Micro evidence for sources of innovation in European countries

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29 May 2012

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This paper investigates sources of product or process innovation, such as investments in research and development, machinery, personnel training and management systems, by examining microdata from eight European countries. We pay particular attention to the effect of research and development in favouring the absorption of new technologies, i.e. the absorptive capacity. Significant positive effects of each source on both product and process innovations are found. Significant evidence of positive absorptive capacity emerges only in firms with low predicted probabilities of introducing innovation.

JEL classification: D22; O31, O32.

Keywords: Innovation; Absorption; Microdata; European countries.

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1. Introduction

Innovation is a multifaceted phenomenon, therefore any attempt to empirically investigate its sources meets a number of difficulties. The availability of microdata has allowed us to overcome some of these difficulties, by looking directly at firm's behaviour. To this end, the Community Innovation Survey (CIS), a well-known European database at firm level, has represented an important resource for many scholars. Indeed, an increasing number of articles has recently provided more accurate evidence on innovation at firm level (e.g. Parisi et al., 2006; Iammarino et al., 2009; Damijan et al., 2012). However, this literature focuses on a single country at a time. In this paper, we provide novel evidence for innovation by looking at the firm's behaviour in eight European countries. In particular, we look at the effect of sources such as investments in research and development (R&D), machinery, personnel training and management systems, on product or process innovation. In addition, we control for some firm characteristics such as membership of a group, openness to international markets, size in terms of employees, and sector of activity. Finally, particular attention is paid to absorptive capacity, i.e. the effect of R&D in favouring the absorption of new technologies (e.g. Cohen and Levinthal, 1989). We use the procedure suggested by Ai and Norton (2003) in order to correctly estimate, in a probit model, the absorptive capacity as an interaction effect between R&D intensity and machinery investment intensity. Most of the previous literature is affected by potential problems of misinterpretation because it neglects the fact that the marginal effect of interaction term incorrectly estimates the interaction effect.

The paper is organized as follows. Section 2 describes the data and the empirical approach. Section 3 presents the results. Section 4 concludes.

2. Data and empirical approach

2.1 Data

In this paper, we use microdata collected by Eurostat as part of the Fourth Community Innovation Survey (CIS4). This survey was based on a standardised questionnaire at European level

administered to firms with at least 10 employees. In particular, we exploit microdata from eight European countries: Belgium, Spain, Hungary, Lithuania, Norway, Portugal, Romania and Slovakia. The CIS4 database provides information on a variety of aspects related to firm's innovative activities during the period 2002-2004. Table 1 shows in detail the definition of variables used in this study.

Some descriptive statistics are reported in Table 2. Belgium, Spain and Portugal are the most innovative countries in terms of both product (Inpd) and process (Inps) innovation. Unexpectedly, the innovative performance is low in Norway and high in Lithuania. Hungary is the least innovative country. As regards the explanatory variables, Belgium shows the highest average values for R&D intensity (Rd) and machinery intensity (Machinery), and high percentage values for the other two sources of innovation (i.e. Training and Management). Portugal exhibits the highest values for Training and Organisation. Finally, the high values of membership of a group (Group) in Portugal and Belgium, the highest values of openness to international markets (Market) in Belgium, the low value of large size firms (Size) in Belgium and the highest value in Slovakia are all results worth mentioning. To sum up, it already emerges: (i) the positive contribution of each source of innovation for a good performance, like in Belgium; (ii) the positive contribution of Group and Market; (iii) the negative contribution of Size.

2.2 Empirical approach

The likelihood of introducing innovation can be estimated using a probit model as follows:

$$Pr(Y = 1 \mid X) = \phi\,(X'\beta) \tag{1}$$

where *Pr* denotes the likelihood of introducing product (Inpd) or process (Inps) innovation, ϕ is the standard normal cumulative distribution function and X is a vector of regressors that includes two sets of variables: (a) sources of innovation, i.e. Rd, Machinery, Training, Management; (b) firm

characteristics, i.e. Group, Market, Size and sectoral dummy variables. The parameters β are estimated by maximum likelihood.[1]

In addition, we aim to estimate the absorptive capacity that has been measured in empirical literature by means of the interaction effect between R&D intensity and fixed investment intensity (e.g. Parisi et al., 2006). However, as argued by Ai and Norton (2003), most of the empirical literature misinterprets the coefficient of the interaction term in logit or probit models. Indeed, the magnitude of the interaction effect in logit or probit models does not equal the marginal effect of the interaction term and even the sign and the significance may be incorrect as a result. To this end, Norton et al. (2004) provide a STATA command in order to estimate the correct interaction effect, as well as the correct standard errors.

