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Does training explain innovation in transition economies?

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ABSTRACT

This study investigates the impact of training programs on innovation for firms in transition economies. We exploit data from the World Bank Enterprise Surveys across 27 countries in Eastern Europe and Central Asia. Results, emerging from several specifications of bivariate probit models, show that: (i) communication training significantly enhances product and process innovation and (ii) on-the-job training proves to be more effective than in-class training to foster innovation. The key role of on-the-job training is even more pronounced focusing on manufacturing sector and at geographical level. These results may favour the attention of policymakers and firms in transition countries to invest in specific training programs to catch-up the innovation standards of developed economies.

1. Introduction

In this paper we investigate the effect of training programs on innovative pursuits of firms within transition countries in Eastern Europe and Central Asia. Existing research on this topic has highlighted a positive impact of training on innovation and previous studies on transition and developing economies, albeit partly inconclusive, point to the same direction (van Uden et al., 2017; Capozza and Divella, 2019; Nazarov and Akhmedjonov 2012). Our contribution to this literature is primarily constituted by providing an examination of the role that various training programs play in fostering innovation within transition economies. In particular, we delve into the heterogeneity of training programs by employing a classification of training informed by Cozzarin and Percival (2023) and Dostie (2018). First, we investigate whether a difference may be envisioned between *on-the-job* and *in-class* training. Secondly, we further investigate whether specific types of training (mathematical, managerial or communication) do exhibit a different impact on innovation.

We use a firm-level dataset sourced from the World Bank Enterprise Surveys, conducted during the period between 2018 and 2020 and we employ a bivariate probit model. Results highlight that training is positively associated with innovation and this result appears to be confirmed for both process and product innovation. To provide additional support to our analysis, we re-run the baseline model focusing first on manufacturing sector and then investigating potential heterogeneity at the geographical level. The resulting evidence leads to the fact that training seems to be a substantial determinant of innovation for firms in transition economies.

The remainder of the article is structured as follows: the next section presents the theoretical background and literature related to training programs and innovation; Section 3 describes the data, and the methodology used in the empirical study, whose basic results are reported and discussed in Section 4. Section 5 presents robustness checks and finally, the last section concludes and outlines the main contributions of the paper.

2. Conceptual background and literature survey

Innovation in developing and transition countries is receiving increasing academic attention due to efforts aimed at understanding how these countries can leverage their potential for economic growth and development through innovation (Vivarelli, 2014). These countries often face challenges where firms operate below their full capacity. However, strategies such as technology acquisition and imitation are identified as critical pathways for closing technological gaps (Goedhuys et al., 2008; van Uden et al., 2017). A crucial aspect of fostering innovation lies in effective training activities, which are widely acknowledged for enhancing firms' innovative capacity and driving higher levels of innovation (Hegde and Shapira, 2007; Hatch and Dyer, 2004). The success of these training programs in promoting innovation, however,

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depends significantly on their ability to impart practical knowledge applicable to processes like product development and continuous improvement (Ichinowski et al., 1997; Chen and Huang, 2009). This highlights the necessity for tailored training approaches that meet specific innovation needs within these economic contexts. While research in developed countries shows a positive association between training and innovation (Cozzarin and Percival, 2023; Caloghirou et al., 2018; Protogerou et al., 2017), evidence from developing and transition economies is mixed and inconclusive (van Uden et al., 2017; Capozza and Divella, 2019; Nazarov and Akhmedjonov 2012). In fact, transition countries typically have lower R&D investment levels compared to developed economies. In this study we examine the impact of training on innovation in transition countries, where one of the main constraints to innovate is the availability of a high-quality workforce with appropriate knowledge and skills that meet the level of human capital required to innovate (George et al., 2016). Therefore, training programs might become more decisive than in industrialized countries. Existing firm-level research has predominantly concentrated on the association between general training and innovation, as evident in studies by Dearden et al. (2006) and Bartel (2000), often neglecting detailed examinations of specific training content. Quite the contrary, the empirical literature on the relationship between in-firm specific training and innovation is relatively scarce, particularly in relation to the impact of different training programs on innovation in transition economies.

Thus, the following survey of literature aims to explore these relationships across developed and transition and emerging economies, providing insights into effective strategies for fostering innovation through targeted training initiatives.

2.1. Training activities and innovation in developed countries

The earlier empirical study on the effect of training on innovation focused on developed countries is Laplagne and Bensted (1999). The authors examine the influence of formal training on the innovation and workplace performance of Australian firms. The results highlight a positive association between training initiatives and innovation in workplaces characterized by robust labor productivity growth. Laursen and Foss (2003) examine the link between human resource management (HRM) systems and innovation performance in Danish manufacturing firms and demonstrate that HRM system dominated by firms providing both internal and external training to their workforce innovates more than those offering only internal training. Exploiting information on firms operating in Northern Britain, Freel (2005) examine the relationship between firm-level innovativeness and a set of indicators of skills, such as the training activity. The analysis reveals that: (i) the service sector is more training-intensive than the manufacturing sector and (ii) manufacturing firms with a higher training intensity are more prone to undertake both product and process incremental innovation. Employing data on Spanish manufacturing firms in low and medium technology industries, Santamaria et al. (2009) observe how firms' innovation may depend on both non-formal R&D strategies and the use of external sources. Their findings show that training activities have a strong impact on product and process innovations. Bauernschuster et al. (2009) explore whether training is crucial for achieving successful innovation and operating on the technological frontier show a strong relationship between continuous training and innovation in German firms. Yet, Zhou et al. (2011) investigate the impact of the flexible labour on product innovation in firms in Netherlands finding a positive association between training and innovation. This association is also evident in the Gallié and Legros (2012), wherein they explore the impact of human capital and technological capital on innovation within French manufacturing firms. González et al. (2016) observe the effect of training programs on radical and incremental innovation in Spanish manufacturing firms. In small firms training enhances incremental innovation, whereas in large ones on-the-job training positively impacts radical innovation. In the same vein, Cordón-Pozo et al. (2017), exploiting information on Spanish firms, pointing out the key role played by the specific innovation training in the development of product innovations. Focusing on a set of European countries, Protogerou et al. (2017) investigate the impact of intangible sources on innovation performance showing that training activities positively impact on two technological innovations in young firms. Børing (2017) examines the nexus between innovation activities and training in Norwegian firms finding a significant effect of training on innovation changes and this effect is even stronger when combined with education. Caloghirou et al. (2018) observing Greek manufacturing firms during times of economic crisis (2011 and 2013) confirm a positive and significant association between training and product innovation also during this turbulent time. When distinguishing between different forms of training, Cozzarin and Percival (2023) investigate the impact of a set classroom training programs on technological innovation of Canadian firms. Results show a positive relationship between training activities and product and process innovation when they are jointly adopted, while when the two innovations are considered in isolation, the training has a strong effect only on product innovation. Finally, a positive effect is also documented by Dostie (2018) grouping the four categories of training into two broader ones: classroom and on-the-job training.

2.2. Training and innovation in transition economies

On this subject, there is a noticeable dearth of research within transition economies. These countries have been developing faster and some of them have been converging to the EU-15 standards in terms of GDP per capita and technological change (Cieślik and Wciślik, 2020; Radosevic, 1999; Petrović and Matić, 2023). In these countries, due to their lower levels of R&D investment compared to developed economies, firms rely on-the-job training programs to enhance workforce skills and foster innovation (Lenihan et al., 2019; Vona and Consoli, 2015; Romijn and Albaladejo, 2002; Friz and Gunther, 2021).

Among the policies put in place to boost firm's economic and innovation performance, Czech Republic has implemented ad-hoc training activities to deal with information and communication technologies (Lloyd-Reason et al., 2002). On the same vein, a survey conducted in multinational firms in Kazakhstan reveals that trained employees positively affect overall firm performance indicators. However, these studies do not clearly identify the type of training performed. On the contrary, Nazarov and Akhmedjonov (2012) explore the impact of education and on-the-job training on firms' performance in Central and Eastern Europe in terms of product innovation during the period 2002–2005. Results indicate that university education does not improve the ability of firms to introduce new products, while training plays a key role in fostering innovation. Notably, the findings also indicate that, in transition economies, innovation is more dependent on assimilating new technologies rather than creating novel ones. Van Uden, Knoben, and Vermeulen (2017) investigate the influence of diverse combinations of human capital—schooling, formal training, and employee slack time—on innovation across a group of firms from various Sub-Saharan countries. The authors highlight that both formal training and the allocation of slack time for generating new ideas are pivotal factors for fostering innovation. Additionally, Capozza and Divella (2019) demonstrate that on-the-job training plays a crucial role in driving business innovation within a collection of transition economies. Despite recent evidence highlighting the impact of various training programs on innovation in developed economies, there remains a considerable gap in understanding these dynamics within transition countries even if plausibly training might be expected to be a driver of innovation in transition economics too.

In what follows, we contribute to fill this gap by investigating how different types of training programs, following the two classifications proposed by Cozzarin and Percival (2023) and Dostie (2018), affect the innovation propensity of firms in transition countries. In fact, we delve into the heterogeneity of training activities by investigating whether a difference may be envisioned between *On-the-job* training is to be preferred to in-class training. Put differently, the underlying question is whether the first contributes to deliver a superior outcome in terms of innovation compared to the latter. Lastly, we also investigate whether specific types of training (mathematical, managerial or communication) do exhibit a different impact on innovation.

3. Data and empirical methodology

To test the relation between training activities and innovation, we rely on firm-level cross-sectional data drawn from the World Bank Enterprise Surveys (hereinafter WBES[1]) wave 2018–2020. The survey collects information on private firms operating in non-agricultural sectors. Respondent firms derive from a stratified random sample technique, considering region, sector, and firm dimension. This reduces the selection bias and provides a representative population structure of firms in each country. The survey collects information on innovation behaviour of firms, innovative activities, organization practices, management, employees, and environmental corporate issues. We rely on a sample of about 16,712 firms distributed in transition countries among three main macro-sectors following the ISIC Revision 3.1 classification, namely: (i) manufacturing, (ii) services, and (iii) other service activities (such as transport, storage, communication, and IT).

