**	**30**	**1.26**	**0.36**	**0.96**	**0.38**	**0.57**	**0.28**

Research Organizations (R.O.) and Private Enterprises (P.I.)
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

Research Institutions and Private Enterprises present low to medium-strength linkages in planning, review, and program activities. The Research Organizations participate more actively in

the training of staff (mean 1.71) and in the joint demonstration of technology (mean 1.71). This can be explained because researchers are more skilled at developing technologies and organizing training programs. Studies by Kassem et al. (2022) and Diab (2015) showed that there were no linkage mechanisms between them.

Finally, according to the t-test, there is no statistically significant difference between Research Organizations and Private Enterprises regarding the strength of the applied linkage mechanisms between them (p >0.05).

Linkage Educational Institutions - Consulting Agencies

Table 6 presents the levels of implementation and the strength of interactions in the linkage mechanisms between Education Institutions and Consulting Agencies. Education Institutions consider the implementation of all mechanisms among Consulting Agencies negligible level (overall average 9%). Similar results are confirmed by the averages of the strength of linkage mechanisms. The overall average of 0.34% for education regarding the strength of linkage mechanisms was estimated, whereas it reached 0.97% for advisory services.

A comparison between Education Institutions and Consulting Agencies regarding the strength of linkages indicated a significant difference, more specifically: joint review and evaluation (p=0*.04*); joint priority setting and planning (*p=0.03*); joint technology development (*p=0.01*); joint technology evaluation (*p=0.01*); and sharing of financial resources and materials (*p=0.01*).

Therefore, we conclude that there is a need for closer collaboration between education and advisors to strengthen and improve the linkages. Agricultural universities should enhance their efforts to extend scientific findings, technologies, and practices to advisors. In turn, the advisory services should play a leading role in facilitating the development of education specialists' curricula so that farmers can meet the industry's current needs and adjust to the inevitable changes that will occur (Eneyew 2013).

Table 6: Differences between Education Institutions and Consulting Agencies depending on the strength of linkages

	Implementation Level %		Strength of Linkages[1]					
	E.I.	C.A.	E.I.		C.A.			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Joint technology development	6	40	0.18	0.12	1.17	0.34	-2.69**	**0.01**
Joint technology evaluation	8	42	0.27	0.19	1.25	0.37	-2.33**	**0.01**
Sharing of financial resources and materials	6	33	0.18	0.12	0.83	0.24	-2.41**	**0.01**
Joint priority setting and planning	9	35	0.27	0.14	1.00	0.33	-2.05*	**0.03**
Joint review and evaluation	11	36	0.36	0.2	1.08	0.36	-1.75*	**0.04**
Joint program development	12	42	0.45	0.28	1.25	0.37	-1.68	0.06
Joint technology demonstration	9	39	0.36	0.28	1.08	0.31	-1.70	0.06
Joint technology diffusion	11	43	0.45	0.31	1.17	0.30	-1.65	0.06
Joint problem diagnosis	12	39	0.45	0.25	1.08	0.31	-1.56	0.06
Joint use of information sources (e.g. lib., Internet)	11	33	0.36	0.2	1.00	0.33	-1.66	0.06
Joint publication of documents	9	35	0.36	0.28	1.08	0.36	-1.57	0.07
Joint training of staff	9	31	0.36	0.24	0.83	0.3	-1.21	0.12
Joint use of facilities (e.g., laboratories)	8	26	0.27	0.19	0.58	0.23	-1.02	0.16
Joint training	11	33	0.45	0.31	0.83	0.24	-0.97	0.17
Joint seminars and workshops	12	29	0.45	0.25	0.75	0.25	-0.84	0.20
Exchange of personnel	9	24	0.36	0.28	0.58	0.23	-0.61	0.27
Overall Average	**9**	**35**	**0.34**	**0.23**	**0.97**	**0.30**	**-2.00**	**0.09**

Education Institutions (E.I.) and Consulting Agencies (C.A.)
* Significant at 0.05 level; ** significant at 0.01 level.
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

Linkage Educational Institutions - Private Enterprises

Table 7 displays the levels of implementation and the strength of interactions in the linkage mechanisms between Education Institutions and Private Enterprises, based on the representative experts' points of view. In almost all linkage mechanisms, the levels of their implementation with initiators, the Educational Institutions are below 50% (overall average: 43%), except for the diagnosis of common problems (53%), while the levels of application by Private Enterprises are at even lower levels (<30%). Correspondingly, the strength of the mechanisms on the part of Educational Institutions shows weak to moderate strength, while the existing strength of the mechanisms for Private companies is marginally weak. This can be explained because education experts are more skilled at developing technologies and organizing training programs. Finally, the t-test indicated a statistically significant difference in terms of the strength of the mechanism of sharing facilities and laboratories (*p=0.02*).

