The role of Biodistricts in enhancing farms' labour productivity: a postKeynesian analysis

Grazini Chiara[a*], Guarini Giulio[b], Alberto Sturla[c]

[a]Economics, engineering, society, business organization Department, University of Tuscia, Viterbo (Italy); E-mail: c.grazini@unitus.it ORCID ID: https://orcid.org/0000-0002-7305-4945

[*]Corresponding Author

[a]Economics, engineering, society, business organization Department, University of Tuscia, Viterbo (Italy); E-mail: giulioguarini@unitus.it ORCID ID: https://orcid.org/0000-0002-9159-3360

[c]Council for agricultural research and Economics, Centre for policies and bioeconomy (CREA PB) E-mail: alberto.sturla@crea.gov.it; ORCID ID: https://orcid.org/0000-0001-5117-5933

Abstract

Biodistricts (BDs) leverage the "significant local presence" of organic farming and its supply chain to reach farmers' economic and environmental viability. Despite growing policy recognition in European strategies, empirical evidence of their effectiveness on farms' competitiveness remains limited. Using Italian FADN data and a post-Keynesian econometric model with dynamic panel data, this paper explores the BDs' impact on farm labour productivity growth, capturing innovation processes and competitiveness. Results suggest BD membership significantly enhances labour productivity growth, highlighting the role of territorial specialisation and collaborative networks. These benefits extend beyond organic farms, as the district's "industrial atmosphere" facilitates broader knowledge spillovers. Findings call for policies to strengthen social capital and promote sustainable farming practices, leveraging BDs as a strategy in enhancing farms' labour productivity and sustainability through agglomeration externalities, whereby the farms' spatial concentration facilitates knowledge sharing, joint resource use, and coordinated practice.

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This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record.

Please cite this article as:

Grazini C, Guarini G, Sturla A. (in press) The role of Biodistricts in enhancing farms' labour productivity: a postKeynesian analysis. *Bio-based and Applied Economics*, Just Accepted. DOI: 10.36253/bae-18332

1. Introduction

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Biodistricts (BDs), or "Eco-Regions", represent a novel approach to Local Food Systems (LFSs), intended as geographically concentrated and specialized local production systems comprising farms, connected businesses, services and institutions engaged in producing and marketing local food (Sanz-Cañada & Muchnik, 2016). BDs enrich LAFS approach by rooting food system development in organic farming principles. A *'Biodistrict' is a geographical area where farmers, the public, tourist operators, associations and public authorities enter into an agreement for the sustainable management of local resources, based on organic principles and practices* (COM (2021)[1] 141 final/2, p. 15). Strengthening local organic supply chains drives multi-stakeholder development of the food sector and wider community, linking territorial organic production with tourism, crafts, environment, and local societal interactions (Assiri et al., 2021). Beyond the territorial concentration of farms and related actors, BDs are distinguished by the embeddedness of production within the local socio-economic context through relationships with local communities, their know-how, dietary practices, and institutions (Muchnik et al., 2007). They foster place-based approaches to sustainable local development (Stotten & Froning, 2023) and economic viability of local food productions, and support horizontal and vertical cooperation networks (Duarte et al., 2025). Due to these abilities, BDs are receiving growing policy attention, as reflected in their recognition under the Italian[2] Law No.

[1] European Commission's Communication on an action plan for the development of organic production, available at https://eur-lex.europa.eu/legal-content/IT/TXT/HTML/?uri=CELEX:52021DC0141R(01)

[2] Italian law No. 23/2022 defines BDs by combining their double nature of production systems characterised by productive specialisation and territorially embedded socio-economic configurations, as follows: "*Territories with a strong agricultural vocation in which there is a significant presence of organic productions, in compliance with the regulations, where organic farmers, processors, consumer associations or local authorities collaborate, on the basis of formal agreements, collaborate for the local uptake of organic farming, for the dissemination of its values and for the support and enhancement of sustainability of local economic activities other than agriculture*" (Art. 13). So, BDs aim at promoting

23/2022. Moreover, both the EU Action Plan for the Development of Organic Production[3] (COM(2021) 141 final) and the EU's long-term vision for rural areas[4]: towards stronger, connected, resilient and prosperous rural areas by 2040 (COM(2021) 345 final) identify BDs as effective instruments for maximising the economic and socio-cultural potential of territories.