3.1. Main variables

To capture a firm's inclination toward innovation, we examine both product and process innovations. We differentiate between firms that have introduced product or process innovations within the last three years. We create two distinct dummy variables, assigned a value of 1 if the firms engage in product or process innovation, 0 otherwise.

In the WBES survey, firms are asked about their overall training programs. Thus, we build a dummy variable taking value 1 if the company has some training activities, 0 otherwise.

Following the approach by Cozzarin and Percival (2023), we construct four distinct dummy variables for those firm performing training activities, defined as follows: (i) training related to mathematics, encompassing numeracy or mathematical skills, and problem-solving or critical thinking skills (*mathematical traning*); (ii) training associated with communication, involving interpersonal and communication skills (*communication training*); (iii) managerial-oriented training, inclusive of managerial and leadership skills, along with job-specific technical skills (*managerial training*); and (iv) miscellaneous and unspecified training activities (*other training*).[2]

The second set of training-related indicators follows the classification proposed by Dostie (2018). We adapt the definition by Dostie to the classification proposed using the WBES data. In particular, Dostie states "The survey defines classroom training in a detailed fashion and indicates that all training activities should have 1) a pre-determined format, including a pre-defined objective; 2) specific content; and 3) progress that may be monitored and/or evaluated. On-the- job training, however, is defined only as being informal." (Dostie, 2018, p.67). Thus, we believe that mathematical training (based on "Numeracy or math skills" and "Problem solving or critical thinking skills") is more objective training type and easier to evaluate and monitored. While, "Managerial and leadership skills", "Job-specific technical skills" and "Interpersonal and communication skills" are more informal activities to be learned "on the field". Thus, we build two separate dummy variables. The first one is *in-class* training, which coincides with the definition of mathematical training as in Cozzarin and Percival (2023) and closely aligns with the characterization provided by Dostie (2018). The second dummy is related to more practical training activities, namely *on-the-job* training, that is based on managerial and leadership skills, interpersonal and communication skills, and job-specific technical skills.

The number and percentages of firms that perform each of training activity is described in Table 1. Unfortunately, the highest percentage of respondents indicates that *other training type* is more performed by the companies in our sample, while "job-specific technical skills" and "interpersonal and communication skills" are those preferred among the specific activities.

Looking at the sectoral and geographical composition of the firms in our sample, Table 2 shows the innovation outcomes of the entire sample and in the three different sectors. As shown in Column 1, the majority of firms in our sample do not engage innovation; however product innovation is preferred over process innovation, about 20 % of the companies declare introducing product innovations in the last three years, with respect to the 7 % of firms adopting process innovations. In term of sectoral distribution, manufacturing firms exhibit the highest percentages in terms of product innovation (21 %) and combined product and process innovations (15.5 %). These results are probably influenced by the fact that manufacturing firms account for almost half of the firms in our sample, thus is more likely that they innovate more than the other two sectors. Notably, when combining the number of firms involved in product innovation across both service sectors, the total of 1197 observations is significantly lower than that of the overall manufacturing.

Then, we analyse the sectoral division of training programs, as reported in Fig. 1. This figure illustrates the percentages of firms investing in different training types, regardless of whether they are innovative firms. The higher amount of training consists in other non-specific activities, which do not fall under mathematical, communication, and managerial training, in the three sectors considered.

By focusing on specific training activities, Fig. 1 highlights that firms in the retail industry are more prone to invest in specific training programs. Managerial training is the preferred activity with almost 22 % of the firms, followed by 10 % in communication and 9 % in mathematical. Conversely, manufacturing firms tend to benefit more from other non-specific training activities to achieve their goals.

These results drive us to better investigate the relation among training programs and innovation. Combining the descriptive statistics reported in Table 2 and Fig. 1, we provide Table 3 which reports the division of training programs for companies that perform innovation (product, process, or both) according to their sector.

According to Table 3 manufacturing firms that innovate benefit more from other non-specific training programs. On the contrary, the retail industry shows proportionally higher percentages for communication related training with respect to the other sectors, as it was highlighted in

Table 1
Training definitions.

Cozzarin and Percival (2023)	Dostie (2018)	WBES definition	#	%
Mathematical	In-class	Numeracy or math skills	115	2.22
		Problem solving or critical thinking skills	258	4.97
Managerial	On-the-job	Managerial and leadership skills	170	3.28
		Job-specific technical skills	545	10.5
Communication		Interpersonal and communication skills	409	7.88
Other	Other	Other training type	3692	71.15

Note: Authors' elaboration based on WBES data.

[1] WBES is part of a joint initiative of the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB) and the World Bank Group (WBG). The surveys were performed in a two-step procedure. In the first step, a telephone questionnaire was conducted to assess eligibility and schedule appointments, while in the second, a face-to-face interview was carried out with the Manager/Owner of each firm.

[2] All the four dummies are mutually exclusive as far as in the questionnaire, responding firms declare they invest in training activities one at a time.

Table 2
Amount and percentages of innovations in the overall sample and in the three different sectors.

	Total (1)		Manufacturing (2)		Retail (3)		Other services (4)	
	#	%	#	%	#	%	#	%
No Innovation	8566	61.1	4294	56.92	1654	66.99	2618	65.34
Product Innovation	2771	19.76	1574	20.86	453	18.35	744	18.57
Process Innovation	944	6.73	507	6.72	149	6.03	288	7.19
Product & Process Innovation	1739	12.4	1169	15.5	213	8.63	357	8.91
Total number of firms	14,020	100	7544	100	2469	100	4007	100
	Total		Manufacturing		Retail		Other services	
	#	%	#	%	#	%	#	%
No Innovation	8566	61.1	4294	56.92	1654	66.99	2618	65.34
Product Innovation	2771	19.76	1574	20.86	453	18.35	744	18.57
Process Innovation	944	6.73	507	6.72	149	6.03	288	7.19
Product & Process Innovation	1739	12.4	1169	15.5	213	8.63	357	8.91
Total number of firms	14,020	100	7544	100	2469	100	4007	100

Note: Authors' elaboration based on WBES data. Percentages in columns (2),(3) and (4) are computed on the total of the firms in each sectors.

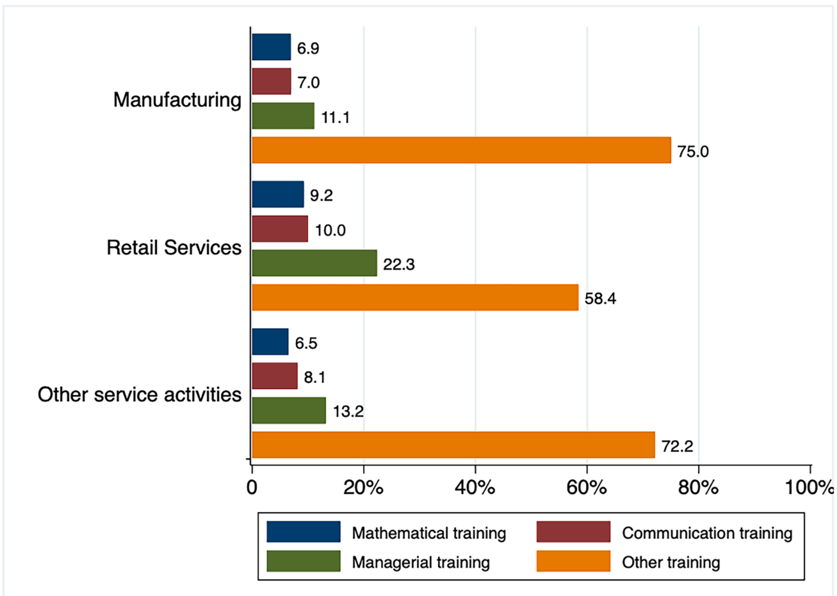

Fig. 1. Percentage of firms investing in different training by sector.
Note: Authors' elaboration based on WBES data. The percentages are computed as the ratio of number of firms investing in each type of training on the total number of firms investing in training in each sector.

Fig. 2. In this case, the absolute number of firms in the service industry (retail and other services) is higher than the manufacturing, regardless of whether they are involved in product, process, or both types of innovations

This evidence requests for an *ad hoc* empirical analysis at sector level when studying the relation among innovation and training, to be sure that there will be no specific industrial mechanisms that might influence our results (Vaona and Pianta, 2008).

Additionally, another important aspect to consider is the geographical distribution of firms investing in various training types. Fig. 2 shows the percentages of training activities at country level. From this figure, it is possible to note that firms investing in managerial training are mainly settled in Armenia, Czech Republic, and Belarus.

Finally, Fig. 3 details the percentages of firms engaged in innovations by country. Ukraine, Kazakhstan, and Uzbekistan occupy the top three positions in terms of innovation rates. If we compare Fig. 3 with Fig. 2, it is possible to note that innovation and training are somehow correlated. This is the case, for example, of Ukraine, where the distribution of training activities is evenly spread across mathematical, managerial, and communication training types and at the same time is the country with the highest rates of innovating firms. This balanced approach to training is also evident in Kazakhstan, Armenia, Czech Republic, and Belarus, which exhibit high training rates in Fig. 2, and report significant innovation rates, as shown in Fig. 3.

Thus, Figs. 2 and 3 suggest a tight correlation among training programs and innovation rates in these countries, that will be empirically tested in the next section.

3.2. Control variables

In our analysis, we incorporate additional characteristics of firms. Particularly relevant in the context of training activities are indicators of human capital, represented by the proportion of full-time employees with a university degree and the cumulative years of experience that top managers have within the specific sector. To account for potential gender-related distinctions, we introduce a dummy variable assigned a value of 1 if the firm is led by a female and 0 otherwise. To assess the organizational composition of the firm, we examine the percentage of firms owned by one or more individuals, providing insights into the ownership structure of the company. To proxy for the past R&D capacity of the firm, we include in the model research and development activities performed in the latest three years, as a dummy variable taking value 1 if

Table 3
Firms' distribution according to training activities, innovation, and sector.