Table 7: Differences between Educational Institutions and Private Enterprises depending on the strength of linkages

	Implementation Level %		Strength of Linkages[1]					
	E.I.	P.E.	E.I.		P.E.			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Joint use of facilities (e,g,, laboratories)	42	15	1.36	0.24	0.50	0.33	2.16*	0.02
Joint problem diagnosis	53	27	1.73	0.27	1.00	0.33	1.71	0.06
Joint publication of documents	30	17	1.27	0.27	0.63	0.42	1.35	0.10
Exchange of personnel	38	15	1.00	0.23	0.50	0.38	1.19	0.13
Joint training	35	17	1.18	0.26	0.63	0.42	1.18	0.13
Joint priority setting and planning	44	23	1.27	0.24	0.88	0.29	1.06	0.15
Joint technology demonstration	47	27	1.45	0.25	1.00	0.38	1.05	0.15
Joint program development	47	25	1.45	0.28	1.00	0.38	0.99	0.17
Joint review and evaluation	44	23	1.27	0.24	0.88	0.35	0.98	0.17
Sharing of financial resources and materials	47	19	1.18	0.23	0.75	0.49	0.88	0.19
Joint seminars and workshops	44	17	1.00	0.23	0.63	0.42	0.83	0.21
Joint training of staff	42	27	1.18	0.26	1.00	0.38	0.41	0.34
Joint technology development	41	27	1.18	0.30	1.00	0.38	0.38	0.35
Joint technology diffusion	44	29	1.27	0.27	1.13	0.40	0.32	0.38
Joint technology evaluation	39	29	1.09	0.25	1.00	0.27	0.24	0.40
Joint use of information sources (e.g., lib, Internet)	42	21	0.91	0.25	0.88	0.40	0.08	0.47
Overall Average	**43**	**22**	**1.24**	**0.25**	**0.84**	**0.37**	**0.92**	**0.21**

Educational Institutions (E.I.) and Private Enterprises (P.I.).
*Significant at 0.05 level.
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

Linkage Consulting Agencies- Private Enterprises

Consulting Agencies' and Private Enterprises' representatives rated the implementation levels and strength of interactions in the linkage mechanisms, as displayed in Table 8. Consulting Agencies realized moderate implementation levels in the linkage mechanisms (<50%), except for the joint problem diagnosis (53%). On the other hand, the Private Enterprises presented even lower levels of application (<30%), characterized as weak linkages, except for jointly diagnosing problems, demonstrating, and disseminating technology, and jointly technology diffusion (38%). As seen in Table 8, they agreed that there was no common mechanism utilized to establish strong linkages (implementation levels >50% among them). Similar results were also reported by Temel et al. (2002) in Azerbaijan and Diab's survey (2015) in New Valley Egypt, that there were not common linkage mechanisms. In contrast, a study by Kassem et al. (2022) in Dakahlia Governorate in Egypt showed that the common mechanism between Consulting Agencies and Private Enterprises is jointly sharing information.

In addition to identifying the existing linkage mechanisms, the strength of these mechanisms was also examined in this study (Table 8), where there are no strong linkages (mean >2.30) in any mechanism on both sides. The overall average of 1.09% (weak linkages) for Consulting Agencies regarding the strength of linkage mechanisms was realized, whereas it reached 0.84% (marginally weak linkages) for Private Enterprises.

Finally, according to the t-test estimation, there is no statistically significant difference between Consulting Agencies and Private Enterprises regarding the strength of the applied linkage mechanisms between them (p >0.05).

