Drivers, effects and peculiarities of innovation activities in the food industry: a comparison across EU Member States using CIS data

Ciliberti Stefano [1], Bröring Stefanie [2], Martino Gaetano [3]

[1] *Dipartimento di Scienze Agrarie, Alimentari e Ambientali (DSA3), Università di Perugia, Italy*

[2] *Institut für Lebensmittel- und Ressourcenökonomik (ILR), Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany*

[3] *Dipartimento di Scienze Agrarie, Alimentari e Ambientali (DSA3), Università di Perugia, Italy*

stefano.ciliberti@studenti.unipg.it s.broering@ilr.uni-bonn.de gaetano.martino@unipg.it

Abstract

Innovation is a clear target of the Europe 2020 growth strategy. It has been widely postulated that cooperation is especially important for innovation in the food industry because it has traditionally been regarded as a “low tech” sector. This paper analyses how different forms of cooperation affect innovation activities in the EU’s food industry. In particular, the study addresses the question of how cooperation between companies and key chain agents influences innovative activity. To do so, we analysed data at the country level drawn from the Community Innovation Survey (CIS). The aggregated data allowed us to investigate national system-level processes that must be considered the outcomes of micro-level decisions and policies. A random effect linear model is formulated and estimated to analyse the panel data obtained from five CIS waves. The model indicates that cooperation with universities positively affects innovative activity and, surprisingly, that government financial support has not been an effective instrument to foster innovation by food companies.

Key words: Innovation; food industry; cooperation; supplier integration.

Introduction

Science, technology and innovation are important drivers of the Europe 2020 growth strategy, and innovation in particular has gained great importance as an element of competition between food companies to allow them to stand out from their competitors and fulfil consumer expectations (Menrad, 2004). R&D spending across the entire landscape of industrial sectors is below 2% in the EU, compared with 2.6% in the US and 3.4% in Japan, and the food industry shows even lower scores, at approximately 0.5% (Arundel and Geuna, 2004). The primary explanation for these results can be found in the financial crisis, which has had a major impact on the capacity of European businesses and governments to finance investment and innovation projects (European Commission, 2010). Low levels of investment in R&D and innovation represent a significant structural weakness for Europe as a whole.

The food industry has traditionally been regarded as a sector that is characterized by very low R&D to sales ratios (Christensen *et al.*, 1996; Grunert *et al.*, 1995; Martinez and Briz, 2000, Avermate *et al.* 2008; Bröring and Cloutier, 2008). Most of the innovations in the industry are incremental in nature and are characterized by a low degree of newness (Salavou and Avlonitis, 2008). However, the pace of product innovation in the food industry is quite high due to short product life cycles. At the same time, knowledge sourcing in many cases stems from related suppliers (e.g., ingredients, machinery, packaging, other manufacturing supplies) (Bröring and Cloutier, 2008).

The Europe 2020 growth strategy specifically defined its flagship initiative as the "Innovation Union", which has the following goals (European Commission, 2010):

- to strengthen and further develop the role of EU instruments to support innovation (e.g., structural funds, rural development funds, R&D framework programme);
- to reform national (and regional) R&D and innovation systems to foster excellence and smart specialization and reinforce cooperation between universities, research institutions and business;
- to strengthen the innovation chain and boost levels of investment throughout the Union.

Although this strategy does not specifically focus on the food sector, it clearly seeks to foster collaboration across actors in the supply and innovation chains of every economic sector and across private companies and research institutions in addition to promoting more effective and efficient public financial support for innovation activities. As such, the food industry is directly involved in promoting the transfer of innovation "from the lab to the market".

The remainder of this work analyses how different forms of cooperation and public financial support affect the innovation activities of food companies in general before examining the differences and similarities between product innovation developed autonomously and that conducted in collaboration with other enterprises or institutions.

Theoretical framework

It can generally be concluded that innovations are characterized by a complicated feedback mechanism and interactive relationships that involve science, technology, learning, production, policy and demand (Grunert *et al.*, 1995). Until the 1980s, the idea of a linear sequential model of the innovation process prevailed in innovation research. This linear model assumed that there were no reciprocal interactions between research institutions and industrial research but only a linear transfer[1] of the results of basic research activities to industrial companies (Menrad, 2004). In contrast, an integrated model is characterized by networking and recursive interactions during the various stages of the innovation process between different types of actors, parallel developments in science, the strategic integration of partners (e.g., suppliers, customers) and the use of cooperation to overcome knowledge and/or competence gaps during the innovation process or to reduce time-to-market and generation of knowledge (Menrad, 2004).

[1] According to this model, the innovation process starts with basic research that tries to analyse the scientific principles of a specific phenomenon without a specific target. This phase is followed by applied research, which intends to find solutions for defined problems or targets. The successful results of this process ("inventions") are transferred into the experimental development phase with the aim of developing a prototype of a new product. Successful prototypes are transferred to industrial development and finally to the production process. The next step is market introduction and – in case of success – market penetration of the new product.

The relationships among the chain agents are thus considered relevant to the entire innovation process. These relationships require attention to be paid to organizational decisions. A relationship between an organization and technology exists that accounts for the changes and constraints a firm faces in its innovation activities (Teece, 1996) and that shapes all of the stages of innovation (Utterback and Abernathy, 1975; Zaltman *et al.*, 1973).

Scholars in Agribusiness Economics and Management have identified the crucial role of network relationships in the development and implementation of innovation (Omta, 2002; Batterink *et al.*, 2010). Successful innovators have special competences in the management of cross-company interfaces and networks (Grunert *et al.*, 1995). Intra-industry exchanges also positively affect the success of innovation projects. If a company continuously exchanges ideas with other companies in the same industry and cooperates intensively with them, there are much higher chances for successful innovation (see also Gulati, 1998). A continuous exchange is also possible with firms from different industry sectors (Bröring and Cloutier, 2008) and universities or other research institutions (Grunert *et al.*, 1995; Etzkowitz and Leydesdorff, 2000). Thus, it is widely accepted that external sources of information that facilitate the use of scientific knowledge are also important for innovation success. In addition, there is a fair amount of empirical evidence showing that academic institutions produce substantial R&D spill-overs (Mohne and Hoareau, 2003) that increase firms' cooperation with universities because of the generic nature of such collaborations, whereas incoming spill-overs do not foster cooperation with suppliers and customers (Mairesse and Mohnen, 2010).