	Product Innovation (1)		Process Innovation (2)		Product and Process Innovation (3)	
Manufacturing						
	#	%	#	%	#	%
No training	1047	66.52	298	58.78	536	45.85
Mathematical	35	2.22	13	2.56	40	3.42
Managerial	40	2.54	15	2.96	65	5.56
Communication	60	3.81	22	4	77	6.59
Other	392	24.9	159	31.36	451	38.58
Total number of firms	1574	100	507	100	1169	100
Retail						
No training	243	53.64	71	47.65	91	42.72
Mathematical	12	2.65	6	4.03	15	7.04
Managerial	19	4.19	5	3.36	17	7.98
Communication	43	9.49	22	14.77	31	14.55
Other	136	30.02	45	30.2	59	27.7
Total number of firms	453	100	149	100	213	100
Other services						
No training	417	56.05	138	47.92	136	38.1
Mathematical	16	2.15	6	2.08	13	3.64
Managerial	22	2.96	10	3.47	22	6.16
Communication	48	6.45	25	8.68	36	10.08
Other	241	32.39	109	37.85	150	42.02
Total number of firms	744	100	288	100	357	100

Note: Authors' elaboration based on WBES data.

the firms have invested in R&D, 0 otherwise. Since external sources of knowledge also contribute to the innovative performance of the firm, we introduce a dummy variable equal to 1 if a firm, over the last three years, has invested financial resources in external knowledge, namely the purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other businesses or institutions, or to 0. In addition, we consider access to credit. We also incorporate variables reflecting the internationalization extent, denoted by the percentage of exported products, and the competitive environment, represented by a categorical variable with values ranging from 1 to 4. The categorical variable defines the number of competitors as follows: 1 for no direct competitors, 2 for 1 to 5 competitors, 3 for 6 to 20 competitors, and 4 for >20 competitors. We also examine structural attributes of the firms, encompassing size (following the EUROSTAT definition of small, medium and large enterprises based on the number of employees), age (computed as the difference between the survey year and the year the firm commenced operations), and whether the firm functions as an independent economic entity (assigned a value of 1) or is part of a group of firms (assigned a value of 0). Finally, the model incorporates sector and country fixed effects. Descriptive statistics are reported in Table 4, while the correlation matrix is presented in Table A1 in the Appendix.

Unfortunately, some observations present missing values and outliers for the variables included in the model. Thus, after some standard cleaning procedure, we end up with our final sample composed by 14,020 firms.

3.3. Methodology

To deal with the probability that a firm might exploit both product and process innovation at the same time, we apply a bivariate probit model (Maddala, 1983). This approach is a natural extension of the univariate probit model, as it involves a system of simultaneous equations that considers two binary outcomes (Greene, 1996). In our case it allows to consider product and process innovation simultaneously. Bivariate probit models allow for two equations having correlated

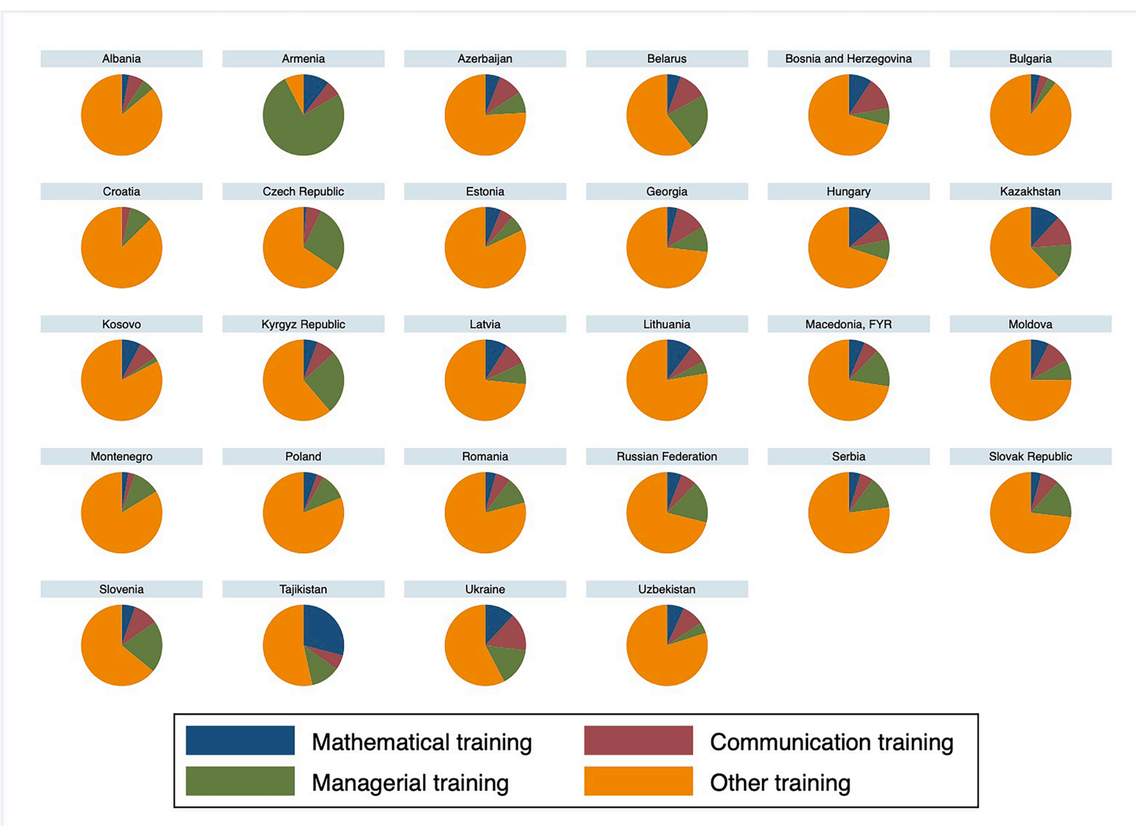

Fig. 2. Percentage of firms investing in different training by Country.
Note: Authors' elaboration based on WBES data. The percentages are computed as the ratio of number of firms investing in each type of training on the total number of firms investing in training in each Country.

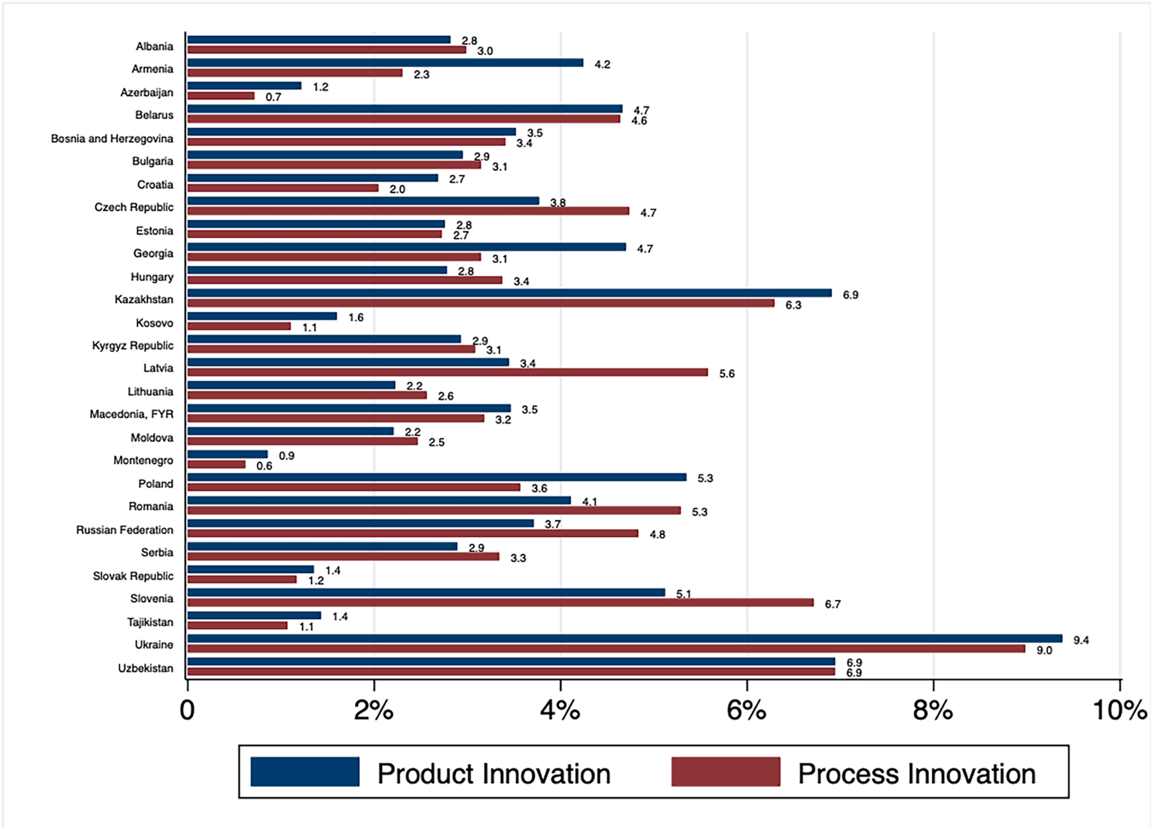

Fig. 3. Percentage of product or process innovation per Country.
Note: Authors' elaboration based on WBES data. Percentages are computed as the number of innovations (product or process) in a Country with respect to the total number of product or process innovations for the overall sample.

disturbances. These disturbances arise from the correlation between the two error terms, that may be due to the following reasons: (i) product and process innovation are two decision variables undertaken by the same firm to implement an innovation strategy and (ii) the errors of the two equations may depend on the potential model misspecification (Beneito et al., 2015). The equation behind the bivariate probit model defines $Y_1^*$and Y_2^* as the two latent variables representing the underlying propensity for the two binary outcomes $Y_1$and Y_2. These latent variables are defined as:

$$Y_1^* = X_1\beta_1 + e_1 \tag{1}$$

$$Y = X_2\beta_2 + e_2 \tag{2}$$

Where $X_1$and $X_2$are vectors of independent variables and $\beta_1$and $\beta_2$are vectors of coefficient. The observed binary outcomes $Y_1$and $Y_2$are related to the latent variables as follows:

$$Y_1 = \begin{cases} 1 \ if \ Y_1^* > 0 \\ 0 \ if \ Y_1^* \leq 0 \end{cases} \tag{3}$$

$$Y_2 = \begin{cases} 1 \ if \ Y_2^* > 0 \\ 0 \ if \ Y_2^* \leq 0 \end{cases} \tag{4}$$

The joint probability of observing a particular pair of outcomes (Y_1, Y_2) is given by: $P(Y_1 = y_1, Y_2 = y_2 \,|X_1, X_2)$. Depending on the values of y_1 and y_2, this probability is computed using the cumulative distribution function (CDF) of the bivariate normal distribution. Thus, in our case, if a company performs both product and process innovation simultaneously ($y_1 = 1$ and $y_2 = 1$), the joint probability will be: $P(Y_1 = y_1, Y_2 = y_2 \,|X_1, X_2) = \phi_2(X_1\beta_1,\ X_2\beta_2;\ \rho)$, where $\phi_2$is the CDF of the bivariate normal distribution and ρ, which represents the correlation between the error terms and the interdependence of the two binary outcome variables, is obtained through maximum likelihood estimation.