3. Results

Tables 3 and 4 report the results of probit regressions for Inpd and Inps respectively. In each country, all sources of innovation (Rd, Machinery, Training and Management) have a positive and strongly significant effect on both Inpd and Inps. In line with expectations, the coefficients of Rd are higher than those of Machinery for Inpd, and opposite results are obtained for Inps. It is worth mentioning the high value of coefficients for Training, independently of the country under analysis. As regards the firm characteristics, Group positively and significantly affects Inpd in four out of eight countries (Belgium, Lithuania, Portugal and Romania) and Inps in six out of eight countries (Belgium, Spain, Hungary, Lithuania, Norway and Portugal). Market has a significant positive effect on Inpd in Lithuania, Portugal and Romania, and on Inps in Belgium, Spain, and Hungary. Unexpectedly, Size does not affect the likelihood of innovation (except in a few cases).

We have to pay much more attention to the interpretation of absorptive capacity (Absorption), here measured as interaction between R&D intensity (Rd) and machinery investment intensity (Machinery). If one simply looks at the coefficient of interaction term, one can conclude that

[1] See Table 1 for the definition of variables.

Absorption negatively and significantly affects both Inpd and Inps. However, as discussed above, a correct estimation of interaction term is needed in probit models and the procedure by Norton et al. (2004) provides a solution. Figures 1 and 2 show the correct interaction effect for each country and the confidence interval used to evaluate the significance.[2] For both Inpd and Inps, we find significant evidence of positive absorptive capacity in firms with a predicted probability of introducing innovation around 0.2, independent of the country of origin. This evidence will be hidden if the correct interaction effect is not estimated. On other hand, firms with a higher probability of introducing innovation exhibit negative and significant effects. This is a novel result which leads to suggestions for further research. For instance, our result is in line with the evidence recently provided by Damijan et al. (2012) that only firms with below average productivity growth are likely to benefit significantly from successful innovation. They find higher returns to innovation in firms that potentially innovate less. In light of this evidence, the result of positive absorptive capacity only in less innovative firms finds a reasonable interpretation.

4. Conclusions

In this paper, we estimate the likelihood of introducing product or process innovation with respect to sources such as investments in R&D, machinery, personnel training and management systems. We also control for some firm characteristics such as membership of a group, openness to international markets, size and sector. Particular attention is paid to absorptive capacity and, to this end, correct estimates of interaction term between R&D intensity and machinery investment intensity are obtained, adopting the approach used by Aim and Norton (2003). We find a strong significant effect of each source on both product and process innovation. On other hand, the firm characteristics selected affect innovative performance only in some countries. Surprisingly, firm size is not significant. We also find significant evidence of positive absorptive capacity only in

[2] Values outside the confidence intervals reject the hypothesis of interaction effect equal to zero.

firms with low predicted probabilities of introducing innovation, independent of the country of origin and of the type (product or process) of innovation.

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Table 1 –List of variables

Variable	Label
Inpd	Product innovation during 2002-2004 (1 yes; 0: no)
Inps	Process innovation during 2002-2004 (1: yes; 0: no)
Rd	R&D intensity = ln(expenditures in intramural R&D during 2002-2004 / sales in 2002)
Machinery	Machinery intensity = ln(expenditures in acquisition of advanced machinery during 2002-2004 / sales in 2002)
Absorption	Interaction effect between Rd and Mac
Training	Internal or external training for employees introducing new products or improving processes during 2002-2004 (1: yes; 0: no)
Management	New or significantly improved knowledge management system during 2002-2004 (1: yes; 0: no)
Group	Enterprise part of an enterprise group during 2002-2004 (1: yes; 0: no)
Market	Enterprise selling its goods and services in European or other countries market during 2002-2004 (1: yes; 0: no)
Size	Large size enterprises in 2002 (0: up to 250 employees; 1: more than 250 employees)

Table 2 – Descriptive statistics

	Belgium	Spain	Hungary	Lithuania	Norway	Portugal	Romania	Slovakia
Observed firms	*2869*	*15224*	*3806*	*3278*	*3484*	*4801*	*8851*	*2195*
Inpd (% yes)	31.37	28.00	16.55	23.67	20.92	26.45	16.95	21.96
Inps (% yes)	32.49	33.87	16.26	28.31	17.22	36.41	19.85	25.69
Rd (mean)	0.943	0.730	0.006	0.008	0.078	0.014	0.014	0.006
Machinery (mean)	0.487	0.011	0.173	0.213	0.016	0.347	0.157	0.021
Training (% yes)	32.62	25.41	14.06	22.76	16.25	32.83	13.86	21.96
Management (% yes)	28.48	28.93	9.51	19.59	13.03	36.87	23.64	22.73
Group (% yes)	50.16	28.59	24.80	25.87	51.46	27.18	9.13	28.61
Market (% yes)	67.03	45.15	48.69	44.72	35.94	46.93	33.41	54.99
Size (% yes)	10.63	15.66	15.32	13.79	6.03	11.58	15.91	18.82

Note: Rd and Mac are here not expressed in natural logarithm.

