11th International Conference on Higher Education Advances (HEAd'25)
Universitat Politècnica de València, València, 2025
DOI: https://doi.org/10.4995/HEAd25.2025.19900

From shop floors to breakthroughs: Is vocational education good for innovation?

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How to cite: Bianchi, P.; Corrocher, N.; Muscio, A. (2025). From shop floors to breakthroughs: Is vocational education good for innovation? In: 11th International Conference on Higher Education Advances (HEAd'25). Valencia, 17–20 June 2025. https://doi.org/10.4995/HEAd25.2025.19900

Abstract

The fundamental impact of human capital on innovative performance is a consensual finding in the innovation literature. Universities play a pivotal role in fuelling innovation across various industries, providing students with essential knowledge and skills to generate new products, processes, and business models. However, while the crucial role of the university is undeniable, it should be remembered that human capital formation is a complex and multifaceted phenomenon, influenced not only by factors such as institutional context and culture but also by the prevailing secondary education system. Since 1999, the Bologna Process has resulted in numerous reforms aimed at ensuring comparability among standard and quality of higher education qualifications in Europe. However, secondary school education systems vary significantly among countries. One of the most striking differences is the relevance attributed to vocational training programmes. Vocational training is essential for preparing students for specific careers and industries and focuses on the development of practical skills and knowledge that are directly applicable in the workplace. This paper analyses the impact of secondary school education on innovation performance in European regions. The rationale is that, despite a widely held belief that innovation requires workers with an academic education, vocational education and training is a major driver of innovation performance. We employ Eurostat data for the last two programming periods to and determine the extent to which secondary school systems and European Commission policy, specifically the European Social Fund Educational and Vocational Training theme, can contribute to innovation performance in European regions.

Keywords: *Innovation; European regions; schooling; human capital; vocational training*

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Editorial Universitat Politècnica de València

1. Introduction and background literature

Vocational Education and Training (VET) in regional development has garnered increasing attention, particularly regarding its potential to address spatial inequalities and support place-based innovation. VET is widely recognized as a key mechanism for fostering a skilled workforce capable of sustaining economic growth. Yet, its relationship with innovation is context-dependent, shaped by local economic structures, institutional settings, and alignment between education systems and labor market demands (Boschma et al., 2013; Sevinc et al., 2020; Corradini et al., 2023; Büyükyazıcı et al., 2023). Research has highlighted VET's contributions to employment and regional resilience, especially in structurally weaker areas or metropolitan settings with diverse human capital needs (Filippetti et al., 2019; Poelhekke, 2013). However, persistent mismatches between skill supply and occupational demand underscore the need for integrated, regionally coordinated VET systems. Although VET is generally seen as vital for equipping individuals with practical, job-ready skills, its innovation impact is nuanced. Some studies argue that VET supports incremental innovation by providing firms with skilled workers able to implement and maintain new technologies (Rupietta et al., 2021; Toner et al., 2004). For instance, apprentices can act as hybrid change agents, facilitating internal and external knowledge flows (Rupietta et al., 2021). Toner et al. (2004) similarly demonstrate that innovation and training intensity are strongly correlated in innovation-intensive sectors. Other evidence reinforces this perspective. Poelhekke (2013) finds that vocationally trained workers, particularly in technical occupations, significantly contribute to employment growth in German metropolitan regions. Büyükyazıcı et al. (2023) emphasize the importance of VET-driven skill relatedness and complexity in supporting regional diversification and innovation. Yet, the literature also reveals limitations. Rodríguez-Soler and Brunet Icart (2017), examining VET–SME interactions in Spain, find that while workplace training is common, it remains underutilized as a lever for broader innovation. Similarly, Lavía et al. (2012) note that continuous training from VET centers benefits industrial SMEs, though engagement levels vary. These findings point to the need for stronger strategic coordination between education and innovation systems—echoing calls for regional skills governance that embeds VET into local innovation strategies (Raagmaa & Keerberg, 2017; Corradini et al., 2023).