From this perspective, our approach assumes that the innovation process is affected by how deeply a company is embedded in cooperation through networks, clusters, and chains (Gellynck *et al.*, 2007; Omta, 2002). In fact, through networking, a company can extend its range of skills through the use of an effective contractual arrangement (Martino and Polinori, 2011). Vertical cooperation might offer more possibilities for innovation in SMEs because cooperation is often used to acquire external know-how, especially by companies that have neither R&D employees nor the special technical requirements necessary to engage in R&D activities (Gellynck *et al.*, 2007; Gellynck and Khüne, 2010; Laperche and Liu, 2013).

In sum, the literature recognizes that cooperation between food industry companies and external partners such as suppliers, end users (both food retail companies and individual consumers) and research institutions is extremely important for successful innovation activities. Companies also acquire knowledge by purchasing new equipment or machinery (Martinez and Briz, 2000; Tatikunda and Stock, 2003) and using new food ingredients developed by supplier firms. Indeed, many suppliers (of machinery and ingredients) and even some retail companies and market research institutes were incorporated based on their innovation activities (Menrad, 2004). Conversely, universities, other companies, consultants and consumers are rarely included in collaborations, although the inclusion of research institutions and market research institutes in particular has shown significant, positive correlations with the success of innovations (Grunert *et al.*, 1995). Nevertheless, concentrating on innovative firms, Avermaete et al. (2004) indicated that the greater a firm's R&D efforts are, the more intensive the firm's collaboration with research institutes will be. Furthermore, in their quest to maximize the social return from innovation, governments should also be concerned with fostering links between private firms and basic research institutions, particularly because the culture in businesses and in basic research institutions is often too far apart to lead to cooperation unless the government establishes such a link (Mohne and Hoareau, 2003). In this regard, the European Innovation Scoreboard has included the percentage of enterprises receiving government support for innovation as an indicator of knowledge creation, and Mairesse and Mohnen (2010) found many studies in the literature that show that government R&D support leads to innovation output.

Against this background, this paper aims to investigate how different forms of cooperation affect innovation activity. In particular, the study addresses the question of how cooperation between companies and key chain agents influences innovative activity. Below, the research hypotheses are reported in detail:

H1) Cooperation between research institutions and food companies is a relevant driver of innovation;

H2) Cooperation between food companies and input suppliers fosters innovation activities;

H3) Food companies acquire external knowledge by means of purchasing equipment, which has a positive impact on innovation activities;

H4) Government funding fosters innovation activities.

To test the hypotheses, we carried out a preliminary study by analysing data at the country level. The aggregated data used allow us to investigate national system-level processes that must be considered the outcomes of micro-level decisions and policies. Consequently, our approach does not examine the basic innovation process that takes place in the EU food industry but instead provides a general overview of the phenomena that are at stake.

Moreover, regarding the dependent variable "innovation activity", we focus exclusively on product innovations, as this type of innovation seems to be the main goal of food companies rather than developing new processes that often are derived from other input sectors (Menrad and Feigl, 2007). In addition, our focus also allows us to integrate different approaches; thus, we not only analyse a model that aims to investigate the impact of selected predictors on innovation activities in total (measured by autonomous product innovation and product development as a result of cooperation), we also compare product innovations that are carried out autonomously with product innovations that are developed in cooperation with other enterprises or institutions to better analyse whether and how different forms of cooperation and public support affect innovation performance.

Data and methods

The need to collect a comprehensive set of data on the multi-faceted nature of innovation activities has led to the widespread use of firm-level innovation surveys. In the past, great effort was expended to harmonise surveys on innovation at the international level (Evangelista *et al.*, 1997). To date, the most useful conceptual and methodological framework used to collect firm-level data on innovation activities is that developed by the OECD in the so-called "Oslo Manual" (OECD, 2005), which represents the international basis for guidelines to define and assess innovation activities (Evangelista *et al.*, 2001; Gunday *et al.*, 2011). Thus, the European Commission launched the Community Innovation Survey (CIS) in 1992. After some revisions, the CIS is currently a biennial national data collection survey based on the OECD manual to gather information on the extent of innovation in European firms across a range of industries and business enterprises (Battisti and Stoneman, 2010; Evangelista *et al.*, 2002). The CIS is widely recognized as a unique instrument for understanding innovation and for benchmarking performance by sector and country (Tether, 2001), and it therefore represents an authoritative, official source of data to use for a quantitative analysis on the drivers that affect the innovation activities of food companies across the EU.

Dataset

The dataset used in the following analysis is based on the biennial CIS surveys carried out from 2004 to 2012 (more precisely, CIS 4, CIS 5, CIS 6, CIS 7 and CIS 8). In particular, the panel database adopted for the quantitative analysis contains only information that refers to food companies (the manufacture of food products) and only data that are aggregated at the national level because Eurostat only publicly disseminates data at this level of aggregation. The aggregated data refer to the 25 European countries (Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Norway (not an EU-28 Member State), Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden), so the maximum number of observations in a panel is 125 (25 countries*5 years). The CIS survey questionnaire addressed several elements of firms (e.g., turnover, number of employees, cooperation activities, innovation expenditures, product and process innovation activities, funding, source of information), but only some of these variables are included in the model described below. A detailed explanation of the definition and measurement of the variables is shown in Table 1, whereas descriptive statistics for the data employed in the model are shown in Table 2.

Table 1 – Variables and labels

Variable name	*Label*
✓ Enterprises engaged in the acquisition of machinery, equipment and software to develop product innovations	ACQEQUIP
✓ Enterprises that cooperate with the suppliers of equipment, materials, components or software	COOPSUPP
✓ Enterprises that cooperate with universities or other higher education institutions	COOPUNI
✓ Enterprises that received any public financial support (tax credits or deductions, grants, subsidised loans, loan guarantees) for innovation activities	GOVFUND
✓ Total product innovations developed	PRODEVTOT
✓ Product innovations developed in cooperation with other enterprises or institutions	PRODEVCOOP
✓ Product innovations that were mainly developed by the enterprise or group	PRODEVENT

Source: Eurostat, 2015

Table 2 - Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max

ACQEQUIP	95	504.252	664.351	6	3310
COOPSUPP	108	104.055	95.967	2	425
COOPUNI	104	59.423	72.612	0	505
GOVFUND	86	94.802	111.779	1	595
PRODEVTOT	86	460.267	706.814	0	3928
PRODEVCOOP	83	99.963	205.952	0	1418
PRODEVENT	83	376.939	528.000	0	2946

Table 2 shows that the number of observations of the variables varies from 83 (PRODEVCOOP and PRODEVENT) to 108 (COOPSUPP). In particular, the table clearly shows that in the 25 countries under analysis, product innovations that were autonomously developed by the food companies are more frequent than those that were developed in cooperation with other enterprises or institutions. This result seems to fit with the assumption that European food companies often buy input (e.g., advanced machinery, software) to produce innovations instead of engaging in collaborations. Finally, with regard to the forms of cooperation in the sample, enterprises involved in collaborations with suppliers of equipment seem to be much more numerous than enterprises cooperating with universities or higher education institutes.