Table 3 – Probit regressions for product innovation (Inpd)

	Belgium	**Spain**	**Hungary**	**Lithuania**	**Norway**	**Portugal**	**Romania**	**Slovakia**
Rd	0.132**	0.134**	0.197**	0.159**	0.186**	0.085**	0.341**	0.220**
	(0.009)	(0.002)	(0.013)	(0.017)	(0.008)	(0.011)	(0.014)	(0.017)
Machinery	0.078**	0.094**	0.150**	0.074**	0.119**	0.065**	0.247**	0.113**
	(0.008)	(0.003)	(0.008)	(0.007)	(0.016)	(0.005)	(0.007)	(0.010)
Absorption	-0.006**	-0.006**	-0.013**	-0.010**	-0.006**	-0.004**	-0.026**	-0.012**
	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Training	0.807**	0.517**	0.637**	1.037**	0.736**	1.178**	0.468**	0.721**
	(0.081)	(0.030)	(0.092)	(0.075)	(0.090)	(0.057)	(0.071)	(0.104)
Management	0.079	0.439**	0.260**	0.268**	0.205**	0.226**	0.336**	0.335**
	(0.071)	(0.029)	(0.099)	(0.074)	(0.099)	(0.053)	(0.062)	(0.096)
Group	0.135**	0.018	0.094	0.295**	-0.073	0.153**	0.212**	-0.048
	(0.066)	(0.031)	(0.079)	(0.069)	(0.082)	(0.056)	(0.083)	(0.096)
Market	0.381**	0.242**	0.188**	0.224**	0.188**	0.301**	0.044	0.078
	(0.079)	(0.031)	(0.081)	(0.069)	(0.086)	(0.052)	(0.063)	(0.098)
Size	-0.049	-0.185**	-0.075	0.083	-0.074	0.021	-0.070	0.042
	(0.105)	(0.103)	(0.094)	(0.085)	(0.148)	(0.078)	(0.077)	(0.107)
Constant	-3.123**	-1.237**	-1.985**	-1.157**	-2.729**	-2.190**	-2.192**	-2.689**
	(0.526)	(0.092)	(0.166)	(0.141)	(0.227)	(0.326)	(0.194)	(0.348)
Observations	2869	15224	3806	3278	3484	4801	8851	2195
Pseudo R^2	0.44	0.40	0.52	0.41	0.64	0.38	0.71	0.52

Note: * 10% significance, ** 5% significance. Robust standard errors in parenthesis. Sector dummies at 1-digit NACE Rev. 1.1 level are included in probit models.

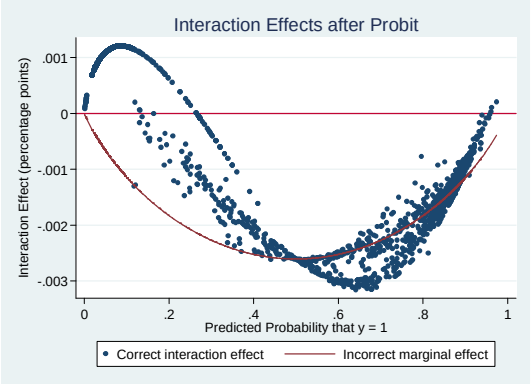
Table 4 – Probit regressions for process innovation (Inps)