Emerging studies also stress the importance of aligning VET systems with regional development priorities. The impact of VET on innovation is influenced by the spatial distribution of skills, the structure of local economies, and the presence of complementary institutions (Boschma et al., 2013; Corradini et al., 2023). In manufacturing-oriented regions, VET often provides a better match with firms' technical demands (Poelhekke, 2013; Allais & Schöer, 2024), whereas service or knowledge-based economies may rely more heavily on tertiary education to drive innovation. Evidence from regional studies confirms these contextual variations. Filippetti et al. (2019) show that training policies in Italy have stronger effects in the South, where structural gaps are greater. Manca (2012) and Canal Domínguez (2021) further highlight the complementarity of

vocational and tertiary education in fostering regional convergence and cohesion. These insights reinforce the idea that VET's effectiveness depends not just on content, but on its interaction with the broader human capital composition of a region. A particularly promising area of research focuses on the role of regional education providers as agents of change within innovation systems. When well-integrated into territorial strategies, VET centers and higher education institutions (HEIs) can function as institutional entrepreneurs—coordinating with firms, anticipating skills needs, and supporting diversification (Raagmaa & Keerberg, 2017; Büyükyazıcı et al., 2023).

This paper contributes to the debate by examining the VET–innovation relationship across European regions using a comprehensive dataset. Our findings show that, at an aggregate level, VET is negatively associated with innovation, whereas tertiary education shows a positive correlation—likely due to its stronger ties to R&D and knowledge generation. However, this pattern is not uniform. In manufacturing-intensive regions, VET exhibits a positive and significant association with innovation, echoing the findings of Bennett et al. (2004) and Allais & Schöer (2024), who emphasize the value of practical, technical skills in driving innovation in these settings. These findings suggest that the impact of VET varies significantly by regional economic structure. In regions with strong manufacturing bases, VET provides essential hands-on skills and technical expertise needed to implement and manage innovation. Conversely, in high-tech or service-based economies, innovation is more tightly linked to the theoretical and research-oriented training provided by HEIs. Overall, while VET may appear to have a weaker link to innovation compared to tertiary education, its positive role in manufacturing regions highlights its underappreciated potential as a driver of place-based innovation. A more strategic integration of VET into regional innovation systems—accounting for local economic conditions—could enhance its contribution to inclusive growth and regional development across Europe.provided by tertiary institutions may be more directly linked to innovation outcomes.

2. Empirical analysis

Our analysis is based on European Commission (EC) open data available on the Eurostat portal. The database includes information on secondary and tertiary education, population, R&D activity, economic activity and patenting. We obtained data at NUTS2 regional level that refers to the period 2016-2021. Therefore, the database is organised in a panel data structure. Data on education takes into account both general student career paths and VET ones. It also includes information on regions' falling into the "talent development trap", which was obtained from the EC report on economic, social and territorial cohesion (European Commission, 2024). The test of the research hypotheses is based on a set of OLS regressions run on a panel data structure with region and year fixed effects. Table 1 and Table 2 present the results of our analysis. In Table 1, patents are the dependent variable; in Table 2 GDP (stock) is the dependent variable. We are aware that patents are an imperfect measure of innovation, especially for sectors such

as services, software, or design, where intellectual property is often protected through secrecy or informal means. Indeed, patents are biased towards certain industries—such as pharmaceuticals, chemicals, and electronics —while underrepresenting sectors where innovation is more tacit, process-oriented, or non-technical. Nonetheless, patents remain one of the few systematic, publicly available, and internationally standardised indicators of technological innovation, particularly useful for capturing knowledge outputs and innovations at the regional or sectoral level. In both tables VET is measured alternatively as percentage of students enrolled in VET over total population (columns 1-3) and percentage of students enrolled in VET over the total students in secondary education (models 4-6).

Our results suggest a complex and context-dependent picture, in which VET's contribution to innovation varies significantly depending on regional economic structures and institutional conditions. Across European regions, VET enrolment at the secondary level shows a negative and significant correlation with patent activity, suggesting that, under certain conditions, vocational training may hinder regional innovation. In Model 1, the estimated elasticity is −0.84, meaning that a 1% increase in the share of the population enrolled in VET correlates with a 0.84% decrease in patent applications, all else being equal. This aligns with broader concerns that VET, while effective for employability, may not foster the high-level cognitive skills—such as critical thinking, creativity, and problem-solving—required for innovation in knowledge-intensive sectors (Boschma et al., 2013; Corradini et al., 2023).