Modelling and estimation

In the implemented models, there were reasons to assume that differences across entities (countries) had some influence on the dependent variables, so random effects might be conveniently adopted. Indeed, the rationale behind a random effects model is that, unlike a fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model (Greene, 2008).

The adoption of a random effects model was mainly due to the results of the Hausman test (Green, 2008), which essentially verifies whether the unique errors are correlated with the regressors and consequently allows one to identify the preferred model, fixed effects or random effects. The results indicated that random effects models should be run (see tables 3, 4, 5).

To examine the empirical evidence on the research hypotheses, random effect linear models for panel data are formulated and estimated such that

$$Y_{it} = \alpha + \beta X_{it} + u_{it} + \varepsilon_{it}$$

where:

- α is the unknown intercept;
- Y_{it} is the dependent variable (DV), where i = entity and t = time;
- X_{it} represents one independent variable (IV);
- β is the coefficient for the IVs;
- u_{it} is the between-entity error;
- ε_{it} is the within-entity error.

Variables considered as predictors in the model were a) the number of enterprises cooperating with suppliers of equipment, materials, components or software (COOPSUPP) as a proxy for cooperation with suppliers, b) enterprises engaged in the acquisition of machinery, equipment and software (number) to develop product innovations as a proxy for the acquisition of external knowledge, c) enterprises cooperating with universities or other higher education institutions as a proxy for collaboration with research institutes and d) enterprises that received financial support from a central government (including central government agencies or ministries) as an indicator of public funding. It must be noted that all of these variables refer only to the subsample of CIS surveys that consist of enterprises that are active in the manufacture of food. Conversely, because the model is formulated to analyse how different forms of cooperation affect innovation activities, the dependent variable is the total number product innovations developed by food companies (PRODEVTOT).

On the basis of these descriptions, the final estimation model specification is given by

i. $PRODEVTOT_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it\,+}\, COOPUNI_{it\,+}\, GOVFUND_{it\,+}\, u_{it} + \varepsilon_{it}$

where i denotes the 25 European countries, t = 2004, 2006, 2008, 2010, 2012 and the variables are based on the definitions shown in Table 1.

In addition, as previously described, two other models are formulated to not only test the research hypotheses but also to compare whether and how the same (potential) innovation drivers affect firms that cooperate and firms that do not usually cooperate; thus, it follows that other dependent variables are needed. They are i) the number of products developed in cooperation with other enterprises or institutions (PRODEVCOOP) and ii) the number of products developed autonomously by an enterprise or (the enterprise's) group (PRODEVENT). On the basis of these descriptions, the model specifications are given by

ii. $PRODEVENT_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it\,+}\, COOPUNI_{it\,+}\, GOVFUND_{it\,+}\, u_{it} + \varepsilon_{it}$

iii. $PRODEVCOOP_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it\,+}\, COOPUNI_{it\,+}\, GOVFUND_{it\,+}\, u_{it} + \varepsilon_{it}$

where again i denotes the 25 European countries, t = 2004, 2006, 2008, 2010, 2012 and the variables are based on the definitions shown in Table 1.

After all of the estimations were run, Breusch-Pagan Lagrange multiplier (LM) tests showed a significant difference across countries, thus confirming the use of random effects models rather than simple OLS regressions (see tables 3, 4, 5).

Finally, post-estimation analyses of the combined residuals allowed us to verify graphically (using residuals-dependent plots, residuals-versus-predictor plots, residuals histograms, box plots and q-q plots) and analytically (by means of Shapiro-Wills normality tests) the absence of correlations between the dependent variables (multicollinearity) and between the dependent variables and the residuals and a normal distribution of the residuals, which therefore allows us to exclude the presence of heteroskedasticity (see Appendix).

Main findings

Tables 3, 4 and 5 summarize the results of the estimated models. As previously mentioned, the diagnostic tests indicate no rejection of the normality hypothesis with respect to the residuals and no correlation between the residuals and the covariates. The models show a satisfactory overall model significance (see the overall R-squares) given the modest sample sizes (n= 55 for model I e iii and n = 54 for model ii).

Starting from model i), which analyses the impact of different forms of cooperation and public support on innovation activities, it is interesting to note the strong influence of cooperation with research institutes in fostering product innovation. In addition, collaboration with suppliers does not appear to show a particular relationship with (product) innovation activity, whereas the acquisition of advanced machinery, equipment or software (e.g., external knowledge purchases) positively affects the development of new or significantly improved products. Finally, public financial support for innovation (tax credits, grants, subsidized loans, etc.) received from central governments surprisingly has a strong negative impact on innovation; this result may be due to a bad allocation of resources or insufficient measures adopted to produce innovation.

Models ii) and iii) were run to analyse how product innovations developed by food companies autonomously or in cooperation with others are differently affected by forms of collaboration and public funding. As for model ii), the results in table 4 clearly show that the acquisition of external input (and technology) from suppliers positively affects innovation performance, namely, the number of new products developed autonomously, whereas cooperation with suppliers does not seem to generate spill-over effects. Conversely, cooperation with universities and research institutes has a strong positive effect on the number of innovations produced autonomously; these results reveal that food companies' autonomous innovation performance is positively influenced by the knowledge creation process. Finally, the results highlight the unexpected negative impact of public financial support by governments on the performance of product innovations that food companies developed autonomously.

With regard to model iii), table 5 confirms – as expected – the fundamental role of cooperation with research institutes on fostering product innovations developed by food companies in collaboration with other enterprises or institutions. The results show that food companies that develop new products in cooperation with enterprises and other institutions benefit from the acquisition of technology (equipment, machinery, etc.), whereas surprisingly, they do not seem to take advantage of collaborations with suppliers. Finally, with regard to public financial support for innovation from central governments, a negative relationship is again revealed with product innovation developed in cooperation with enterprises and other institutions, which means that counterintuitively, these types of public actions seem to hinder this fundamental activity instead of incentivizing it; nonetheless, it must be noted that the negative impact is stronger for autonomous companies than for those that cooperate[2].