Table 8: Differences between Consulting Agencies and Private Enterprises depending on the strength of linkages

	Implementation Level %		Strength of Linkages*					
	C.A.	P.E.	C.A.		P.E.			
Linkage Mechanisms			**Mean**	**SE**	**Mean**	**SE**	**t**	**p-value**
Sharing of financial resources and materials	42	15	1.00	0.30	0.35	0.26	1.46	0.08
Joint use of facilities (e.g., laboratories)	40	17	1.00	0.35	0.50	0.33	0.99	0.17
Joint publication of documents	46	19	1.17	0.37	0.63	0.42	0.96	0.17
Joint problem diagnosis	53	38	1.50	0.38	1.13	0.29	0.78	0.22
Joint training	42	23	1.50	0.30	0.63	0.37	0.78	0.22
Joint seminars and workshops	33	17	0.83	0.32	0.50	0.33	0.70	0.25
Joint program development	47	31	1.17	0.30	0.88	0.30	0.67	0.26
Joint use of information sources (e.g., lib, Internet)	43	29	1.17	0.34	0.88	0.40	0.55	0.29
Joint priority setting and planning	47	33	1.25	0.35	1.00	0.33	0.49	0.31
Joint technology evaluation	44	33	1.17	0.30	1.00	0.33	0.37	0.36
Joint review and evaluation	44	33	1.08	0.31	1.00	0.33	0.18	0.43
Joint technology development	44	33	1.08	0.34	1.00	0.33	0.17	0.43
Exchange of personnel	31	25	0.67	0.28	0.75	0.41	-1.72	0.43
Joint training of staff	43	25	1.08	0.34	1.00	0.38	0.16	0.44
Joint technology demonstration	46	38	1.17	0.34	1.13	0.29	0.08	0.46
Joint technology diffusion	44	38	1.08	0.34	1.13	0.35	-0.08	0.47
Overall Average	**43**	**28**	**1.09**	**0.33**	**0.84**	**0.34**	**0.41**	**0.31**

Consulting Agencies (C.A.) and Private Enterprises (P.I.)
*Average values (< 0.70) considered negligible to no exist; average values (0.70-1.40) considered weak; average values (1.40-2.30) considered moderate; average values (>2.30) considered strong.

In conclusion, this research analysed the levels of implementation and the strength of the connections of 16 mechanisms used to enhance the interaction between the main participating actors of AKIS in the Greek case and reveals the differences that exist between them for the empowerment of the AKIS framework. The levels of application and the strength of the linkage mechanisms are differentiated even in the same binary interaction and depend on its initiator. Also, the study determined that Educational Institutions have stronger links with the Research Institutes and, respectively, the Research Institutes with the Educational Organizations in relation to the rest of the actors.

In addition, the representatives of Consulting Organizations state that they maintain a stronger link with Research Organizations than the rest of the actors. Governance issues surrounding regulation of complementary advisor services are becoming more pronounced (Nettle et al. 2017), with a focus on improving research support, converging resource utilization, and service delivery in supplementary and complementary modes (Jaishi 2020). The constraints in the governance of pluralistic advisory systems associated with privatization (Nettle et al. 2017) is also evident in Greece.

Furthermore, the same is stated by Private Companies, but with much lower levels of application of these linkage mechanisms. Almost all mechanisms in total have weak to moderate enforcement intensity, except for the mechanisms applied by Educational Institutes to Research Organizations.

The lack of funds, combined with horizontal and vertical fragmentation and the lack of proper evaluation criteria for collaborative innovation networks are among the most important threats (Hermans et al. 2012). Similar results are reported by Birke et al. (2022) in the report on AKIS in the EU from the i2connect project. The different categories of advisory service providers perceived their cooperation with research and education as rather weak to medium, which is confirmed in many of the partner countries. Findings lead to the conclusion that there is a need for closer collaboration among the main actors in AKIS to strengthen and improve the linkages.

To address all these challenges, policies that proactively optimize collaboration and social learning are needed (e.g., the types of organizations involved and their linkages), and the institutional settings (e.g., the incentives for collaboration, intellectual property rights, the organization of research agenda setting mechanisms) (Klerkx et al. 2012).

Interaction linkages between the AKIS's actors

The importance of each type of linkage in supporting the coordination and cooperation of the participating actors in the AKIS system is presented in Table 9. The results demonstrated that all the linkages were in the category of moderately important to quite important in strengthening the interaction in the system. The most important items in descending order were considered activities (laboratories, research projects, consulting projects) (overall average: 4.27), networks (overall average: 4.26), and digital platforms (overall average: 4.25).