Given these peculiarities, BDs can be studied through the economic literature on industrial districts and economies of scale. According to Marshall (1920), territorial concentration enhances local firms' efficiency by activating external economies of scale. Building on Marshall's work, Porter (1990) posits that geographic concentrations of interconnected companies, specialised suppliers, service providers, and institutions can enhance competitiveness and drive innovation by raising labour productivity, supply chain coordination, knowledge spillovers and specialised human and technical resources, thereby strengthening firms' competitive advantage (David & Rosenbloom, 1990). These mechanisms are particularly relevant in LFSs, where small farms benefit from cooperation, vertical integration and collective production and marketing approaches (Mantino & Vanni, 2018). Consistent with Porter's cluster theory, BDs exhibit institutional and strategic arrangements for enhancing competition in local organic farming (Zanasi et al., 2020) and can represent an innovative approach to sustainable, integrated and participatory territorial development[5]. However, while the literature has extensively discussed the externalities of spatial concentration, quantitative evidence remains limited and mixed, despite offering valuable qualitative insights (Sturla et al., 2024). Truant et al. (2019) find no particular economic benefits for organic farmers associated with BD membership, contrary to expectations from localisation economics. Instead, studies based on self-evaluation of farmers in BDs through FAO's CAET assessment framework (Mottet et al., 2020) show that high "efficiency" scores driven by higher productive autonomy, reduced reliance on external inputs, and lower use of chemical

both the local uptake of organic farming and its supply chain, and the multifunctionality of agriculture, including integration with tourism (e.g., agritourism and social agriculture) and environmental protection (Pomponi et al., 2026).

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021DC0141

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021DC0345

[5] https://openknowledge.fao.org/server/api/core/bitstreams/be3a420b-37c0-4805-98c1-6d91783c9e4f/content

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inputs, leading to cost reduction and higher net income (Passaro & Randelli, 2022b). While efficiency is thus attributed to technical choices, these studies describe the existence of producer networks and knowledge-sharing within BDs, enabling economies of scale for better economic performances (Sciurano et al., 2024).

There's limited evidence on the contribution of BDs to farm labour productivity. To fill this gap, empirically assessing whether clustering processes in BDs enhance competitive advantages is highly relevant for policymaking, as this paper contributes to the effectiveness of territorial approaches to organic supply chains by examining labour productivity dynamics, which are closely linked to socio-economic outcomes such as unemployment and inequality (Wu et al., 2020), as well as to process and production innovation. The econometric model is based on the post-Keynesian framework, whereby labour productivity growth depends on the value-added dynamic (the so-called Smith effect or Kaldor-Verdoorn Law (see Sylos Labini, 2006)), thanks to division of labour and static and dynamic economies of scale, and on the capital intensity growth rate, according to Kaldor's technical progress function (Garofalo & Guarini, 2018). Using the System Generalized Method of Moments (GMM-SYS) estimator on a dynamic panel of the farms from the Italian FADN, this paper estimates how the labour productivity growth rate is impacted by local productive specialisation in BDs. Since this is not measured directly, the presence of a BD is used as its proxy, justified by the BD's definition as homogeneous territories with a relevant concentration of organic productions.

The remainder of the paper is organised as follows. Section 2 presents a literature review on industrial districts, territorial economies of scale and open eco-innovation, with a focus on food systems and BDs. Section 3 describes the database and the econometric model. Section 4 discusses results, while Section 5 concludes.