4. Results

4.1. Product and process innovation

Table 5 reports the marginal effects of the bivariate probit models both for the four training types and the in-class vs. on-the-job types. We compute the marginal effects as these more informative than leaving the results expressed as odds ratios or relative risks (Greene, 1996; Christofides et al., 1997). The results in log-likelihoods with the control variables are reported from Tables A2–A6 in the Appendix where the first iteration log corresponds to running the univariate probit model for the first equation (that is by considering firms that present only product innovation), and the second log corresponds to running the univariate probit for the second model (process innovation only).

In Column [1] and [4] are reported the results for those firms that perform only product innovation. Columns [2] and [5] are related to firms that have only process innovation, while Columns [3] and [6] are related to firms that jointly undertake both product and process innovations. Only communication training matters for product innovation, in Column [1]; while, mathematical, communication and other training types are always positive and significant when we consider process innovation in Column [2]. These findings are confirmed for those firms performing both innovations jointly in Column [3]. We obtain quietly different outcomes when we look at in-class vs. on-the-job definition. For firms that introduce product innovation, there are no incentives to invest in-class training. On the contrary the on-the-job and other training activities have a positive association with this dependent variable (Column [4]).

Table 4
Summary statistics and description of variables.

Variable	Description	# Obs.	Mean	St. Dev.	Min	Max
Dependent variables:						
Product Innovation	1 if a firm, in the last three years, has introduced new or improved product; 0 otherwise	14,020	0.322	0.467	0	1
Process Innovation	1 if a firm, in the last three years, has introduced new or improved process; 0 otherwise	14,020	0.191	0.393	0	1
Focal regressors:						
Overall Training	If a company performs or not training activities.:	14,020	0.312	0.463	0	1
4 Types Training	Mathematical related training	14,020	0.0216	0.145	0	1
	Communication related training	14,020	0.024	0.153	0	1
	Managerial related training	14,020	0.043	0.203	0	1
	Other training activities	14,020	0.224	0.417	0	1
In-class vs. on-the-job	In-class;	14,020	0.021	0.145	0	1
	On-the-job	14,020	0.067	0.250	0	1
Control Variables:						
Multi-plant	1 if a firm is a part of a multi-establishment, 0 otherwise	14,020	0.093	0.290	0	1
Owner	Percentage held by largest owner or owners	14,020	82.82	24.77	1	100
Manager Experience	Year of experience working in the sector of top manager	14,020	18.44	10.47	1	62
Ext. Knowledge	External Knowledge: 1 if a firm, in the last three years, has spent on the acquisition of external knowledge (purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other businesses or organizations), 0 otherwise	14,020	0.142	0.349	0	1
Firm's Age (ln)	Difference between the current year and the year the firm registers to start the business activity in natural logarithm	14,020	17.76	13.43	1	205
Competitors	Number of direct competitors, following these categories: 1 if a firm has no direct competitors (4.74 %) [*No competitors*] 2 if a firm has :$\geq$ 1-and $\leq$ 5 competitors (28.54 %) [*Few competitors* 3 if a firm has$\geq$ 6 and $\leq$20 competitors (19.55 %) [*Avg. competitors*] 4 if a firm has >20 competitors (47.17 %) [*Many competitors*]	14,020	3.080	0.967	1	4
Female Ownership	1 if a firm has female owners, 0 if firm ownership is exclusively male	14,020	0.342	0.474	0	1
Employees	Number of employees 1 if small firm: <50 (45.97 %) 2 if medium firm: between 50 and 250 employees (32.24 %) 3 if large firm: >250 employees (21.79 %)	14,020	1.731	0.776	1	3
RD	1 if a firm invest on R&D activities in the last three years	14,020	0.231	0.421	0	1
Export	Percentage of exported products	14,020	13.82	28.05	0	100
Credit line	1 if a firm, in the fiscal year, has a line of credit or a loan from a financial institution, 0 otherwise	14,020	0.394	0.489	0	1
Education	Percentage of permanent full-time employees with a university degree	14,020	27.011	26.554	0	100

Table 5
Regression results for different training programs on innovation.

	4 training types			In-class vs. on-the-job		
	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes
	(1)	(2)	(3)	(4)	(5)	(6)
Ref. cat.: No training						
Mathematical training	0.010	0.022**	0.049***			
	[0.018]	[0.009]	[0.012]			
Communication. Training	0.045**	0.024**	0.081***			
	[0.018]	[0.089]	[0.011]			
Managerial training	0.015	0.031***	0.069***			
	[0.014]	[0.007]	[0.009]			
In-class				0.010	0.022**	0.049***
				[0.018]	[0.009]	[0.012]
On-the-job				0.026**	0.028***	0.073***
				[0.011]	[0.006]	[0.007]
Other training	0.034***	0.017***	0.059***	0.034***	0.017***	0.059***
	[0.007]	[0.004]	[0.005]	[0.007]	[0.004]	[0.005]
Control Variables	YES			YES		
Industry FE	YES			YES		
Country FE	YES			YES		
Observations	14,020			14,020		
Wald chi2	3696.08			3692.97		
Prob > chi2	(0.000)			(0.000)		
ρ	0.392			0.392		

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Process innovation and the joint innovation benefit from training, no matter if these activities are performed in a more or informal way (Columns [5] and [6]). In line with the descriptive statistics, communication training seems to have a greater effect on the innovation output, with an increase of 8 % of both product and process innovation jointly. This outcome can be attributed to the necessity for firms to enhance interpersonal and communication skills, possibly driven by a desire to enhance competitiveness in global markets or sustain their existing market niche.

Looking at results of the two univariate probit model in Tables A2 and A3 in the Appendix, the overall training variable is positive and significant both for product and process innovation, confirming our first hypothesis both for the four categories of training and for the in-class vs. on-the-job definition. When we consider mathematical training, taken separately from the other training activities (Column [3], Table A2), this is positive and significant only in relation with product innovations, while it turns significant also for product innovations when all the trainings are considered together (Column [7]). The other training activities reflect the same findings of Table 4, both when they are taken separately and all together.

For what concerns the control variables, firm's age seems to be not relevant for both products and process innovations, as well as the propensity of firm's internationalisation via export activities and the educational level of employees. On the contrary, research and development (R&D) expenditures strongly elevate the likelihood of introducing both types of innovation. Additionally, the acquisition of external knowledge from businesses and institutions positively enhances the probability of both product and process innovations. Thus, the higher the knowledge sharing with external actors, the higher the incentive to create and develop new product and production processes. Furthermore, our results indicate that the probability of being innovative increases for firms with access to financial support. Put differently, firms with a line of credit are more inclined to incorporate innovation compared to those without access to this financial resource. Concerning firm size, we detect a negative effect when we introduce the training types separately for those small firms that perform process innovation. However, the coefficient is any longer significant when all the training activities are included in the model together. However, for companies that are part of a larger group, the likelihood of engaging in innovative activities increases by approximately 11 % to 15 % in comparison to unaffiliated firms (Castellacci, 2015; Chang et al., 2006). Looking at the owner variable that shows identity between ownership and control (Dostie, 2018), it is slightly significant but negative related to the decision to implement process innovation activities compared to firms in which the degree of ownership concentration is not in the hands of one or more owners. On the contrary, female ownership positively impacts product innovation, indicating that gender diversity in leadership fosters a more innovative environment (Nazarov and Akhmedjonov 2012; George et al., 2016). Market competition of firms can negatively impact the innovation level, especially when product innovation is considered (Mulkay, 2019). This result seems to validate the traditional approach better known as the Schumpeterian effect according to which a high level of competition in the market could reduce the monopoly profits and rents for potentially innovative firms, thereby reducing their incentives to engage in R&D (Nickell, 1996; Geroski, 1990; Scherer, 1967).

Table A3 reports the log-likelihoods for the in-class vs. on-the-job definitions of training.

Results show that on-the-job training is preferrable both for product and process innovation, both alone and with the in-class activities as reported in Columns [5] and [6]. This result is consistent with previous literature pointing to the fact that employees receive informal training rather than formal one, because the former is less expensive than the latter (Dostie, 2018). When looking at the control variables, they present the same signs and significance as in Table A2.

The bottom part of both Tables A2 and A3 report the Wald test rather than a likelihood-ratio test of the log likelihood as our errors are treated as robust. The Wald test is significant, revealing that the two outcomes are related, and some unobserved factors are positively related to both dependent variables. Thus, the bivariate model is preferrable with respect to separate univariate probit models.

Thus, both from Tables 5 and A2 and A3, we can confirm the first hypothesis: training is positively associated with the innovation propensity of the firm hypothesis 2 is partially confirmed, as we find positive association with respect to the three training activities both when product and process innovations are jointly performed and only for process ones, while we find no evidence in the case of product innovations. Finally, our results support our third hypothesis, as we find evidence in all the three cases that more informal, i.e. on-the-job, training in relation with innovation propensity is preferrable for firms in our sample.

4.2. Sector heterogeneity

In line with previous literature analysing the role of innovation and training in manufacturing sector for firms in transition countries (Ramadani et al., 2019; Crowley and McCann, 2018; Szirmai and Verspagen, 2015), and as highlighted by the trends for innovation and training activities in Table 2 and Fig. 1, it is worth to further investigate on sectoral mechanism that might occur among the firms in our sample.