Table 3 – Model i) Random effects model estimates (n=55)

[2] The number of products developed in cooperation with other enterprises or institutions (that is, the dependent variables in the final estimation model) and the number of products developed by enterprises autonomously were also used to predict companies' annual economic growth rate (measured by the natural logarithm of the ratio of turnover/employees). The results indicated a weak, significant relationship (p-value = 10.7%) for the first covariate and no significant relationship for the second covariate, which may demonstrate a more relevant impact of cooperation activities on economic performance.

Independent variable	Dependent variable: PRODEVTOT		
	Coefficient	Z- value	[95% conf. Interval]
COOPUNI	3.824***	7.12	[2.77; 4.87]
COOPSUPP	-0.129	0.67	[-0.73; 0.48]
ACQEQUIP	0.757***	8.79	[0.58; 0.92]
GOVFUND	-2.187***	-5.87	[-2.91; -1.45]
Constant	1,96	1.47	[-15.64; 109.82]
R-square within	0.779		
R-square between	0.960		
R-square overall	0.918		
sigma_u	129.940		
sigma_e	152.886		
Rho	0.419		
Tests on model specification			
Hausman test_H0: difference in coefficient not systematic	1.36 (not rejected)		
Breusch and Pagan Lagrange multiplier test_H0: random effect is not appropriate	10.00***(rejected)		
Wald chi2 (5)_HO: all of the coefficients in the model are equal to zero	295.81*** (rejected)		

**** - 10% level of significance***

***** -5% level of significance***

******-1% level of significance***

Table 4 – Model ii) Random effects model estimates (n=54)

Independent variable	**Dependent variable: PRODEVENT**		
	Coefficient	**Z- value**	**[95% conf. Interval]**
COOPUNI	2.579***	5.31	[1.62; 3.53]
COOPSUPP	0.272	0.88	[-0.33; 0.88]
ACQEQUIP	0.626***	8.31	[0.47; 0.77]
GOVFUND	-1.890***	-5.80	[-2.52; -1.25]
Constant	39.605	1.49	[-12.57; 91.78]
R-square within	0.756		
R-square between	0.959		
R-square overall	0.909		
sigma_u	90.528		
sigma_e	134.514		
Rho	0.311		
Tests on model specification			
Hausman test_H0: difference in coefficient not systematic	2.93(not rejected)		
Breusch and Pagan Lagrange multiplier test_H0: random effect is not appropriate	6.74***(rejected)		
Wald chi2 (5)_HO: all of the coefficients in the model are equal to zero	299.51*** (rejected)		

**** - 10% level of significance***

***** -5% level of significance***

******-1% level of significance***

Table 5 – Model iii) Random effects model estimates (n=55)

Independent variable	Dependent variable: PRODEVCOOP		
	Coefficient	Z- value	[95% conf. Interval]
COOPUNI	1.275***	5.35	[0.80; 1.74]
COOPSUPP	-0.406**	-2.27	[-0.75; -0.05]
ACQEQUIP	0.122***	5.73	[0.08; 0.16]
GOVFUND	-0.271***	-3.45	[-0.42; -0.11]
Constant	14.061	1.08	[-11.36; 39.48]
R-square within	0.667		
R-square between	0.920		
R-square overall	0.844		
sigma_u	40.769		
sigma_e	45.646		
Rho	0.443		
Tests on model specification			
Hausman test_H0: difference in coefficient not systematic	3.62(not rejected)		
Breusch and Pagan Lagrange multiplier test_H0: random effect is not appropriate	12.11***(rejected)		
Wald chi2 (5)_HO: all of the coefficients in the model are equal to zero	92.14*** (rejected)		

**** - 10% level of significance***

***** -5% level of significance***

******-1% level of significance***

To summarize, each hypothesis proposed in this paper is discussed below:

- **Hypothesis 1:** Cooperation between research institutions and food companies is a relevant driver of innovation. The coefficient for the cooperation with a research institution variable is strongly positive, which shows that it significantly affects innovation activities as measured by the number of new products developed. Thus, collaboration activities with universities positively affect innovation through both direct partnerships and, at a more abstract level, the knowledge creation process. In addition, it must be noted that firms that usually develop innovations in collaborations and firms that develop innovations autonomously are both positively influenced by collaborations with research institutions; this latter relationship appears to be even stronger, which demonstrates a relevant spill-over effect of the knowledge creation process.
- **Hypothesis 2:** Cooperation between food companies and input suppliers fosters innovation activities. This hypothesis was not confirmed. Unexpectedly, we could not find strong impacts from supplier cooperation. In particular, this form of collaboration does not appear to have any impact on product innovations developed

autonomously, and very surprisingly, cooperation between food companies and suppliers shows a negative effect on the performance of food companies' innovation activities carried out in cooperation with other enterprises or institutions. On the one hand, the explanation for these unpredictable effects may be that the models do not take into account the process innovation, which is usually affected either directly or indirectly by food industry suppliers. On the other hand, collaborations with suppliers might sometimes reduce firms' decisional autonomy regarding the procurement of raw materials, which is an activity in which firms may benefit from a greater freedom of choice and action.

- **Hypothesis 3:** Food companies acquire external knowledge by means of purchasing equipment, which has a positive impact on innovation activities. The results confirm that the acquisition of inputs to produce new products positively affects innovation activities; in particular, this positive effect is verified for food companies that develop product innovations both autonomously and in cooperation with other enterprises and institutions. These results appear to show that the insourcing of equipment (and, at the same time, of the technology incorporated in new equipment, software and machinery) generates a benefit for food companies as an indirect effect of new knowledge transfers.
- **Hypothesis 4:** Governments provide useful public financial support for innovation. Public funding by a central government (including central agencies or ministries) that can be provided in various forms (tax credits or deductions, grants, subsidized loans, etc.) does not positively impact innovation; therefore, this hypothesis is rejected. In particular, both autonomous food enterprises and enterprises that cooperate with other firms or institutions do not benefit at all from public financial instruments that are designed to foster innovation activities. To be more precise, this unexpected and counterintuitive result is less drastic for firms that cooperate with other enterprises and institutions than for enterprises that develop innovations autonomously, which means that cooperation seems to facilitate a more efficient use of public financial support from governments to improve innovation performance.