Table 9: Importance of each type of linkage for coordination between actors

Linkages	Research Organizations		Education Institutions		Consulting Agencies		Private Enterprises		Overall Average*	Rank
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Activities (workshops, Advisory programs)	4.43	0.53	4.18	0.40	4.33	0.78	4.13	0.99	4.27	1
Networks	4.57	0.79	4.18	0.75	4.16	0.83	4.13	0.83	4.26	2
Platforms	4.29	0.76	4.36	0.67	4.00	0.74	4.38	0.92	4.25	3
Solidarity	4.14	0.90	4.00	0.89	4.25	0.75	4.38	1.06	4.19	4
Agreements	3.86	0.90	4.09	0.83	3.75	0.87	4.13	0.83	3.95	5
Partnership	3.43	1.51	4.09	0.83	4.16	0.58	3.63	1.41	3.82	6
Coordination committees	3.71	0.76	3.45	1.04	3.41	1.00	3.75	1.04	3.58	7
Contracting	3.14	1.21	3.73	1.27	4.08	0.79	3.38	1.19	3.58	8
Advocacy linkages	3.14	1.46	3.27	1.10	3.25	0.87	3.63	1.19	3.32	9

***** Ranking by Overall Average in descending order

There are numerous strategies to enhance collaboration and coordination with the Agricultural Knowledge and Innovation System. These approaches encompass workshops, research endeavours, consultancy projects, networks, and digital platforms. Several countries have implemented governing frameworks like networks and platforms to facilitate these processes (Kilelu et al. 2013). Morar (2015) concluded that the establishment of the innovation network assisted in achieving consensus to avoid duplication and inconsistent advice. As per Birke et al. (2022), thematic platforms can be a portent type of linkage to facilitate knowledge transfer and discussion during the priority-setting phase and solve current problems. They are already extensively utilized in countries such as Austria and Switzerland. Similarly, in Germany, the DAFA (German Agricultural Research Alliance) is a platform that aims to support AKIS functioning by setting strategic agendas for agricultural research.

Also, contrary to the results of Zahran et al. (2020), our results revealed that contracts and partnerships are ranked poorly according to the opinions of experts. A body of empirical literature—summarized in Otsuka et al. (2016); Ton et al. (2017), and Bellemare & Bloem (2018)—has investigated the positive economic and social impact of contract farming in supporting coordination and interactions between actors. On the other hand, some studies found that contract farming participation might entail negative welfare effects for farmers (Guo et al. 2007; Miyata et al. 2009). Moreover, partnerships mainly between public and private actors were considered suitable as systemic policy instruments in the early stages of developing an innovation system as they stimulate system functions such as knowledge development, network building, diffusion and mentoring and development (Hermans et. al. 2019). Particularly in the agricultural sector they have been cited as a solution to address interaction problems between actors (Lamprinopoulou et al. 2014; Turner et al. 2016). However, they are less able to stimulate

functions that are necessary for the final development of the market and consumer demand (Hermans et al. 2019) and despite their popularity they present problems in their implementation, where they do not really go along with the idea of collaborating actors who jointly achieve added value and share risks (Klijn & Teisman 2003).

It is obvious that the importance of implementing these different linkages is determined by the nature of relationships among the actors. Furthermore, the services provided, the stakeholders, and the scope of work differentiate the potential linkages (Zahran et al. 2020).

Conclusions

By analysing the existing linkage mechanisms between the four main pillars of AKIS in Greece in terms of implementation and strength, this study provides valuable insights to decision-makers on mechanisms that still need to be strengthened and the information gaps between actors to address coordination, information flow, technology diffusion, and solving common problems. Our findings encourage generative collaboration in process forms to enable co-innovation to effectively address barriers and opportunities of AKIS. Governance arrangements to coordinate service offerings, decisions relating to incentives, and structures for the development of new offerings with the private sector in response to new challenges of pluralistic advisory systems are required. Better coordination can improve the design and implementation of innovation policies by allowing more actors to voice their needs and concerns, resulting in more inclusive policies.

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