We focus on the manufacturing sector, which presents the highest number of innovations both for what concerns product and process, and almost double the amount of innovations of the retail and other services industries taken together. Results of the bivariate probit model are reported in Table 6 as marginal effects, while the outcomes of the separate univariate probit models are reported in Tables A4 and A5 in the Appendix.

As in Table 5, all the training types are positively correlated with product and process innovation jointly performed (Column [3]). On the contrary, mathematical training and managerial training do not influence the innovation propensity of firms nor for product and for process (Columns [1] and [2]).

When we look at the in-class vs. on-the-job classification, we find that formal training, i.e. in-class, has no significance with respect to the two dependent variables in Column [4] and [5], while it turns out significant in Column [6] for firms performing both product and process innovations.

The effect of mathematical and managerial training on both product and process innovation taken separately are consistent also by looking at the univariate probit models reported in Table A4 in the Appendix. However, in Columns [11] and [12], where the training activities are considered all together, they all turn positive and significantly correlated with the two dependent variables.

Moving to Table A5, for in-class vs. in-the-job training, all these activities are positive and significant, a part for in-class training related to product innovation in Column [1]. The signs and significance of controls variables in both Tables A4 and A5 reflect the findings of previous tables. However, we find three main differences: the multi-implant variable has a small impact in the case of manufacturing sector, which reveal that for firms in this industry it is not so relevant being a part of a group; having a female owner is much more important probably because a different leadership perspective can improve innovation levels; too much educated employees are detrimental to develop new product or process due to the potential lack of practical experience leading to inefficiencies and misalignment with business needs (Bogliacino et al., 2012; Hernadez and Roberts, 2021). However, the coefficient is quite small, thus the effect on the dependent variables is limited.

4.3. Geographical heterogeneity

As an additional analysis, we perform a further estimation to identify the effect of training on the technological capacity at the geographical

Table 6
Regression results for the training programs in the manufacturing sector.

	4 training types			In-class vs. on-the-job		
	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes
	(1)	(2)	(3)	(4)	(5)	(6)
Ref. cat.: No training						
Mathematical training	0.014	0.017	0.057***			
	[0.027]	[0.013]	[0.019]			
Communication. Training	0.058**	0.024*	0.122***			
	[0.028]	[0.013]	[0.017]			
Managerial training	0.021	0.015	0.061***			
	[0.023]	[0.011]	[0.016]			
In-class				0.014	0.016	0.046***
				[0.027]	[0.013]	[0.019]
On-the-job				0.035*	0.019**	0.086***
				[0.018]	[0.009]	[0.012]
Other training	0.029***	0.018***	0.076***	0.029***	0.018***	0.076***
	[0.100]	[0.005]	[0.007]	[0.100]	[0.005]	[0.007]
Control Variables	YES			YES		
Industry FE	YES			YES		
Country FE	YES			YES		
Observations	7544			7544		
Wald chi2	2196.77			2188.90		
Prob > chi2	(0.000)			(0.000)		
ρ	0.432			0.433		

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

level (Bogliacino et al., 2012). In more detail, we split our sample in four macro-regions to understand where the impact of training on innovative activity is most pronounced. We identify four groups of transition countries: (i) region1 - European Former-USSR Countries, such as Belarus, Estonia Georgia, Latvia, Lithuania, Moldova, Russia, Ukraine; (ii) region2 -Central European Countries which comprehend Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic; (iii) region3 - Former Yugoslavian Countries and Albania, that include Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro, North Macedonia, Serbia and Slovenia; and (iv) region4 - Eurasian Former-USSR Countries, with Armenia, Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan, and Uzbekistan. Tables 7 show the marginal effects of training for product and process innovation for the four categories of training, while in Table 8 are presented the marginal effects for in-class vs. on-the-job classification. Tables A6 and A7 in the Appendix reports the results expressed in log-likelihoods.

Table 7 highlights strong geographical heterogeneity: European Former-USSR countries exhibit better training outcomes for both product and process innovation across all four types of training activities. They also show significant results for communication-related and other training activities when product or process innovations are taken separately. For Central European Countries, ccommunication and managerial training are more important for process innovations, or for combined product and process innovations. Similarly for Former Yugoslavian Countries and Albania, with the only difference that communication training is more important for product innovation rather than for process innovation only. In contrast, Eurasian Former-USSR Countries do not reveal specific relation between training an innovation. This result is probably attributed to the requirement for these countries to align their workforce and innovations with European standards before joining the European Community (Hernandez and Roberts, 2021).

Table 8 presents similar findings for in-class vs. on-the-job activities for region 1 and 2, confirming the relevance of these training types in boosting innovation. Unfortunately, for regions 3 and 4 we find no evidence supporting nor in-class neither on-the-job training, except for on-the-job when firms' innovation includes both product and process. Thus, in Former Yugoslavian Countries and Albania and Eurasian Former-USSR Countries other not specified training activities are positively related to process innovation and product innovation respectively, and to both as indicated in Column [9] and [12].

5. Conclusion

This study has investigated the effect of different training programs on innovative activities in transition economies, by exploiting firm-level data drawn from the World Bank Enterprise Surveys. We consider product, process innovation and both. To do this, we have employed several bivariate probit model considering different classifications of training activities. Our results seem to suggest that training is a necessary condition for innovation in transition economies. More in details results highlight that: (i) training is positively associated with innovation for both process and product innovation. This is evident across the different training types; (ii) a positive association for the three training activities when both product and process innovations are jointly performed, as well as for process innovations alone. However, no evidence is found for product innovations; (iii) on-the-job training activities have a stronger positive association with both product and process innovation compared to in-class training.

Further estimations have shown that: (iv) in the manufacturing sector, all training types are positively correlated with joint product and process innovation with on-the-job training having a stronger positive association than in-class training; (v) European former-USSR countries show the highest training outcomes, whereas Central European Countries benefit from communication and managerial training. On-the-job training is most effective in these two regions, with Eurasian Former-USSR Countries showing no specific relation between training and innovation.

Unfortunately, our study is constrained by the use of cross-sectional data, which inherently implies a static relationship between training programs and a firm's innovation activities. This limitation underscores the necessity for additional research grounded in panel data, which could validate the findings obtained. Despite this limitation, our study might offer insights for policymakers and entrepreneurs, for policies related to incentives targeting transition economies to avoid the middle-income trap and prevent these economies from future economic shocks (Vivarelli, 2016; Győrffy, 2022). Based on the results, firms ought to prioritize training practices, including continuous knowledge update initiatives for existing employees and providing coaching and assistance for newcomers. Through these proactive measures, firms can effectively

Table 7
Regional heterogeneity for the four training activities.

	Region 1			Region 2			Region 3			Region 4		
	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ref. cat.: No training												
Mathematical training	0.038	0.023	0.083***	−0.035	0.005	−0.012	−0.029	0.029	0.067	0.017	0.011	0.017
	[0.031]	[0.017]	[0.021]	[0.037]	[0.021]	[0.022]	[0.056]	[0.027]	[0.042]	[0.035]	[0.017]	[0.035]
Communication. training	0.058**	0.028*	0.112***	−0.018	0.054**	0.045**	0.130**	−0.024	0.133***	0.001	0.013	0.001
	[0.029]	[0.015]	[0.019]	[0.039]	[0.021]	[0.017]	[0.048]	[0.021]	[0.034]	[0.038]	[0.016]	[0.038]
Managerial training	0.025	0.023	0.071***	−0.029	0.050***	0.036***	−0.014	0.034*	0.111***	0.029	0.013	0.029
	[0.027]	[0.014]	[0.017]	[0.026]	[0.015]	[0.012]	[0.037]	[0.017]	[0.027]	[0.028]	[0.012]	[0.028]
Other training	0.023*	0.012*	0.046***	0.031**	0.029***	0.045***	0.008	0.017**	0.083***	0.064***	0.008	0.059***
	[0.013]	[0.007]	[0.009]	[0.012]	[0.007]	[0.006]	[0.017]	[0.008]	[0.013]	[0.016]	[0.007]	[0.009]
Control Variables		YES			YES			YES			YES	
Industry FE		YES			YES			YES			YES	
Country FE		YES			YES			YES			YES	
Observations		4465			3678			2303			3574	
Wald chi2		1357.98			765.97			647.11			684.02	
Prob > chi2		(0.000)			(0.000)			(0.000)			(0.000)	
ρ		0.401			0.336			0.402			0.463	

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Region1: European Former-USSR Countries, such as Belarus, Estonia Georgia, Latvia, Lithuania, Moldova, Russia, Ukraine; Region2: Central European Countries which comprehend Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic; Region3: Former Yugoslavian Countries and Albania, that include Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro, North Macedonia, Serbia and Slovenia; Region4: Eurasian Former-USSR Countries, with Armenia, Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan, and Uzbekistan.

Table 8
Regional heterogeneity for in-class vs. on-the-job activities.

	Region 1			Region 2			Region 3			Region 4		
	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes	Product Innovation	Process Innovation	Product Innovation=Yes Process Innovation=Yes
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ref. cat.: No training												
In-class	0.039	0.023	0.083***	−0.035	0.005	−0.012	−0.029	0.029	0.067	0.017	0.011	0.032
	[0.032]	[0.017]	[0.021]	[0.037]	[0.021]	[0.022]	[0.056]	[0.027]	[0.042]	[0.035]	[0.017]	[0.021]
On-the-job	0.038*	0.025**	0.089***	−0.025	0.051***	0.038***	0.038	0.012	0.118***	0.019	0.013	0.038***
	[0.021]	[0.011]	[0.013]	[0.022]	[0.013]	[0.010]	[0.031]	[0.014]	[0.022]	[0.023]	[0.010]	[0.013]
Other training	0.023*	0.012*	0.046***	0.031**	0.029***	0.045***	0.008	0.017**	0.083***	0.064***	0.008	0.059***
	[0.013]	[0.007]	[0.009]	[0.012]	[0.007]	[0.006]	[0.017]	[0.008]	[0.013]	[0.016]	[0.007]	[0.009]
Control Variables		YES			YES			YES			YES	
Industry FE		YES			YES			YES			YES	
Country FE		YES			YES			YES			YES	
Observations		4465			3678			2303			3574	
Wald chi2		1353.99			765.83			646.02			682.91	
Prob > chi2		(0.000)			(0.000)			(0.000)			(0.000)	
ρ		0.401			0.337			0.399			0.463	

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Region1: European Former-USSR Countries, such as Belarus, Estonia Georgia, Latvia, Lithuania, Moldova, Russia, Ukraine; Region2: Central European Countries which comprehend Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic; Region3: Former Yugoslavian Countries and Albania, that include Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro, North Macedonia, Serbia and Slovenia; Region4: Eurasian Former-USSR Countries, with Armenia, Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan, and Uzbekistan.

capitalize on the benefits derived from such activities to bolster their innovation capacity. Policymakers should explicitly support and enhance innovation activities by implementing initiatives to raise awareness among entrepreneurs and managers.