Conclusions

The random effect linear models formulated and estimated to analyse the panel data obtained from five CIS waves (from 2004 to 2012) carried out in 25 European countries generated some interesting findings with regard to what affect the innovation activities of food companies. Specifically, this paper was motivated to verify the effects of different forms of cooperation as well as the impact of public financial support on product innovation. It also focused on the differences between food companies that usually develop their product innovations autonomously and those that do so in collaboration with other enterprises or institutions by showing the different impacts of the analysed drivers on innovation activity performance.

The models performed reasonably well (taking into account the limited number of observations), and the results were fairly significant for the main hypotheses. The first and most significant result is that cooperation with research institutions matters. Indeed, collaborations with universities were significant drivers of innovation, and such collaborations play a positive role in fostering product innovation both for food companies that usually cooperate with other enterprises or institutions and for companies that develop new products autonomously (which highlights a strong spill-over effect due to the relevant knowledge creation process).

The hypothesis that cooperation with suppliers affects (product) innovation activities could not be confirmed. In particular, while these collaborations do not significantly affect the amount of product innovations developed autonomously, they even appear to hinder the development of new goods in cooperation with other companies. These unexpected results might have been improved by including process (and not only product) innovations in the models.

In addition, the findings show that innovation activities are generally positively affected by acquisitions of external input such as machinery, software and equipment, which means that these activities play an important role in the knowledge and technology transfer process. The contradictory role attributed to suppliers should also be noted: in fact, food companies that innovate attributed a significant role to the acquisition of input (from suppliers), but at the same time, they did not recognize cooperation with suppliers as a significant (and positive) driver of innovation performance. One explanation for this result could be that companies neglect the unspecific (and undefined) impact of suppliers on innovation (as framed in the CIS questionnaire), but their relevance increases if the firms are asked about the effect of equipment and technology acquired from external suppliers.

Finally, the hypothesis that public financial support is an effective and efficient instrument to foster innovation is very surprisingly rejected. The results show that food companies' innovation performances (especially for those developing new products autonomously) have not been positively affected at all by public financial support, which should instead be primarily devoted to incentivizing innovation activities.

In conclusion, the results obtained from the last decade's CIS data demonstrate that the Europe 2020 flagship initiative of the "Innovation Union" has promoted actions and objectives that appear to be well targeted to European food industry needs. In particular, the significant and positive linkage between universities and enterprises (which is especially effective for firms that engage in some type of cooperation) requires further reinforcement to continue to positively and strongly affect the entire innovation chain. However, the initiative's purposes will not be achieved if the current low level of effectiveness of the public financial support offered by governments and ministries is not improved. This aspect would seem to be a priority challenge that the European Commission should undertake in the coming years to effectively stimulate innovation in the food industry. In addition, due to the methodological shortcomings of the present work, more insights may be obtained from micro-level data, which would allow reduced heterogeneity of the samples (in terms of firm size, R&D budget, etc.) and the analysis of differences between the food companies of different countries.

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APPENDIX

$$PRODEVTOT_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it\,+}\ COOPUNI_{it\,+}\ GOVFUND_{it\,+}\ u_{it} + \varepsilon_{it}$$

Multicollinearity test

```
. vif, uncentered
```

Variable	VIF	1/VIF
COOPUNI	5.66	0.176593
ACQEQUIP	5.03	0.198767
GOVFUND	3.34	0.299680
COOPSUPP	2.85	0.351178
Mean VIF	4.22	

Plot residuals – dependent variable

```
. plot r PRODEVTOT

 492.948 +
    u    |         *
    [    |
    C    |                   *
    O    |
    U    |
    N    |     *                                                         *
    T    |      ** *   *
    R    |    *   * *         *                   *
    Y    |      *  ***
    ]    |     *  *
         | ****    *    *
    +    | ****   **   *    *
         |  * *   *       *
    e    | *     *    *
    [    | *
    C    | *    **
    O    |                            *
    U    |                        *
    N    |
-480.828 + *     *
          +---------------------------------------------------------------+
                0                   PRODEVTOT                       3928
```

Plot residuals – covariates

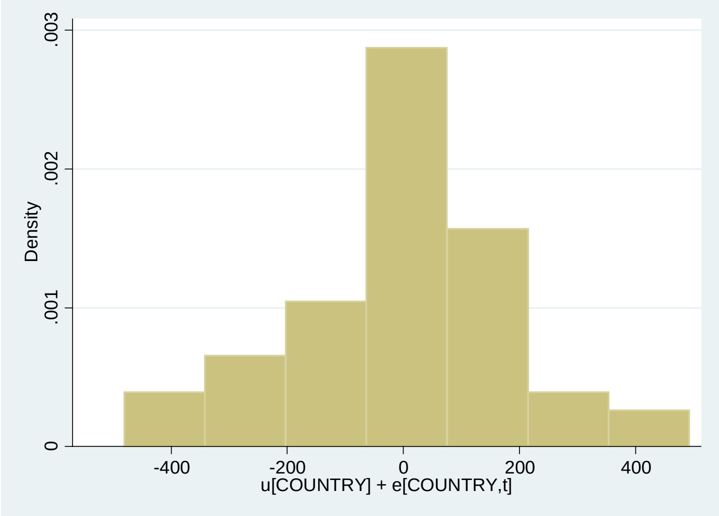
```
. plot r COOPUNI

 492.948 +
    u    |       *
    [    |
    C    |                  *
    O    |
    U    |
    N    |    *                                                             *
    T    |       ***       *
    R    | * *     *          *        *
    Y    |    **     *
    ]    |  *  *
         | ** *  *
    +    | *****  *   *    *
         |     ** **
    e    |  *         *
    [    |                        *
    C    |  *       * *
    O    |                         *
    U    |                       *
    N    |
-480.828 +                 * *
          +-----------------------------------------------------------------+
                1                     COOPUNI                          505
```

```
. plot r COOPSUPP

 492.948 +
    u    |                     *
    [    |
    C    |                                    *
    O    |
    U    |
    N    |          *                          *
    T    |                *     *          **
    R    |             **     *  *                                           *
    Y    |             *           *           *
    ]    |     ** *
         |     ***     *     *                                           *
    +    | *  *  ****            *      *       *
         |        * *    *                                            *
    e    |             **         *
    [    |                                                         *
    C    |           *           *        *
    O    |                            *
    U    |              *
    N    |
-480.828 +                               *     *
          +------------------------------------------------------------------+
                2                    COOPSUPP                         425
```