2. Literature review

Becattini (1991) defines the industrial district as a socio-territorial construct combining a community of individuals and a concentration of enterprises within a geographically and historically delimited

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area, predominantly operating in the same sector. Marshall's (1920) agglomeration advantages arise from three key factors: a) the ability to support specialised suppliers; b) a geographically concentrated industry allows for labour market pooling; c) a geographically concentrated industry promotes knowledge spillovers. Rabellotti (1995) observes four sources of competitive advantage in industrial districts: 1- spatial concentration and sectoral specialization of small and medium-sized enterprises (SMEs); 2- the existence of forward and backwards linkages, involving market and non-market exchanges of goods, information, and personnel; 3- a shared socio-cultural foundation connecting and shaping implicit but occasionally explicit actors' behavioural code; 4- the presence of local public and private institutional network supporting the cluster activities. These advantages can be interpreted as Marshallian external economies, manifesting statically as reducing production costs, and dynamically, encompassing education, workforce training, and the collective accumulation of tacit knowledge. Learning by doing and informal learning processes within districts foster innovation, leading to collective improvements in labour productivity (Bellandi & Caloffi, 2008), faster technological adoption (Foster & Rosenzweig, 1995), and the development of local learning communities (Volpentesta & Ammirato, 2013).

Becattini and Coltorti (2004) highlight that labour productivity growth depends on the interaction between the local community and the productive system, whose environment and human values and knowledge permeate the productive apparatus, while intra-district competition lowers the transaction costs in the local market (Becattini, 1991). The role of geographical concentration has been further developed in economic theory: Porter (1990), drawing on the Italian geographic clustering concentration and on the case of Sassuolo's industrial district (Sforzi, 2008), equates industrial districts as a specific form of industrial clusters within the broader cluster concept. Early-stage cluster development may intensify local competition, stimulating innovation and the continuous renewal of competitive dynamics (Pouder & St. John, 1996). Clusters enhance firms' productivity incentives through intense competitive pressure, continuous benchmarking, shared local conditions (e.g., labour

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costs and market access), and geographical proximity-driven differentiation among firms (Porter, 2000). The strong formulation of the Porter hypothesis, instead, posits that environmental regulation can induce eco-innovation, improving competitiveness by reducing costs and increasing productivity (Porter & Van der Linde, 1995).

Productivity growth is typically attributed to endogenous knowledge diffusion, promoted by firms' spatial proximity (Gustavsson, 2003). Synergistic mechanisms, including imitation, stakeholder collaboration, public–private partnerships, research–industry linkages, and supplier–customer interactions, strengthen regional innovation capacity (Rabellotti, 1995). Especially, industrial districts act as engines of economic development due to their flexibility and innovation capacity, as the "industrial atmosphere" sustains continuous grassroots innovation; however, global flows of knowledge and labour and the increasing integration of science into production challenge local identities and tacit capabilities, prompting both traditional and emerging districts to adopt the *open innovation mode* (Bellandi & De Propris, 2017). Under this approach, firms rely on external sources of knowledge, combining diverse competences and codified knowledge (Fabrizi et al., 2018). Indeed, the existence of a "*knowledge relations spiral*" within districts facilitates an ongoing circulation of tacit and codified knowledge among internal and external actors (de Felice et al., 2019), making knowledge accumulation and exchange a key source of sustained competitive advantage at both firm and district levels.

Despite manufacturing sector has received predominant attention due to its significant socio-economic implications associated with labour productivity growth, agglomeration can activate technology and knowledge spillovers, enhance competition in the agricultural industry, and more mature factor markets through stronger upstream–downstream linkages (Wang et al., 2022). Structural changes in the food industry (for instance, increased vertical integration, greater network coordination, and growing demands for "localities") parallel those in other sectors (Carbone, 2017), with evidence of output growth in downstream segments of food supply chains and territorial

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proximity-drive spillover effects. Specifically, the local clustering of wholesalers, retailers, food service providers, and concentrated agricultural production enhances firm revenues, with effects varying with urbanisation and non-linear agglomeration dynamics in rural areas (Schmit & Hall, 2013). However, empirical evidence on farm-level labour productivity in relation to territorial agglomeration remains limited. Garrone et al. (2019) examine how EU decoupled subsidies support labour productivity growth in agriculture, while coupled payments actually hinder it, although geographical factors are not fully accounted for. Instead, consistent with the Marshallian perspective, proximity and density improve farms' technical efficiency through knowledge exchange and spillovers (Hailu & James Deaton, 2016; Lakner et al., 2012).