	Belgium	**Spain**	**Hungary**	**Lithuania**	**Norway**	**Portugal**	**Romania**	**Slovakia**
Rd	0.072**	0.092**	0.111**	0.116**	0.129**	0.057**	0.298**	0.153**
	(0.010)	(0.003)	(0.013)	(0.017)	(0.007)	(0.011)	(0.013)	(0.017)
Machinery	0.153**	0.168**	0.161**	0.160**	0.200**	0.146**	0.362**	0.209**
	(0.008)	(0.004)	(0.008)	(0.008)	(0.017)	(0.006)	(0.009)	(0.011)
Absorption	-0.009**	-0.011**	-0.010**	-0.012**	-0.013**	-0.007**	-0.030**	-0.015**
	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Training	0.950**	0.592**	0.923**	1.245**	0.700**	1.388**	0.690**	1.080**
	(0.083)	(0.031)	(0.092)	(0.081)	(0.083)	(0.058)	(0.091)	(0.108)
Management	0.600**	0.809**	0.694**	0.600**	0.746**	0.581**	0.426**	0.481**
	(0.071)	(0.028)	(0.099)	(0.081)	(0.085)	(0.054)	(0.075)	(0.104)
Group	-0.035	0.041	0.075	0.297**	0.080	0.220**	0.244**	-0.028
	(0.068)	(0.031)	(0.081)	(0.075)	(0.074)	(0.062)	(0.104)	(0.105)
Market	0.230**	0.166**	0.152*	0.114	0.086	0.005	0.050	-0.013
	(0.080)	(0.030)	(0.085)	(0.076)	(0.079)	(0.055)	(0.077)	(0.107)
Size	0.161	-0.024	-0.020	0.460**	0.073	0.130	-0.238	-0.035
	(0.105)	(0.039)	(0.094)	(0.093)	(0.130)	(0.087)	(0.096)	(0.123)
Constant	-1.517**	-1.250**	-1.902**	-1.167**	-2.220**	-1.804**	-2.593**	-2.034**
	(0.329)	(0.096)	(0.160)	(0.172)	(0.189)	(0.363)	(0.260)	(0.310)
Observations	2869	15224	3806	3278	3484	4801	8851	2195
Pseudo R^2	0.47	0.40	0.55	0.56	0.49	0.53	0.83	0.64

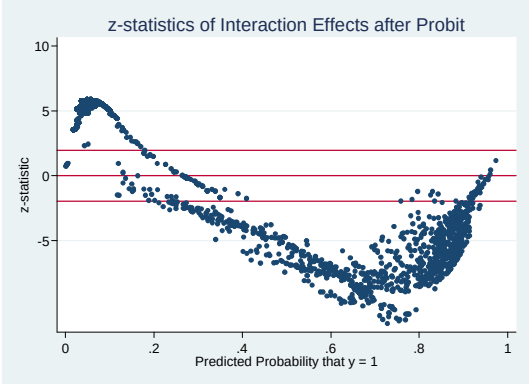
Note: * 10% significance, ** 5% significance. Standard errors in parenthesis. Sector dummies at 1-digit NACE Rev. 1.1 level are included in probit models.

Figure 1 - Absorption effect in European countries (product innovation)

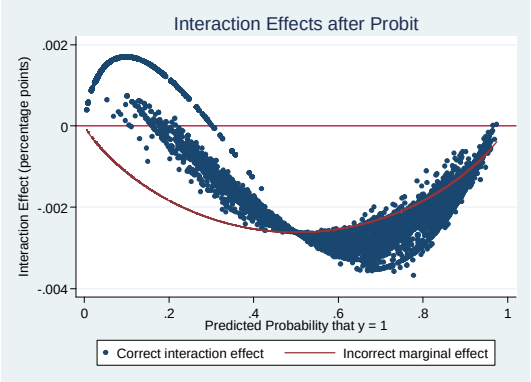
(a1) Belgium



(a2) Belgium



(b1) Spain



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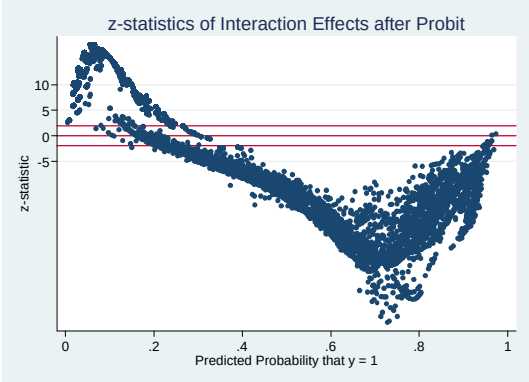
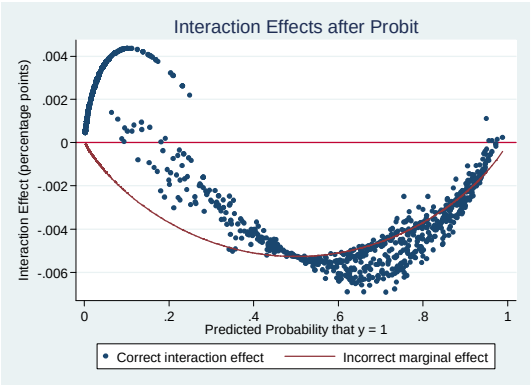