Unlike tertiary education, which emphasizes abstract and research-based knowledge, VET focuses on applied, sector-specific competencies. While this practical orientation supports entry into the labor market, particularly in traditional industries, it may not cultivate the interdisciplinary and adaptable skillsets increasingly demanded in dynamic and high-tech environments (Manca, 2012; Büyükyazıcı et al., 2023). The negative correlation may also reflect structural limitations, including the prestige gap between vocational and general education in countries like Italy. This status divide can lead to self-selection effects, where more academically inclined students avoid vocational tracks, reducing VET's innovation potential (Poelhekke, 2013; Canal Domínguez, 2021). Further, the short-term employability advantage of VET may disincentivize students from pursuing tertiary education, reducing the regional supply of highly qualified graduates in STEM and R&D-intensive fields. In sectors like ICT and pharmaceuticals, where disruptive innovation is key, the absence of deeper theoretical training can be a limiting factor. Cultural perceptions of VET as a "second-best" option may further restrict its contribution to innovation (Cabus, 2015; Filippetti et al., 2019).

However, the negative relationship is not universal. When we account for regional economic structure, the picture changes. Introducing an interaction term between VET enrolment and manufacturing employment reveals a positive and significant effect. In regions with strong manufacturing bases, a one-unit increase in the VET share is associated with a 3.36% increase

Table 1. VET and Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Pat	Pat	Pat	Pat	Pat	Pat
Region FE	yes	yes	no	yes	yes	no
Year FE	yes	yes	yes	yes	yes	yes
population_age	-0.103	-0.080	0.087	-0.133	-0.155	0.088
	[0.152]	[0.150]	[0.057]	[0.151]	[0.149]	[0.058]
emp_manuf	0.024	-0.688**	-0.094	0.010	-0.929**	-0.094
	[0.168]	[0.229]	[0.057]	[0.168]	[0.273]	[0.059]
TDT			0.001			0.000
			[0.009]			[0.011]
tertiary educ	0.304**	0.294**	-0.008	0.302**	0.271**	-0.005
	[0.077]	[0.076]	[0.035]	[0.077]	[0.077]	[0.036]
VET_educ_pop	-0.866+	-5.713**	0.756*			
	[0.455]	[1.166]	[0.306]			
VET_educ_pupils				-0.050	-0.370**	0.034
				[0.031]	[0.080]	[0.021]
VET_educ_pop * emp_manuf		35.565**				
		[7.897]				
VET_educ_pop * TDT			-0.595+			
			[0.329]			
VET_educ_pupils * emp_manuf					2.007**	
					[0.464]	
VET_educ_pupils * TDT						-0.023
						[0.017]
Constant	0.274	0.289	-0.265	0.392	0.634	-0.271
	[0.573]	[0.565]	[0.214]	[0.568]	[0.564]	[0.218]
Observations	875	875	812	875	875	812
Number of id	157	157	143	157	157	143
Standard errors in brackets						
**** p<0.01, * p<0.05, + p<0.1**						

in patent applications. This interaction suggests that VET's contribution to innovation depends on the sectoral context. Where manufacturing employment is high, VET plays a more complementary role in supporting innovation. This result reflects the reality of manufacturing-oriented regions—such as Baden-Württemberg, Lombardy, Emilia-Romagna, Catalonia, Flanders, and Upper Silesia—where VET systems are often well-integrated into local economies and closely aligned with the skill needs of firms (Brunello & Rocco, 2017). In these settings, VET facilitates incremental innovation, particularly in production processes and product improvements. The practice-based orientation of vocational programmes aligns with the evolutionary nature of innovation in manufacturing sectors. Moreover, the embeddedness of VET in regional production systems fosters collaboration between firms, schools, and public institutions. This supports knowledge spillovers and builds coherent regional innovation systems (Rupietta & Backes-Gellner, 2019; Rodríguez-Soler & Brunet Icart, 2017; Albizu et al., 2017). Regions with dense manufacturing networks benefit from more frequent and productive exchanges of knowledge and talent, reinforcing a culture of continuous improvement and mutual learning (Rodríguez-Pose & Wilkie, 2020; Boschma et al., 2013; Sevinc et al., 2020).