Following the decline of mass production in the 1970s, nationally specific forms of geographic concentration gave rise to "Italian industrial districts", defined by clusters of SMEs specialising in consumer goods and related equipment (Sforzi, 2008), embedded in shared cultural contexts, local development dynamics, and dense inter-firm collaborations. This tradition progressively reframed Italian agricultural systems not only in spatial or environmental terms but also as places of social and economic relationships (Becattini, 2017), fostering the identification of geographically bounded agro-industrial systems shaped by local knowledge, territorial conformation and local traditions about techniques and agricultural products (Cavallo & Marino, 2014; Montresor, 2000). Organic farming - given its systemic nature and its environmental, social, and educational objectives - lends itself to district organisation, providing the foundation for the BDs' development and a conceptual link with the industrial district and territorial economies of scale literature.

The integrated territorial approach emphasises agrifood systems' ability to leverage their embeddedness and social networks, recognising their interdependence with local resources and proximity-based social relations (Kristensen et al., 2016). BDs can function as intermediate territorial entities, promoting the transition toward more sustainable food systems (Passaro & Randelli, 2022a). Although quantitative evidence remains limited, the literature situates BDs within Marshallian and Porterian frameworks of agglomeration externalities. By activating external economies of scale, BDs

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provide institutional and strategic arrangements for enhancing competition in local organic farming (Zanasi et al., 2020). In BDs, organic farming serves as a cohesive element around which actors coordinate and share goals and activities (Favilli et al., 2015), enabling the development of collective institutional arrangements, knowledge networks and market coordination that foster knowledge exchange, peer learning, and cooperative practices in input procurement and product distribution, thereby enhancing farm competitiveness (Saenz et al., 2024; Stotten et al., 2017).

BDs coordinate local farmers in adopting agroecological and organic practices, often involving eco-innovation aimed at environmental preservation and the sustainability of food systems (Canwat & Onakuse, 2022). Although eco-innovations improve process efficiency, labour productivity, and environmental performance, they require greater technological complexity and depend more on codified, heterogeneous knowledge than in other agricultural districts (Barbieri et al., 2020). BD provides a place-based agency for innovation grounded in shared knowledge fostered by social and geographical proximity (Chaminade & Randelli, 2020). However, SMEs' limited capabilities to develop eco-innovations can be mitigated through external knowledge and collaboration, as the open eco-innovation paradigm emphasises the role of external knowledge sources, responsible partnerships, and integration into eco-innovation systems in overcoming internal constraints and accessing diverse expertise through collaborative networks (Ghisetti et al., 2015). Although locally embedded, BDs benefit from engagement with national and international networks (e.g., the International Network of Eco-Regions), which support knowledge exchange and the diffusion of best practices (Belliggiano et al., 2020).

Since eco-innovations require more heterogeneous knowledge, the effectiveness of innovation capabilities depends on the cooperation among heterogeneous stakeholders to facilitate efficient, low-cost knowledge integration (Fritsch & Schwirten, 1999). The Quintuple Helix model frames innovation as emerging from interactions between universities, industry, institutions, civil society and the "society's natural environments" (Carayannis et al., 2022), and clusters embody such multi-actor

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configurations (Porter, 2000). Although geographically extensive districts are gaining importance, they can complement localised relationships, fostering knowledge creation and diffusion, especially via strong university–industry linkages and civil society engagement, enabling multi-stakeholder innovation hubs. BDs, bringing together farmers, public authorities, civil society, and economic actors, can be interpreted as locally coordinated Quintuple Helix systems, where multi-level collaboration and environmental embeddedness foster knowledge accumulation, supply-chain specialisation, and farm-productivity gains (Donati et al., 2023).

3. Data and Econometric Model

This study investigates the impact of BDs on farms' labour productivity growth rate using an unbalanced dynamic panel from the Italian FADN database, covering over 122,000 farms[6] between 2008 and 2021.