(c1) Hungary



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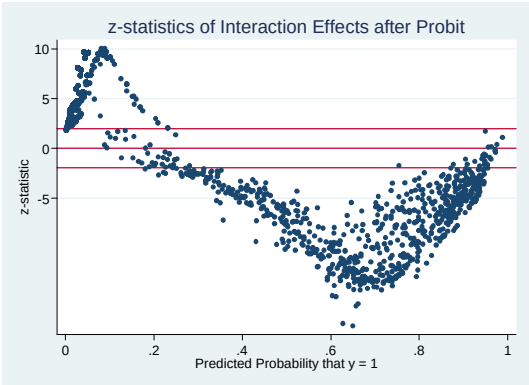

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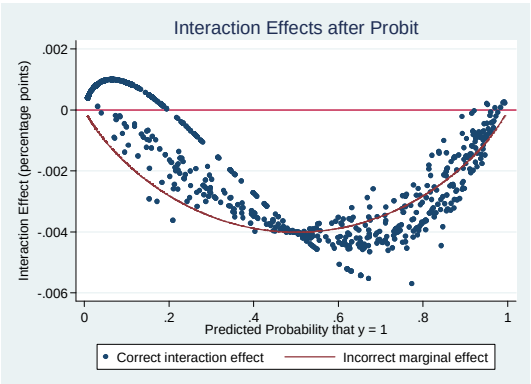

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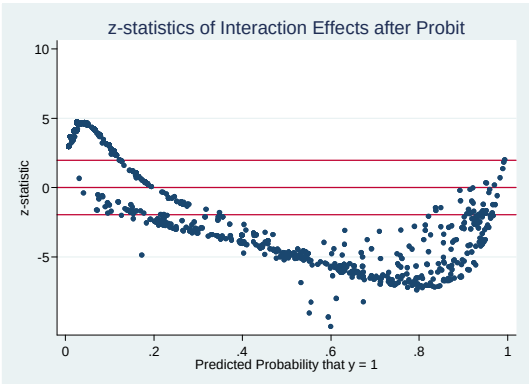
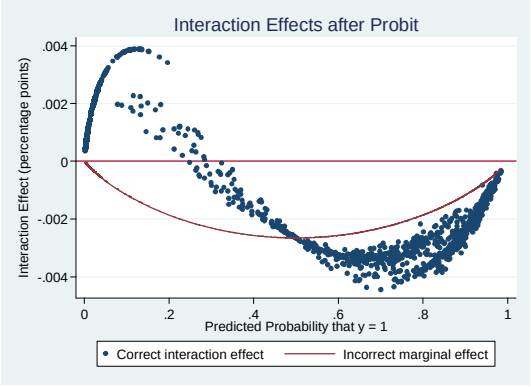


(e1) Norway



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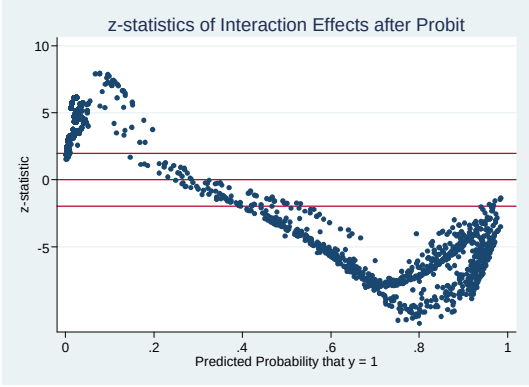

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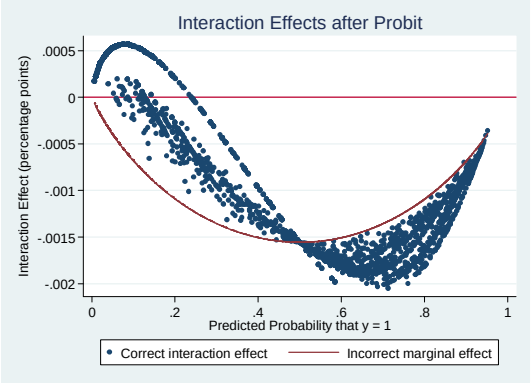

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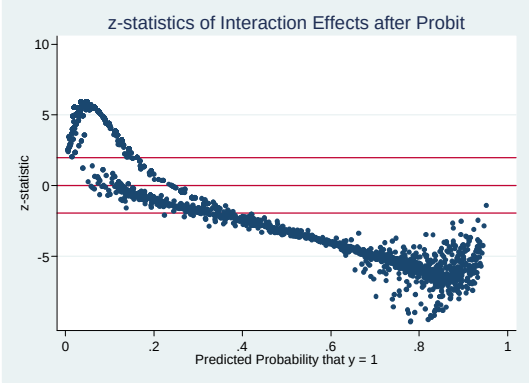
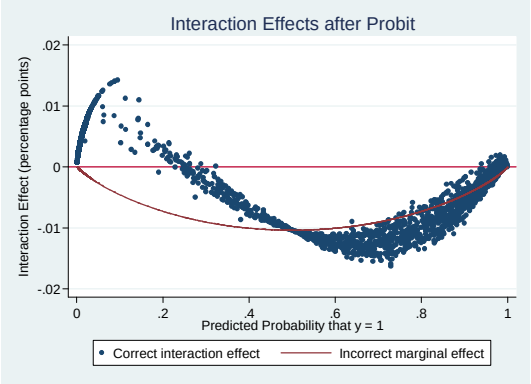