Authors' statement

The authors declare no conflict of interest.

CRediT authorship contribution statement

Chiara Burlina: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Antonella Biscione:** Writing – original draft, Methodology, Data curation, Conceptualization. **Raul Caruso:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Appendix

Table A2
Regression results in log-likelihoods for the four training programs on innovation.

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno	(7) prod_inno	(8) proc_inno	(9) prod_inno	(10) proc_inno	(11) prod_inno	(12) proc_inno
Ref. cat.: No training												
Overall training	0.307***	0.363***										
	[0.027]	[0.030]										
Mathematical related training			0.064	0.149*							0.197**	0.317***
			[0.078]	[0.085]							[0.078]	[0.085]
Communication related training					0.288***	0.302***					0.419***	0.472***
					[0.073]	[0.075]					[0.073]	[0.076]
Managerial related training							0.153***	0.291***			0.280***	0.445***
							[0.059]	[0.061]			[0.060]	[0.062]
Other training									0.260***	0.259***	0.311***	0.341***
									[0.029]	[0.031]	[0.030]	[0.032]
Firms' Age (ln)	−0.026	0.010	−0.031*	0.005	−0.031*	0.005	−0.031	0.005	−0.028	0.008	−0.026	0.010
	[0.019]	[0.021]	[0.019]	[0.021]	[0.019]	[0.021]	[0.019]	[0.021]	[0.019]	[0.021]	[0.019]	[0.021]
Female ownership	0.068***	0.026	0.072***	0.031	0.070***	0.029	0.071***	0.030	0.073***	0.032	0.068***	0.025
	[0.026]	[0.029]	[0.026]	[0.029]	[0.026]	[0.029]	[0.026]	[0.029]	[0.026]	[0.029]	[0.026]	[0.029]
Ext. Knowledge	0.441***	0.540***	0.500***	0.604***	0.494***	0.600***	0.497***	0.600***	0.468***	0.575***	0.440***	0.539***
	[0.036]	[0.037]	[0.035]	[0.036]	[0.035]	[0.036]	[0.035]	[0.036]	[0.035]	[0.036]	[0.036]	[0.037]
Education	0.001	−0.000	0.001**	0.000	0.001**	−0.000	0.001*	−0.000	0.001*	−0.000	0.001	−0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Export	−0.000	0.001***	−0.000	0.001***	−0.000	0.001***	−0.000	0.001***	−0.000	0.001***	−0.000	0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
R&D	0.601***	0.466***	0.647***	0.520***	0.642***	0.517***	0.642***	0.512***	0.627***	0.501***	0.601***	0.463***
	[0.030]	[0.032]	[0.030]	[0.032]	[0.030]	[0.032]	[0.030]	[0.032]	[0.030]	[0.032]	[0.030]	[0.032]
Multi-implant	0.112***	0.155***	0.130***	0.177***	0.127***	0.173***	0.127***	0.171***	0.123***	0.169***	0.111***	0.152***
	[0.042]	[0.044]	[0.041]	[0.043]	[0.042]	[0.044]	[0.041]	[0.044]	[0.041]	[0.043]	[0.042]	[0.044]
Owner	−0.000	−0.001**	−0.001	−0.001**	−0.001	−0.001**	−0.001	−0.001**	−0.000	−0.001**	−0.000	−0.001**
	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Manager Experience	0.003**	0.003*	0.003***	0.003**	0.004***	0.003**	0.004***	0.003**	0.003**	0.002*	0.003**	0.003**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Credit line	0.192***	0.270***	0.206***	0.287***	0.205***	0.286***	0.206***	0.287***	0.194***	0.275***	0.191***	0.271***
	[0.025]	[0.028]	[0.025]	[0.028]	[0.025]	[0.028]	[0.025]	[0.028]	[0.025]	[0.028]	[0.025]	[0.028]
Ref. cat.: No competitors												
Few competitors	0.075	0.061	0.075	0.060	0.073	0.058	0.074	0.057	0.079	0.065	0.075	0.059
	[0.058]	[0.067]	[0.058]	[0.067]	[0.058]	[0.067]	[0.058]	[0.067]	[0.058]	[0.067]	[0.058]	[0.067]
Avg. competitors	0.095	0.155**	0.099*	0.160**	0.098*	0.159**	0.097	0.157**	0.099*	0.160**	0.096	0.153**
	[0.060]	[0.069]	[0.060]	[0.069]	[0.060]	[0.069]	[0.060]	[0.069]	[0.060]	[0.069]	[0.060]	[0.069]
Many competitors	−0.134**	0.009	−0.142**	−0.001	−0.143**	−0.003	−0.144**	−0.003	−0.137**	0.004	−0.135**	0.008
	[0.057]	[0.066]	[0.057]	[0.066]	[0.057]	[0.066]	[0.057]	[0.066]	[0.057]	[0.066]	[0.057]	[0.066]
Ref. cat.: Large companies												
Small	0.057	−0.047	−0.003	−0.116***	0.003	−0.110***	0.001	−0.109***	0.028	−0.088**	0.058	−0.044
	[0.036]	[0.039]	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.039]	[0.036]	[0.039]
Medium	0.052	0.011	0.017	−0.028	0.021	−0.024	0.020	−0.025	0.036	−0.011	0.053	0.012
	[0.035]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.035]	[0.037]
Constant	−1.038***	−1.430***	−0.929***	−1.299***	−0.938***	−1.306***	−0.933***	−1.304***	−0.996***	−1.365***	−1.040***	−1.429***
	[0.096]	[0.109]	[0.095]	[0.108]	[0.095]	[0.108]	[0.095]	[0.108]	[0.095]	[0.109]	[0.096]	[0.109]
Observations	14,020	14,020	14,020	14,020	14,020	14,020	14,020	14,020	14,020	14,020	14,020	14,020
Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Wald chi2	3690	3690	3466	3466	3487	3487	3477	3477	3593	3593	3696	3696
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.392	0.404	0.404	0.403	0.403	0.404	0.404	0.398	0.398	0.392	0.392	0.392

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A3
Regression results in log-likelihoods for the in-class vs. on the-job training programs on innovation.

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno
Ref. cat.: No training						
In-class	0.064	0.149*			0.197**	0.317***
	[0.078]	[0.085]			[0.078]	[0.085]
On-the-job			0.215***	0.316***	0.330***	0.455***
			[0.047]	[0.049]	[0.048]	[0.050]
Other training					0.311***	0.341***
					[0.030]	[0.032]
Firm's Age (ln)	−0.031*	0.005	−0.030	0.006	−0.026	0.010
	[0.019]	[0.021]	[0.019]	[0.021]	[0.019]	[0.021]
Female ownership	0.072***	0.031	0.069***	0.028	0.068***	0.025
	[0.026]	[0.029]	[0.026]	[0.029]	[0.026]	[0.029]
Ext. Knowledge	0.500***	0.604***	0.490***	0.592***	0.441***	0.539***
	[0.035]	[0.036]	[0.035]	[0.036]	[0.036]	[0.037]
Education	0.001**	0.000	0.001*	−0.000	0.001	−0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Export	−0.000	0.001***	−0.000	0.001***	−0.000	0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
R&D	0.647***	0.520***	0.635***	0.505***	0.601***	0.463***
	[0.030]	[0.032]	[0.030]	[0.032]	[0.030]	[0.032]
Multi-implant	0.130***	0.177***	0.123***	0.167***	0.111***	0.152***
	[0.041]	[0.043]	[0.042]	[0.044]	[0.042]	[0.044]
Owner	−0.001	−0.001**	−0.001	−0.001**	−0.000	−0.001**
	[0.000]	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]
Manager Experience	0.003***	0.003**	0.004***	0.003**	0.003**	0.003**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Credit line	0.206***	0.287***	0.205***	0.286***	0.191***	0.271***
	[0.025]	[0.028]	[0.025]	[0.028]	[0.025]	[0.028]
Ref. cat.: No competitors						
Few competitors	0.075	0.060	0.072	0.055	0.075	0.059
	[0.058]	[0.067]	[0.058]	[0.067]	[0.058]	[0.067]
Avg. competitors	0.099*	0.160**	0.096	0.156**	0.095	0.153**
	[0.060]	[0.069]	[0.060]	[0.069]	[0.060]	[0.069]
Many competitors	−0.142**	−0.001	−0.144**	−0.004	−0.135**	0.008
	[0.057]	[0.066]	[0.057]	[0.066]	[0.057]	[0.066]
Ref. cat.: Large companies						
Small	−0.003	−0.116***	0.009	−0.099**	0.057	−0.044
	[0.035]	[0.038]	[0.035]	[0.039]	[0.036]	[0.039]
Medium	0.017	−0.028	0.024	−0.019	0.052	0.012
	[0.034]	[0.037]	[0.034]	[0.037]	[0.035]	[0.037]
Constant	−0.929***	−1.299***	−0.943***	−1.317***	−1.038***	−1.429***
	[0.095]	[0.108]	[0.095]	[0.108]	[0.096]	[0.109]
Observations	14,020	14,020	14,020	14,020	14,020	14,020
Industry dummies	YES	YES	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES	YES	YES
Wald chi2	3466	3466	3499	3499	3693	3693
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.404	0.404	0.402	0.402	0.392	0.392

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A4
Regression results in log-likelihoods for the four training programs on innovation – manufacturing sector.