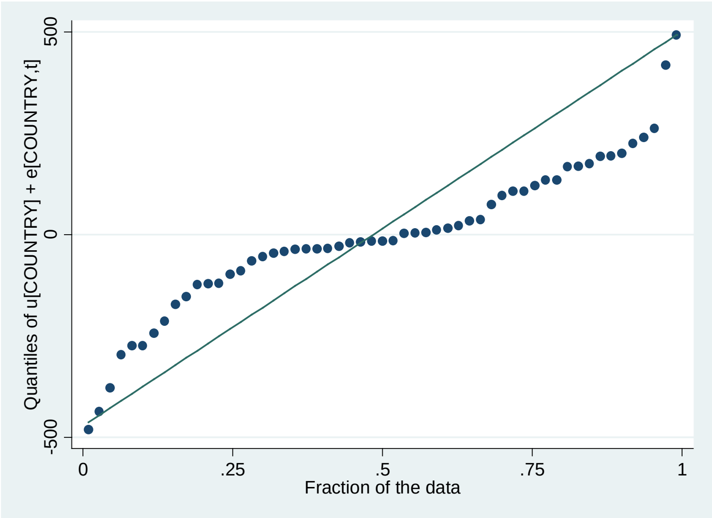
```
. plot r ACQEQUIP

 492.948 +
    u    |        *
    [    |
    C    |                     *
    O    |
    U    |
    N    |      *                                                            *
    T    |       ***    *
    R    |      *  *   *      *                             *
    Y    |       *  ** *
    ]    |      *  *
         | ** *       *         *
    +    | ****     **     *              *
         |    *         *            *
    e    |        * *                             *
    [    |                       *
    C    |        *    *
    O    |                                                 *
    U    |                                               *
    N    |
-480.828 +            *
          +------------------------------------------------------------------+
               11                    ACQEQUIP                         3310
```

```
. plot r GOVFUND

 492.948 +
    u    |                      *
    [    |
    C    |                             *
    O    |
    U    |
    N    |              *                        *
    T    |          *    *     *  *
    R    |     *  * *     *        *
    Y    |   *     **    *
    ]    | ***
         | * *** *  *
    +    | ***      *                   *
         | *  *    **
    e    |    *       *                                        *
    [    |                                                                 *
    C    |  ***
    O    |                           *
    U    |                               *
    N    |
-480.828 +        *                  *
          +----------------------------------------------------------------+
                3                    GOVFUND                          595

.
```

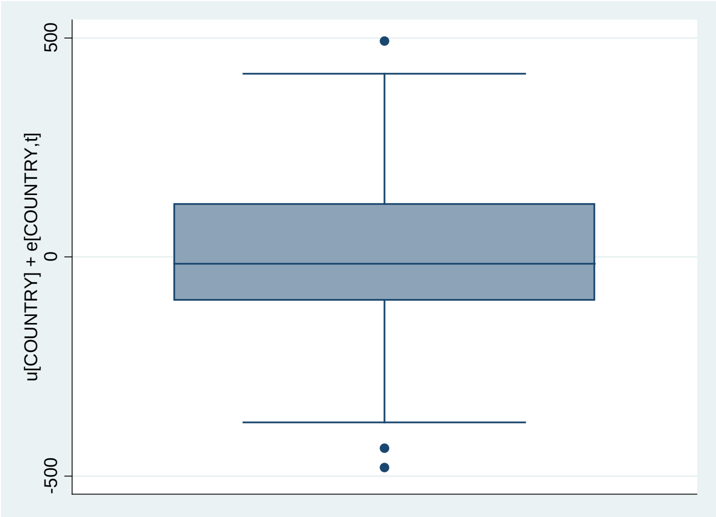
Histogram of residuals



QQplot of residuals



Boxplot of residuals



Shapiro Wilk normality test for residuals

```
. swilk r

                   Shapiro-Wilk W test for normal data

    Variable |        Obs       W           V         z       Prob>z
-------------+------------------------------------------------------
           r |         55    0.97539      1.248     0.475    0.31734
```

$$PRODEVENT_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it\,+}\ COOPUNI_{it\,+}\ GOVFUND_{it\,+}\ u_{it} + \varepsilon_{it}$$

Multicollinearity test

```
. vif, uncentered
```

Variable	VIF	1/VIF
COOPUNI	5.68	0.176201
ACQEQUIP	5.04	0.198406
GOVFUND	3.34	0.299080
COOPSUPP	2.85	0.350783
Mean VIF	4.23	

Plot residuals - dependent variable

```
. plot re PRODEVENT

 478.851 +
    u    |                        *
    [    |
    C    |
    O    |
    U    |        *
    N    |
    T    |               *          *
    R    |      *     *
    Y    |      * **    *                              *                   *
    ]    |     * *
         |      *  ***         *
    +    | *** *  *  *
         | * **          **
    e    |  * *   **  *
    [    | *                 *
    C    | *    * *                  *
    O    |       *
    U    |                             *
    N    | *
-397.643 +        *
          +----------------------------------------------------------------+
                0                    PRODEVENT                        2946

.
```

Plot residuals - covariates

```
. plot re COOPUNI

 478.851 +
    u    |                  *
    [    |
    C    |
    O    |
    U    |       *
    N    |
    T    |                 *           *
    R    | *  *
    Y    |    *  ***          *                                            *
    ]    |   *       *
         |  * **     *    *
    +    | *** * *    *
         | ****  **
    e    |     ** *   *
    [    |         *             *
    C    |  *       * *          *
    O    |            *
    U    |                        *
    N    |                  *
-397.643 +                    *
          +----------------------------------------------------------------+
                1                     COOPUNI                          505

.
```

```
. plot re COOPSUPP

 478.851 +
    u    |                                    *
    [    |
    C    |
    O    |
    U    |                    *
    N    |
    T    |                                  *                               *
    R    |          *   *
    Y    |             *  *   * **         *   *
    ]    |             *           *
         |     **            *     *           **
    +    |    *****    *                *
         | *    * ***                          *                       *
    e    |       * *  * *        *
    [    |                                                        *  *
    C    |              *       **
    O    |                                *
    U    |                            *
    N    |                               *
-397.643 +                                     *
         +------------------------------------------------------------------+
               2                    COOPSUPP                         425
```