(g1) Romania



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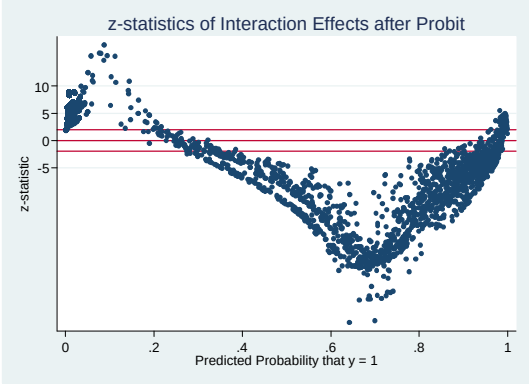

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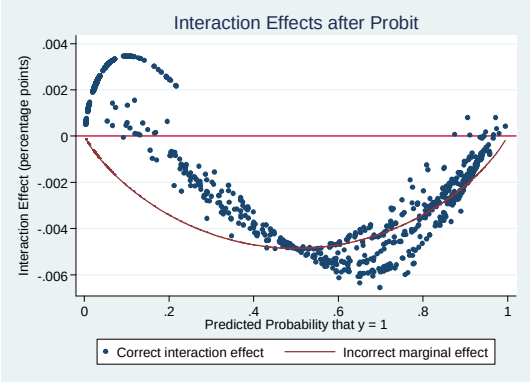

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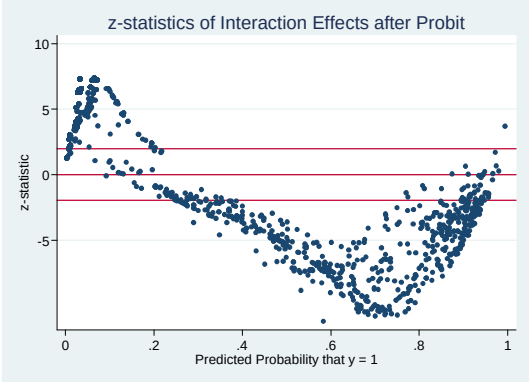
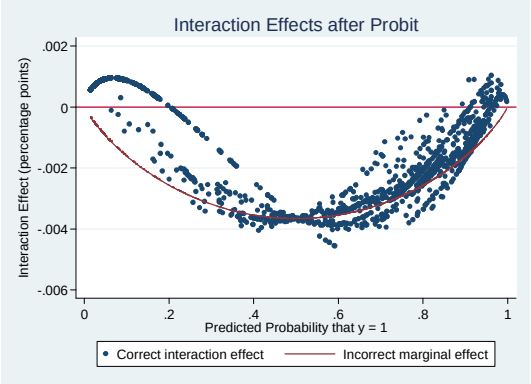


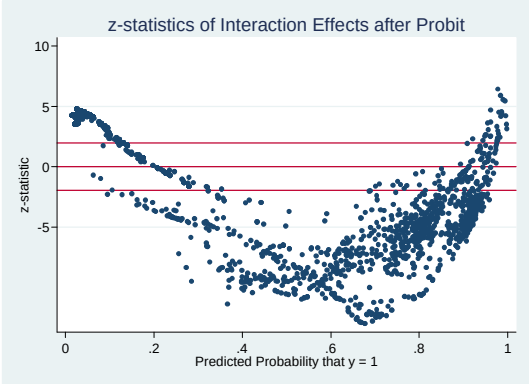
Note: Absorption (interaction) effect is estimated by STATA command *inteff* (Norton et al., 2004).