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno	(7) prod_inno	(8) proc_inno	(9) prod_inno	(10) proc_inno	(11) prod_inno	(12) proc_inno
Ref. cat.: No training												
Overall training	0.340***	0.391***										
	[0.038]	[0.040]										
Mathematical related training			0.091	0.131							0.229**	0.302***
			[0.109]	[0.117]							[0.109]	[0.116]
Communication related training					0.449***	0.442***					0.578***	0.602***
					[0.114]	[0.106]					[0.114]	[0.106]
Managerial related training							0.120	0.142			0.261***	0.315***
							[0.094]	[0.094]			[0.095]	[0.094]
Other training									0.291***	0.325***	0.339***	0.388***
									[0.040]	[0.042]	[0.041]	[0.043]
Firms' Age (ln)	−0.005	0.035	−0.008	0.029	−0.008	0.030	−0.008	0.030	−0.005	0.035	−0.005	0.035
	[0.025]	[0.027]	[0.025]	[0.027]	[0.025]	[0.027]	[0.025]	[0.027]	[0.025]	[0.027]	[0.025]	[0.027]
Female ownership	0.099***	0.070*	0.107***	0.080**	0.103***	0.076**	0.107***	0.081**	0.105***	0.078**	0.098***	0.068*

(*continued on next page*)

Table A4 (*continued*)

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno	(7) prod_inno	(8) proc_inno	(9) prod_inno	(10) proc_inno	(11) prod_inno	(12) proc_inno
	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]
Ext. Knowledge	0.423***	0.532***	0.480***	0.594***	0.472***	0.588***	0.479***	0.593***	0.448***	0.560***	0.421***	0.531***
	[0.050]	[0.049]	[0.049]	[0.048]	[0.049]	[0.049]	[0.049]	[0.048]	[0.050]	[0.049]	[0.050]	[0.049]
Education	−0.002***	−0.002**	−0.002***	−0.002**	−0.002***	−0.002**	−0.002***	−0.002**	−0.002***	−0.002**	−0.002***	−0.002**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Export	0.000	0.001*	0.000	0.001**	0.001	0.001**	0.000	0.001**	0.000	0.001**	0.000	0.001*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
R&D	0.661***	0.519***	0.713***	0.581***	0.709***	0.577***	0.711***	0.579***	0.685***	0.547***	0.662***	0.519***
	[0.039]	[0.041]	[0.038]	[0.040]	[0.038]	[0.040]	[0.038]	[0.040]	[0.038]	[0.040]	[0.039]	[0.041]
Multi-implant	0.098*	0.093	0.112*	0.114*	0.110*	0.110*	0.111*	0.112*	0.112*	0.110*	0.099*	0.093
	[0.058]	[0.059]	[0.058]	[0.060]	[0.058]	[0.060]	[0.058]	[0.060]	[0.058]	[0.059]	[0.058]	[0.059]
Owner	−0.000	−0.001	−0.000	−0.001	−0.000	−0.001	−0.000	−0.001	−0.000	−0.001	−0.000	−0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Manager Experience	0.004**	0.003	0.004**	0.003*	0.004**	0.003*	0.004**	0.003*	0.004**	0.002	0.004**	0.003
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Credit line	0.181***	0.299***	0.200***	0.318***	0.199***	0.317***	0.199***	0.317***	0.185***	0.303***	0.180***	0.298***
	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]
Ref. cat.: No competitors												
Few competitors	0.093	0.125	0.087	0.116	0.088	0.117	0.086	0.115	0.093	0.124	0.094	0.126
	[0.073]	[0.082]	[0.073]	[0.082]	[0.072]	[0.082]	[0.073]	[0.082]	[0.073]	[0.082]	[0.073]	[0.082]
Avg. competitors	0.110	0.231***	0.107	0.229***	0.111	0.232***	0.106	0.227***	0.111	0.234***	0.113	0.234***
	[0.077]	[0.086]	[0.077]	[0.086]	[0.076]	[0.086]	[0.077]	[0.086]	[0.077]	[0.086]	[0.077]	[0.086]
Many competitors	−0.149**	0.064	−0.166**	0.042	−0.163**	0.045	−0.166**	0.041	−0.156**	0.054	−0.148**	0.065
	[0.072]	[0.081]	[0.072]	[0.081]	[0.071]	[0.081]	[0.072]	[0.081]	[0.072]	[0.081]	[0.072]	[0.081]
Ref. cat.: Large companies												
Small	0.110**	0.042	0.052	−0.025	0.062	−0.015	0.055	−0.022	0.081*	0.007	0.111**	0.044
	[0.048]	[0.052]	[0.047]	[0.051]	[0.047]	[0.051]	[0.047]	[0.051]	[0.047]	[0.051]	[0.048]	[0.052]
Medium	0.054	0.067	0.019	0.027	0.025	0.034	0.021	0.029	0.035	0.045	0.055	0.068
	[0.045]	[0.047]	[0.044]	[0.047]	[0.044]	[0.047]	[0.044]	[0.047]	[0.044]	[0.047]	[0.045]	[0.047]
Constant	−0.663***	−1.391***	−0.571***	−1.273***	−0.586***	−1.288***	−0.574***	−1.275***	−0.630***	−1.350***	−0.668***	−1.396***
	[0.119]	[0.132]	[0.118]	[0.131]	[0.118]	[0.132]	[0.118]	[0.131]	[0.119]	[0.132]	[0.119]	[0.132]
Observations	7544	7544	7544	7544	7544	7544	7544	7544	7544	7544	7544	7544
Wald chi2	2189	2189	2044	2044	2058	2058	2043	2043	2136	2136	2197	2197
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.433	0.433	0.447	0.447	0.445	0.445	0.447	0.447	0.438	0.438	0.432	0.432

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A5

Regression results in log-likelihoods for the in-class vs. on the-job training programs on innovation – manufacturing sector.

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno
Ref. cat.: No training						
In-class	0.091	0.131			0.228**	0.300***
	[0.109]	[0.117]			[0.109]	[0.116]
On-the-job			0.267***	0.283***	0.389***	0.434***
			[0.074]	[0.072]	[0.075]	[0.073]
Other training					0.340***	0.389***
					[0.041]	[0.043]
Firm's Age (ln)	−0.008	0.029	−0.007	0.030	−0.005	0.035
	[0.025]	[0.027]	[0.025]	[0.027]	[0.025]	[0.027]
Female ownership	0.107***	0.080**	0.104***	0.077**	0.099***	0.070*
	[0.035]	[0.038]	[0.035]	[0.038]	[0.035]	[0.038]
Ext. Knowledge	0.480***	0.594***	0.471***	0.586***	0.423***	0.532***
	[0.049]	[0.048]	[0.049]	[0.049]	[0.050]	[0.049]
Education	−0.002***	−0.002**	−0.002***	−0.002**	−0.002***	−0.002**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Export	0.000	0.001**	0.000	0.001**	0.000	0.001*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
R&D	0.713***	0.581***	0.703***	0.571***	0.660***	0.518***
	[0.038]	[0.040]	[0.038]	[0.040]	[0.039]	[0.041]
Multi-implant	0.112*	0.114*	0.106*	0.106*	0.098*	0.092
	[0.058]	[0.060]	[0.058]	[0.060]	[0.058]	[0.059]
Owner	−0.000	−0.001	−0.000	−0.001	−0.000	−0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Manager Experience	0.004**	0.003*	0.004**	0.003*	0.004**	0.003
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Credit line	0.200***	0.318***	0.198***	0.317***	0.180***	0.298***
	[0.034]	[0.037]	[0.034]	[0.037]	[0.034]	[0.037]
Ref. cat.: No competitors						
Few competitors	0.087	0.116	0.086	0.115	0.093	0.125
	[0.073]	[0.082]	[0.073]	[0.082]	[0.073]	[0.082]
Avg. competitors	0.107	0.229***	0.106	0.227***	0.110	0.231***

(*continued on next page*)

Table A5 (*continued*)

Dep. Var.	(1) prod_inno	(2) proc_inno	(3) prod_inno	(4) proc_inno	(5) prod_inno	(6) proc_inno
	[0.077]	[0.086]	[0.077]	[0.086]	[0.077]	[0.086]
Many competitors	−0.166**	0.042	−0.164**	0.044	−0.149**	0.063
	[0.072]	[0.081]	[0.072]	[0.081]	[0.072]	[0.081]
Ref. cat.: Large companies						
Small	0.052	−0.025	0.067	−0.010	0.111**	0.043
	[0.047]	[0.051]	[0.047]	[0.051]	[0.048]	[0.052]
Medium	0.019	0.027	0.029	0.037	0.055	0.068
	[0.044]	[0.047]	[0.044]	[0.047]	[0.045]	[0.047]
Constant	−0.571***	−1.273***	−0.587***	−1.289***	−0.665***	−1.393***
	[0.118]	[0.131]	[0.118]	[0.131]	[0.119]	[0.132]
Observations	7544	7544	7544	7544	7544	7544
Industry dummies	YES	YES	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES	YES	YES
Wald chi2	2044	2044	2053	2053	2189	2189
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.447	0.447	0.445	0.445	0.433	0.433

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A6
Regression results in log-likelihoods for the four training programs on innovation – regional heterogeneity.

	Region 1		Region 2		Region 3		Region 4	
Dep. Var.	prod_inno	proc_inno	prod_inno	proc_inno	prod_inno	proc_inno	prod_inno	proc_inno
Ref. cat.: No training								
Mathematical related training	0.413***	0.465***	−0.174	−0.034	0.110	0.351*	0.160	0.205
	[0.139]	[0.140]	[0.190]	[0.201]	[0.202]	[0.213]	[0.135]	[0.166]
Communication related training	0.576***	0.614***	0.099	0.513***	0.760***	0.398**	0.081	0.181
	[0.127]	[0.127]	[0.175]	[0.175]	[0.185]	[0.165]	[0.151]	[0.161]
Managerial related training	0.324***	0.410***	0.027	0.447***	0.280**	0.531***	0.240**	0.278**
	[0.117]	[0.119]	[0.117]	[0.120]	[0.138]	[0.137]	[0.110]	[0.119]
Other	0.231***	0.251***	0.281***	0.379***	0.264***	0.366***	0.398***	0.321***
	[0.056]	[0.059]	[0.056]	[0.063]	[0.063]	[0.069]	[0.067]	[0.073]
Constant	−0.911***	−1.103***	−1.675***	−2.074***	−0.070	−0.773***	−0.606***	−1.344***
	[0.180]	[0.196]	[0.242]	[0.278]	[0.249]	[0.277]	[0.156]	[0.179]
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	4465	4465	3678	3678	2303	2303	3574	3574
Wald chi2	1358	1358	766	766	647.1	647.1	684	684
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.401	0.401	0.337	0.337	0.402	0.402	0.463	0.463

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A7
Regression results in log-likelihoods for the in-class vs. on the-job training programs on innovation – manufacturing sector.