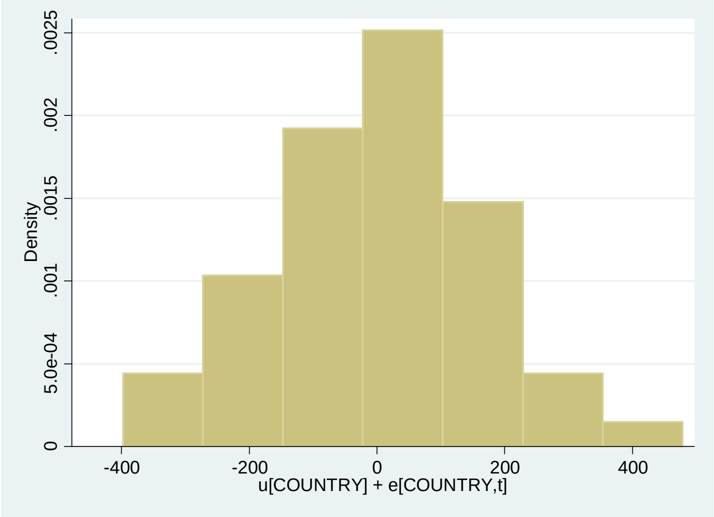
```
. plot re ACQEQUIP

 478.851 +
    u    |                    *
    [    |
    C    |
    O    |
    U    |       *
    N    |
    T    |             *     *
    R    |     *      *
    Y    |      ***   *                                  *              *
    ]    |     **
         |     *  ***                    *
    +    | ** *   *  *
         | ****          *    *
    e    |   *      *  *                        *
    [    |                      *   *
    C    |       * *  *                               *
    O    |       *
    U    |                                              *
    N    |           *
-397.643 +           *
         +---------------------------------------------------------------+
              11                    ACQEQUIP                       3310
```

.

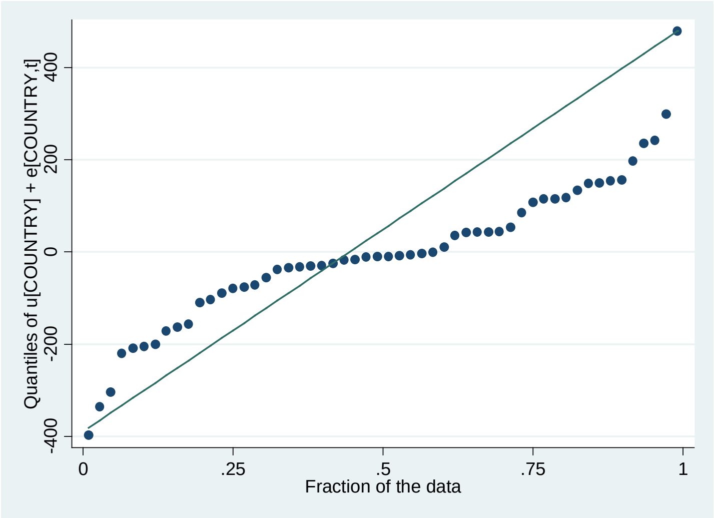
```
. plot re GOVFUND

 478.851 +
    u    |                            *
    [    |
    C    |
    O    |
    U    |                     *
    N    |
    T    |                       **
    R    |     *        *
    Y    |   *    * *   **    *                 *
    ]    |          *    *
         | ** *    **                  *
    +    | ***** *  *
         | ***      *
    e    | ** *     *                                        *
    [    |         *                                                     *
    C    |    *       *                 *
    O    |   *
    U    |                          *
    N    |                          *
-397.643 +        *
         +---------------------------------------------------------------+
               3                     GOVFUND                         595
```

.

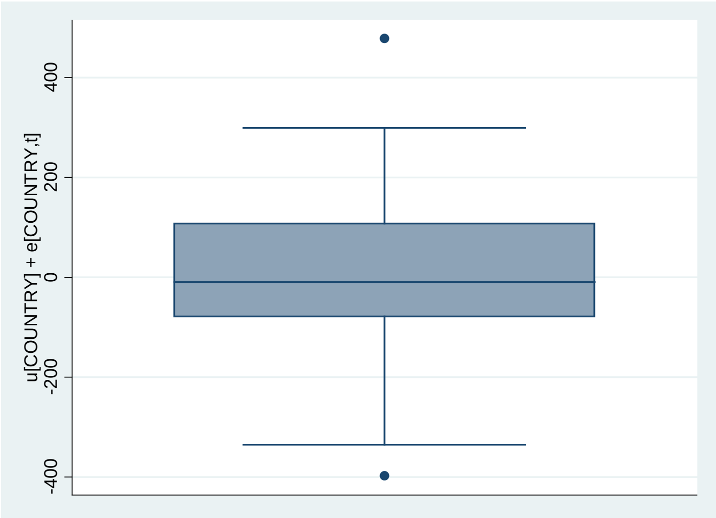
Histogram of residuals



QQplot of residuals



Boxplotof residuals



Shapiro Wilk normality test for residuals

```
. swilk re

                   Shapiro-Wilk W test for normal data

    Variable │        Obs       W           V         z       Prob>z
─────────────┼──────────────────────────────────────────────────────
          re │         54    0.97763      1.118     0.239    0.40538
```

$$PRODEVCOOP_{it} = \alpha + COOPSUPP_{it} + ACQEQUIP_{it} + COOPUNI_{it} + GOVFUND_{it} + u_{it} + \varepsilon_{it}$$

Multicollinearity test

```
. vif, uncentered
```

Variable	VIF	1/VIF
COOPUNI	5.66	0.176593
ACQEQUIP	5.03	0.198767
GOVFUND	3.34	0.299680
COOPSUPP	2.85	0.351178
Mean VIF	4.22	

Plot residuals - dependent variable

```
. plot res PRODEVCOOP

  184.19 +
    u    |              *
    [    |
    C    |
    O    |
    U    |                                                                *
    N    |        *
    T    |         * *
    R    |      **  *
    Y    |    **  * *
    ]    |  *** *                        *
         | ****                       *
    +    | *** **
         |  * **      *
    e    |  ** *
    [    | * *  *
    C    |      **
    O    | *    *
    U    |
    N    |
-170.135 +                *
          +----------------------------------------------------------------+
                0                  PRODEVCOOP                        982
```