Figure 2 - Absorption effect in European countries (process innovation)

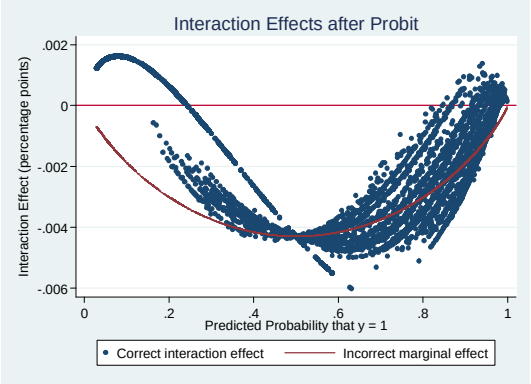
(a1) Belgium



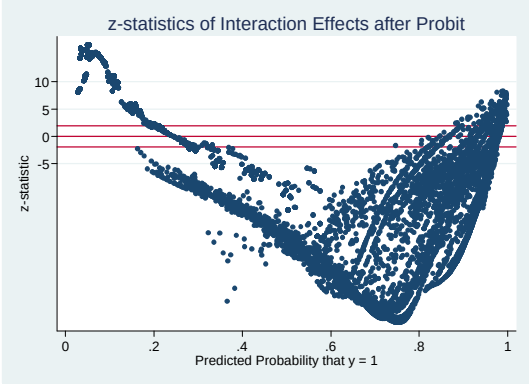
(a2) Belgium



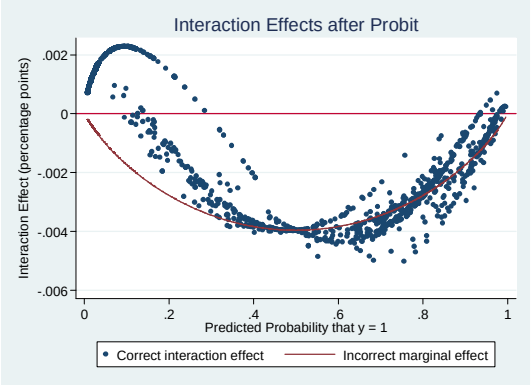
(b1) Spain



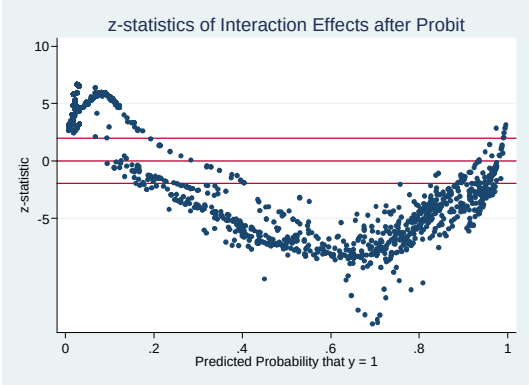
(b2) Spain



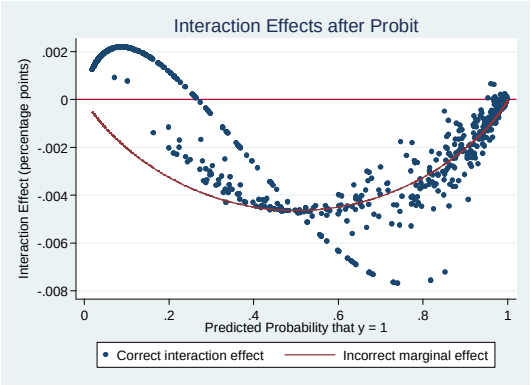
(c1) Hungary



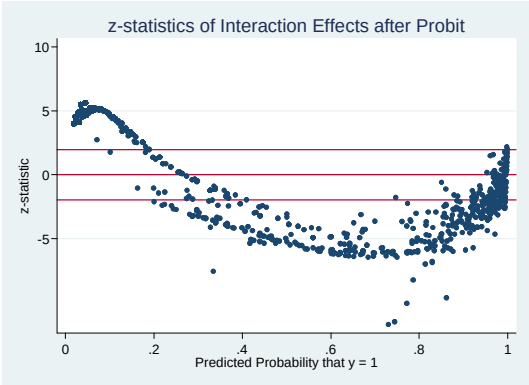
(c2) Hungary



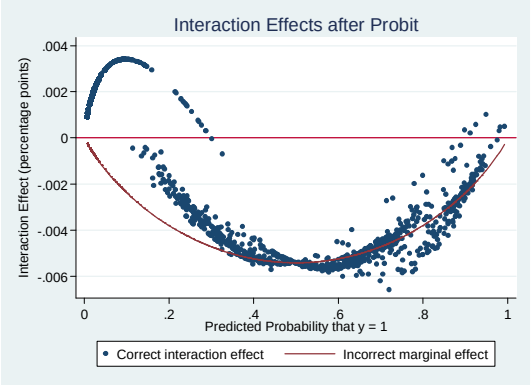
(d1) Lithuania



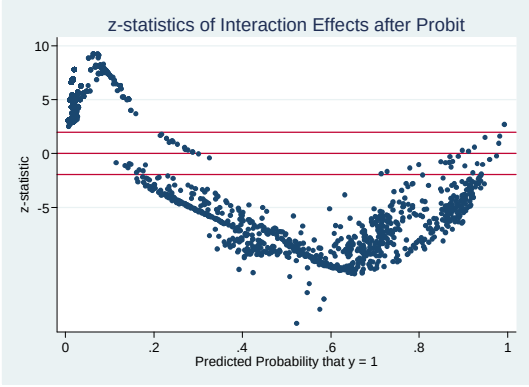
(d2) Lithuania