We further explore the role of regional structural conditions by introducing the talent development trap (TDT) into our analysis. The results indicate that VET's positive effects on innovation are conditioned by the absence of a high TDT score. In regions with high TDT scores—indicating structural weaknesses such as low educational attainment, demographic decline, and youth outmigration—VET is significantly less effective in contributing to patent activity. In such regions (e.g., parts of Southern Italy or the Western Balkans), even a well-structured VET system struggles to offset broader labor market constraints and institutional deficiencies. This finding highlights the limitations of VET in isolation. Without strong institutional support, robust labor demand, and policies to retain talent, VET cannot fulfill its potential to drive innovation. In areas suffering from brain drain or limited opportunities for skilled employment, vocational graduates may either leave or fail to find roles that allow them to apply their competencies in innovation-oriented settings. This reinforces existing inequalities and risks turning VET into a mechanism for reproducing, rather than mitigating, territorial disadvantage (Filippetti et al., 2019; Sevinc et al., 2020). Ultimately, our findings support the case for place-sensitive, systemic skills policies. In regions with favorable conditions—especially strong manufacturing sectors and institutional coordination—VET can be a driver of incremental innovation. But in regions facing structural traps, it must be complemented by industrial policy, investment in skills retention, and stronger coordination between education providers, firms, and regional authorities (Raagmaa & Keerberg, 2017; Corradini et al., 2023). Only under these conditions can VET contribute meaningfully to innovation and inclusive regional development.

Table 2. VET and GDP

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	GDP	GDP	GDP	GDP	GDP	GDP
Region FE	yes	yes	no	yes	yes	no
Year FE	yes	yes	yes	yes	yes	yes
population_age	0.812**	0.860**	0.991**	0.882**	0.866**	1.032**
	[0.246]	[0.245]	[0.230]	[0.242]	[0.241]	[0.231]
emp_manuf	-0.236	-1.295**	-0.807**	-0.211	-1.759**	-0.688**
	[0.263]	[0.403]	[0.246]	[0.263]	[0.476]	[0.246]
TDT			-0.482**			-0.522**
			[0.046]			[0.051]
tertiary educ	-0.065	-0.089	0.247+	-0.068	-0.110	0.198
	[0.119]	[0.119]	[0.128]	[0.119]	[0.119]	[0.127]
VET_educ_pop	2.282**	-5.664*	0.387			
	[0.872]	[2.456]	[1.122]			
VET_educ_pupils				0.142*	-0.398**	-0.131+
				[0.056]	[0.150]	[0.077]
VET_educ_pop * emp_manuf		54.037**				
		[15.628]				
VET_educ_pop * TDT			6.513**			
			[1.164]			
VET_educ_pupils * emp_manuf					3.301**	
					[0.851]	
VET_educ_pupils * TDT						0.337**
						[0.059]
Constant	6.351**	6.336**	6.453**	6.050**	6.376**	6.372**
	[0.889]	[0.884]	[0.863]	[0.878]	[0.875]	[0.867]
Observations	1,071	1,071	978	1,071	1,071	978
Number of id	193	193	177	193	193	177
Standard errors in brackets						
**** p<0.01, * p<0.05, + p<0.1**						

While the relationship between Vocational Education and Training (VET) and innovation remains mixed, our findings reveal a positive and statistically significant association between VET and regional GDP. As shown in Table 5, the baseline model estimates an elasticity of 0.84, indicating that a 1% increase in the share of population in VET education is associated with a 0.84% increase in per capita GDP, all else equal. This effect reflects VET's contribution to improving workforce employability and productivity across key sectors such as manufacturing, logistics, healthcare, and construction (Cedefop, 2020; Rodríguez-Pose & Wilkie, 2020). VET equips individuals with practical, occupation-specific skills that align closely with local labor market needs. These capabilities are crucial in sectors that rely on day-to-day operational effectiveness and process-based improvements. Unlike innovation-led growth, which often depends on advanced research and highly specialized human capital, GDP growth in many European regions is more sensitive to labor force participation and skills matching—areas where VET has proven strengths. Columns 2 and 5 of our regression models introduce an interaction term between VET and manufacturing employment, yielding a positive and significant result. This finding suggests that the GDP-enhancing effect of vocational education is amplified in regions with a strong manufacturing base. Eichhorst et al. (2013) and Sevinc et al. (2020) similarly argue that VET's alignment with regional economic structures boosts productivity, even in less technologically advanced regions. Corradini et al. (2023) further note that VET systems embedded in place-based strategies can drive structural transformation in lagging territories.