Plot residuals - covariates

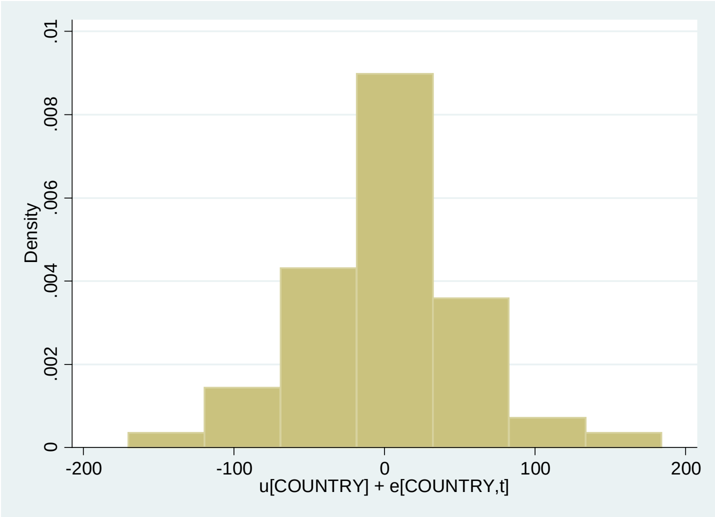
```
. plot res COOPUNI

  184.19 +
    u    |       *
    [    |
    C    |
    O    |
    U    |                                                                  *
    N    |         *
    T    |     *     *
    R    |     * ***
    Y    |    *  * *  *
    ]    | *** *              *
         | **        *            *
    +    | ****** *
         |       **   *
    e    |    *             *
    [    |          *        *    *
    C    |                *   *
    O    |                  *           *
    U    |
    N    |
-170.135 +                        *
          +-----------------------------------------------------------------+
                1                     COOPUNI                           505

.
```

```
. plot res COOPSUPP

  184.19 +
    u    |                    *
    [    |
    C    |
    O    |
    U    |                                    *
    N    |                                *
    T    |        *                           *
    R    |               *        *                                 *  *
    Y    |         *         * * *
    ]    |      *     *         *
         |     *       *          *  *
    +    | *  *******  **                      *
         |       *    *                *  *
    e    |            *     *              *
    [    |                      *            *                   *
    C    |                                    **
    O    |                              *                                  *
    U    |
    N    |
-170.135 +             *
          +----------------------------------------------------------------+
                2                    COOPSUPP                        425
```

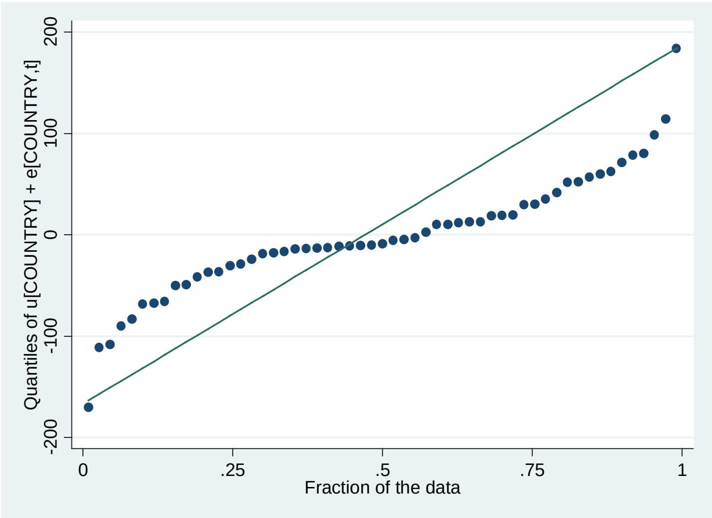
```
. plot res ACQEQUIP

  184.19 +
    u    |       *
    [    |
    C    |
    O    |
    U    |                                                              *
    N    |        *
    T    |        **
    R    |       *  *          *    *
    Y    |     ****
    ]    |  *  *    *                                    *
         | **   *     *                                *
    +    | ***** * *  *  *
         |   **  *   *                       *
    e    |          ***
    [    |            *      * *
    C    |           *                  *
    O    |           *      *
    U    |
    N    |
-170.135 +                                          *
          +-------------------------------------------------------------+
               11                  ACQEQUIP                      3310
```

```
. plot res GOVFUND

  184.19 +
    u    |                      *
    [    |
    C    |
    O    |
    U    |                                       *
    N    |                     *
    T    |   *      *
    R    |         **
    Y    |    *         ***
    ]    | ** *   * *
         |   ***         *           *
    +    | ***      * *
         |   **  *  *                                        *
    e    |   **                *
    [    |    *                     *                                   *
    C    |        *                  *
    O    |                     * *
    U    |
    N    |
-170.135 +                               *
          +----------------------------------------------------------------+
                3                    GOVFUND                           595
```

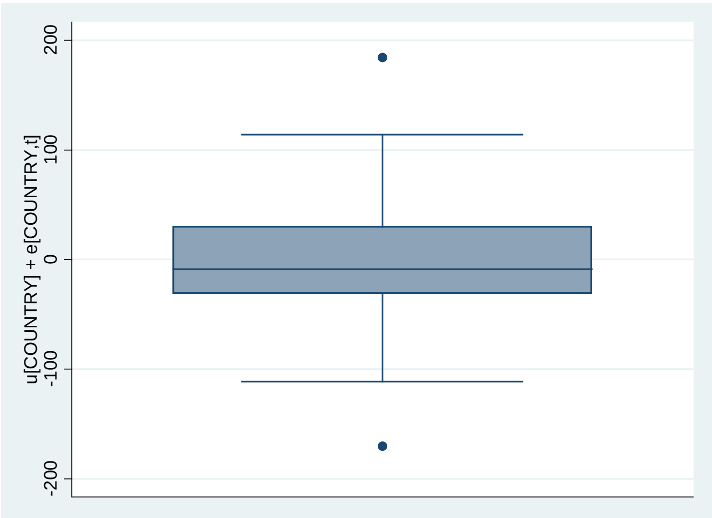
Histogram of residuals



QQplot of residuals



Boxplot of residuals



Shapiro Wilk normality test for residuals

```
. swilk res

                   Shapiro-Wilk W test for normal data

    Variable |        Obs       W           V         z       Prob>z
-------------+------------------------------------------------------
         res |         55    0.97572      1.231     0.446    0.32781
```