	Region 1		Region 2		Region 3		Region 4	
VARIABLES	prod_inno	proc_inno	prod_inno	proc_inno	prod_inno	proc_inno	prod_inno	proc_inno
Ref. cat.: No training								
In-class	0.412***	0.463***	−0.174	−0.035	0.109	0.352*	0.160	0.205
	[0.139]	[0.140]	[0.190]	[0.201]	[0.202]	[0.213]	[0.136]	[0.166]
On-the-job	0.432***	0.499***	0.047	0.465***	0.453***	0.480***	0.186**	0.245**
	[0.089]	[0.091]	[0.101]	[0.104]	[0.114]	[0.112]	[0.091]	[0.099]
Other training	0.230***	0.250***	0.281***	0.379***	0.265***	0.366***	0.400***	0.322***
	[0.056]	[0.059]	[0.056]	[0.063]	[0.063]	[0.069]	[0.067]	[0.073]
Constant	−0.910***	−1.101***	−1.674***	−2.072***	−0.078	−0.773***	−0.609***	−1.346***
	[0.180]	[0.196]	[0.242]	[0.277]	[0.249]	[0.277]	[0.156]	[0.179]
Observations	4465	4465	3678	3678	2303	2303	3574	3574
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Wald chi2	1354	1354	765.8	765.8	646	646	682.9	682.9
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.401	0.401	0.337	0.337	0.400	0.400	0.464	0.464

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.strueco.2024.12.005.

Data availability

Data will be made available on request.

References

Bartel, A.P., 2000. Measuring the employer's return on investments in training: evidence from the literature. Ind. Relat. (Berkeley). 39 (3), 502–524.
Bauernschuster, S., Falck, O., Heblich, S., 2009. Training and Innovation. J. Hum. Cap. 3 (4), 323–353.
Beneito, P., Coscolla-Girona, P., Rochina-Barrachina, M.E., Sanchis, A., 2015. Competitive Pressure and Innovation at Firm Level. J. Ind. Econ. 63 (3), 422–457.
Bogliacino, F., Perani, G., Pianta, M., Supino, S., 2012. Innovation and development: the evidence from innovation surveys. Lat. Am. Bus. Rev. 13 (3), 219–261.
Børing, P., 2017. The relationship between training and innovation activities in enterprises. Int. J. Train. Develop. 21 (2), 113–129.
Caloghirou, Y., Giotopoulos, I., Korra, E., Tsakanikas, A., 2018. How do employee training and knowledge stocks affect product innovation? Econ. Innov. New. Technol. 27 (4), 343–360.
Capozza, C., Divella, M., 2019. Human capital and firms' innovation: evidence from emerging economies. Econ. Innov. New. Technol. 28 (7), 741–757.
Castellacci, F., 2015. Institutional voids or organizational resilience? Business groups, innovation, and market development in Latin America. World. Dev. 70, 43–58.
Chang, S.J., Chung, C.N., Mahmood, I.P., 2006. When and how does business group affiliation promote firm innovation? A tale of two emerging economies. Organ. Sci. 17 (5), 637–656.
Chen, C.J., Huang, J.W., 2009. Strategic human resource practices and innovation performance. The mediating role of knowledge management capacity. J. Bus. Res. 62 (1), 104–114.
Christofides, L.N., Stengos, T., Swidinsky, R., 1997. On the calculation of marginal effects in the bivariate probit model. Econ. Lett. 54 (3), 203–208.
Cieślik, A., Wciślik, D.R., 2020. Convergence among the CEE-8 economies and their catch-up towards the EU-15. Struct. Chang. Econ. Dyn. 55, 39–48.
Cordón-Pozo, E., Vidal-Salazar, M.D., de la Torre-Ruiz, J.M., 2017. Innovation training and product innovation performance: the moderating role of external cooperation. Int. J. Technol. Manage. 73, 3–20.
Cozzarin, B.P., Percival, J.C., 2023. Differential Effects of Training on Innovation. Econ. Innov. New. Technol. 32 (1), 53–68.
Crowley, F., McCann, P., 2018. Firm innovation and productivity in Europe: evidence from innovation-driven and transition-driven economies. Appl. Econ. 50 (11), 1203–1221.
Dearden, L., Reed, H., Van Reenen, J., 2006. The impact of training on productivity and wages: evidence from British Panel Data. Oxf. Bull. Econ. Statist. 68 (4), 397–421.
Dostie, B., 2018. The impact of Training on Innovation. ILR Rev. 71 (1), 64–87.
Freel, M.S., 2005. Patterns of innovation and skills in small firms. Technovation 25 (2), 123–134.
Friz, K., Gunther, J., 2021. Innovation and economic crisis in transition economies. Euras. Bus. Rev. 11, 537–563.
Gallié, E.P., Legros, D., 2012. Firms' Human Capital, R&D and Innovation: a Study on French Firms. Empir. Econ. 43 (2), 581–596.
George, G., Corbishley, C., Khayesi, J., Haas, M., Tihanyi, L., 2016. Bringing Africa in: promising directions for management research. Acad. Manage. J. 59, 377–393.
Geroski, P., 1990. Innovation, Technological Opportunity, and Market Structure. Oxf. Econ. Pap. 42 (3), 586–602.
Goedhuys, M., Janz, N., Mohnen, P., 2008. What drives productivity in Tanzanian manufacturing firms: technology or business environment? Eur. J. Develop. Res. 20, 199–218.
González, X., Miles-Touya, D., Pazó, C., 2016. R&D, worker training and innovation: firm-level evidence. Ind. Innov. 23 (8), 694–712.
Greene, W.H. (1996). Marginal Effects in the Bivariate Probit Model. NYU Working Paper No. EC-96-11, Available at SSRN: https://ssrn.com/abstract=1293106.
Győrffy, D., 2022. The middle-income trap in Central and Eastern Europe in the 2010s: institutions and divergent growth models. Compar. Eur. Politi. 1–24.
Hatch, N.W., Dyer, J.H., 2004. Human capital and learning as a source of sustainable competitive advantage. Strateg. Manage. J. 25 (12), 1155–1178.
Hegde, D., Shapira, P., 2007. Knowledge, technology trajectories, and innovation in a developing country context: evidence from a survey of Malaysian firms. Int. J. Technol. Manage. 40 (4), 349–370.
Hernandez, R., Roberts, S., 2021. Aligning Workforce and Innovations to European Standards. J. Econ. Stud. 48 (4), 567–589.
Laplagne, P., Bensted, L., 1999. The role of training and innovation in workplace performance. Product. Commiss. Staff Res. Pap. AusInfo, Canberra.
Laursen, K., Foss, N., 2003. New Human Resource Management Practices, Complementarities and the Impact on Innovation Performance. Cambr. J. Econ. 27 (2), 243–263.
Lenihan, H., McGuirk, H., Murphy, K.R., 2019. Driving innovation: public policy and human capital. Res. Policy. 48 (9), 103791.
Maddala, G.S., 1983. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, New York, pp. 257–291.
Mulkay, B., 2019. How does competition affect innovation behaviour in french firms? Struct. Chang. Econ. Dyn. 51, 237–251.
Nazarov, Z., Akhmedjonov, A., 2012. Education, on-the-job training and innovation in transition economies. East. Europ. Econ. 50 (6), 28–56.
Nickell, S., 1996. Competition and corporate performance. J. Politi. Econ. 104 (4), 724–746.
Petrović, P., Matić, M.G., 2023. Manufacturing productivity in the EU: why have Central and Eastern European countries converged and Southern EU countries have not? Struct. Chang. Econ. Dyn. 65, 166–183.
Protogerou, A., Caloghirou, Y., Vonortas, N.S., 2017. Determinants of Young Firms' innovative performance: empirical evidence from Europe. Res. Polic. 46 (7), 1312–1326.
Radosevic, S., 1999. Transformation of science and technology systems into systems of innovation in central and eastern Europe: the emerging patterns and determinants. Struct. Chang. Econ. Dyn. 10 (3–4), 277–320.
Ramadani, V., Hisrich, R.D., Abazi-Alili, H., Dana, L.P., Panthi, L., Abazi-Bexheti, L., 2019. Product innovation and firm performance in transition economies: a multi-stage estimation approach. Technol. Forecast. Soc. Chang. 140, 271–280.
Romijn, H., Albaladejo, M., 2002. Determinants of Innovation Capability in Small Electronics and Software Firms in Southeast England. Res. Policy. 31, 1053–1067.
Santamaria, L., Nieto, L.J., Barge-Gil, A., 2009. Beyond formal R&D: taking advantage of other sources of innovation low and medium technology industries. Res. Polic. 38 (3), 507–517.
Scherer, F.M., 1967. Research and development resource allocation under rivalry. Q. J. Econ. 81 (3), 359–394.
Szirmai, A., Verspagen, B., 2015. Manufacturing and economic growth in developing countries, 1950–2005. Struct. Chang. Econ. Dyn. 34, 46–59.
van Uden, A., Knoben, J., Vermeulen, P., 2017. Human capital and innovation in Sub-Saharan countries: a firm-level study. Innovation 19 (2), 103–124.
Vivarelli, M., 2014. Innovation, employment and skills in advanced and developing countries: a survey of economic literature. J. Econ. Issue. 48 (1), 123–154.
Vivarelli, M., 2016. The middle income trap: a way out based on technological and structural change. Econ. Chang. Restructur. 49, 159–193.
Vona, F., Consoli, D., 2015. Innovation and skill dynamics: a life-cycle approach. Ind. Corp. Chang. 24 (6), 1393–1415.
Vaona, A., Pianta, M., 2008. Firm size and innovation in European manufacturing. Small Bus. Econ. 30, 283–299.