While VET may not directly fuel breakthrough innovations, it strengthens regional economies by reducing unemployment, improving job matching, and increasing workforce participation (Brunello & Wruuck, 2019). These effects are particularly relevant for regions where innovation is incremental and sectoral stability is more important than technological disruption. Cedefop (2018) underscores that VET responds to the needs of foundational industries, ensuring their competitiveness through a reliable supply of skilled labor. VET also plays a crucial role in fostering inclusive growth. By providing career pathways for individuals who do not pursue university education, VET contributes to social mobility and economic resilience. This inclusiveness expands labor force participation and supports income generation in communities that may otherwise be excluded from the benefits of growth (Eichhorst et al., 2013; Cedefop, 2020). The impact is particularly relevant for non-core or peripheral regions, where tertiary education rates are lower, and vocational training can fill significant human capital gaps (Canal Domínguez, 2021).

Columns 3 and 6 introduce the talent development trap (TDT) variable and its interaction with VET. The TDT captures vulnerabilities such as youth outmigration, demographic decline, and low educational attainment. Our results show that while TDT is negatively associated with GDP, VET has a positive moderating effect. In regions affected by development traps, increases in vocational education can help mitigate economic stagnation. These interaction terms are

consistently positive and significant, indicating that VET strengthens regional economic performance, even under adverse structural conditions. This supports the view that VET is particularly effective in structurally weaker regions, acting as a buffer against development traps when embedded in coordinated skills strategies. Filippetti et al. (2019) and Corradini et al. (2023) highlight that training policies have a greater impact on employment and economic performance where baseline conditions are weaker. Our findings confirm that VET's contribution to GDP is not only robust but also especially critical in vulnerable regions. In summary, while VET's role in supporting innovation may depend on specific regional and sectoral conditions, its impact on GDP is consistently positive and reinforced in contexts with strong manufacturing or structural challenges. These results underscore the importance of integrating VET into regional development strategies aimed at boosting inclusive, place-based economic growth.

3. Conclusions

This paper explored the role of Vocational Education and Training (VET) in shaping regional innovation and economic performance across Europe. We found that while VET is negatively associated with innovation overall, it is positively linked to GDP and promotes innovation in manufacturing-oriented regions. These findings underscore the importance of regional economic structures in mediating the effects of VET. VET enhances productivity by equipping workers with practical, job-relevant skills—particularly in sectors like manufacturing, logistics, and healthcare. Its economic benefits are amplified when embedded in supportive regional frameworks that align training with local industrial needs. Public-private partnerships between VET institutions and firms ensure that programmes remain responsive to evolving technologies and market demands. When integrated into coordinated regional governance structures, such partnerships can foster dynamic innovation ecosystems (Boschma et al., 2013; Corradini et al., 2023). Several European regions illustrate this approach. In Germany's Baden-Württemberg, the dual apprenticeship system aligns vocational training with firm-level innovation needs. Emilia-Romagna in Italy connects VET programmes with firms like Ferrari and Ducati, while Upper Silesia in Poland has developed similar models for Industry 4.0 upskilling. These cases show that VET can contribute meaningfully to innovation when institutionally embedded in regional development strategies (Raagmaa & Keerberg, 2017; Rodríguez-Soler & Brunet Icart, 2017). Innovation hubs also demonstrate how VET can support applied R&D. In the Netherlands' Brainport Region, Summa College involves students in real-world projects with firms like Philips and ASML. Similarly, the Pôle Formation UIMM in Nantes integrates VET students into collaborative manufacturing and maritime innovation efforts. These examples highlight the value of aligning VET with research and industry to stimulate regional innovation.

For VET to fulfill its potential, it must be part of a broader, place-sensitive policy mix. Effective strategies require coordination across education, industrial, and innovation policy domains and should include mechanisms for lifelong learning and upskilling (Cedefop, 2019; Filippetti et al.,

2019). In structurally weaker regions, VET can support resilience, but only if backed by sustained investment and institutional capacity. The observed negative correlation between VET and innovation in some areas highlights the risk of overly rigid, narrowly defined training. Future-oriented VET systems must integrate entrepreneurial and R&D components and engage with broader innovation networks. When spatially embedded and strategically governed, VET can support both incremental and transformative innovation in an evolving regional economy.

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