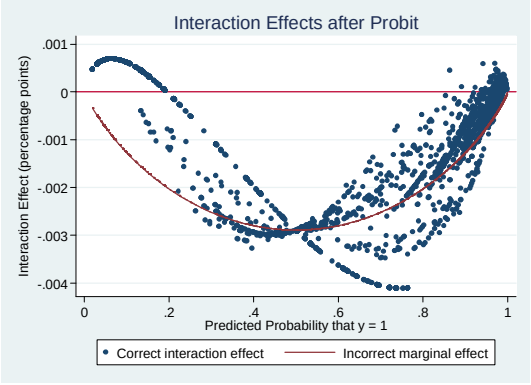
(e1) Norway



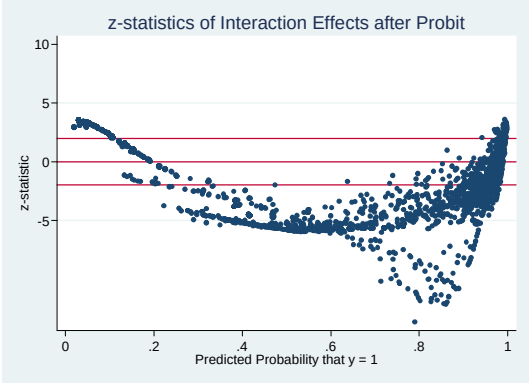
(e2) Norway



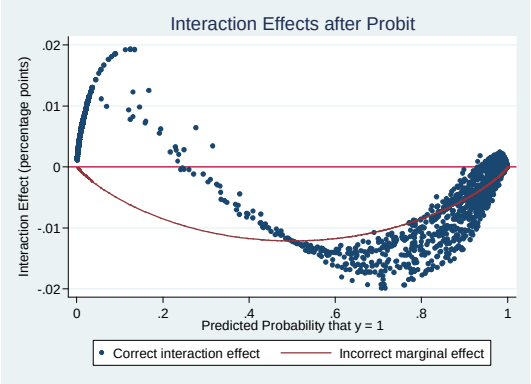
(f1) Portugal



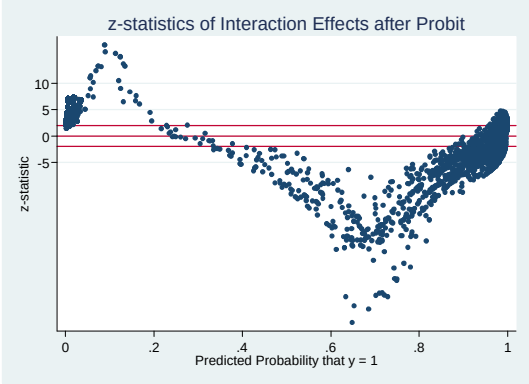
(f2) Portugal



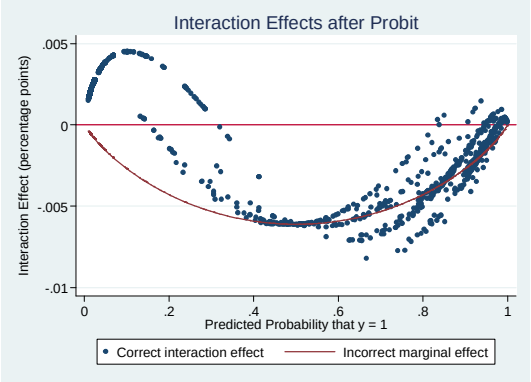
(g1) Romania



(g2) Romania



(h1) Slovakia



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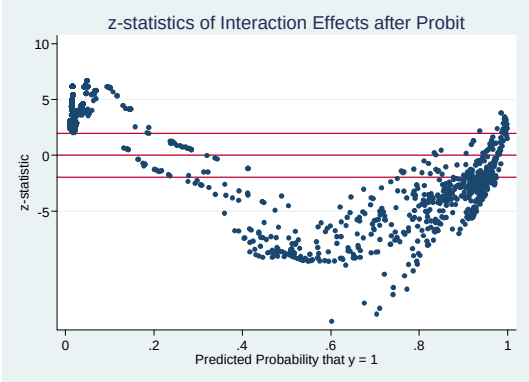

Note: Absorption (interaction) effect is estimated by STATA command *inteff* (Norton et al., 2004).