In the post-Keynesian thought, labour productivity growth rate is a crucial variable for economic development, capturing innovation, competitiveness and efficiency improvements. The output growth rate and the capital accumulation process can endogenously determine it. The former concerns the so-called Smith effect (Sylos Labini, 2006): the market expansion stimulates the horizontal and vertical division of labour, fostering technical and organisational innovations and, consequently, labour productivity gains. This effect is also called the Kaldor-Verdoorn law (Thirlwall, 1983), which links labour productivity growth to value-added growth rate via static decreasing fixed unit costs for the enlargement of the production scale and dynamic increasing returns or economies of scale for learning by doing, learning by using and learning by networking (Hein & Tarassow, 2010). The latter corresponds to the mechanisation effect expressed by Kaldor's technical progress function concerning the innovation processes for labour saving (Antenucci et al., 2020). Increases in capital per worker enhance labour productivity growth, as technological progress is embodied in new capital equipment,

[6] Farms located in the regions of Sardinia and Marche were excluded from the sample to prevent potential bias due to the presence of BDs covering the entire regional territory, which would compromise estimates based on inside–outside geographical comparisons

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enabling the adoption of more advanced methods, with consequent higher labour productivity (Kaldor, 1961). Therefore, the econometric strategy is specified as follows (see Supplementary material for detailed description of Italian BDs, summary statistics and robustness check):

$$dPROD_{it} = \alpha_0 + \alpha_1 dPROD_{it-1} + \alpha_2 dVA_{it} + \alpha_3 dKL_{it} + \alpha_4 BD + \alpha_5 \sum_{i=1}^{n} FARM\_CHAR_i + \gamma_{ij} + \mu_t + c_i + u_{it} \quad (1)$$

$$dPROD_{it} = \beta_0 + \beta_1 dPROD_{it-1} + \beta_2 dVA_{it} + \beta_3 dKL_{it} + \beta_4 \sum_{i=1}^{n} BD\_CHAR + \beta_5 \sum_{i=1}^{n} FARM\_CHAR_i + \gamma_{ij} + \mu_t + c_i + u_{it} \quad (2)$$

Where for farms $i = 1, \dots, 122000$ and the reference year $t = 2008, \dots, 2021$. The terms γ_{ij}, μ_t, c_i and u_{it} are regional dummies, year dummies, the idiosyncratic individual and time-invariant firm fixed effects and a white noise residual, respectively.

In equations (1) and (2), the dependent variable is the farm's labour productivity growth rate ($dPROD_{it}$), calculated as the first difference of the logarithm of the ratio between value-added and Agricultural Working Unit (AWU). All models include the lagged dependent variable ($dPROD_{it-1}$), the capital intensity growth rate (dKL_{it}) given by the logarithm of the ratio between tangible assets and the number of employees, the value added growth rate (dVA_{it}) measured as the logarithm of deflated value added. All models control for important farm characteristics ($FARM\_CHAR$): $LEGAL\_FORM$ dummies[7] based on the farm's legal form from the registration to the Chamber of Commerce; $MANAG\_SYS$[8] dummies, which indicate the management system of farms, depending on the type of labour is used; OTE_CODE dummies[9], controlling for the type of farming as defined by REG (EC) No 1242/2008 and implemented in the FADN survey to identify the type of agricultural

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[7] The legal forms in the FADN dataset are: 1) Sole proprietorship; 2) Simple partnership; 3) General partnership (s.n.c.); 4) Limited partnership (s.a.s.); 5) Joint-stock company (s.p.a.); 6) Limited liability company (s.r.l.); 7) Partnership limited by shares (s.a.p.a.); 8) Cooperatives (with limited or unlimited liability); 9) Social cooperative; 10) Producers' association; 11) Other recognized or unrecognized association; 12) Public entity; 13) Other profit-oriented legal form (Consortium); 14) Other non-profit legal form (Foundation); 15) Common ownership or collective lease; 16) Other type.

[8] Farmers can adopt the six management systems: 1 = Direct management with only family members; 2 = Direct management with a majority of family members; 3 = Direct management with a majority of non-family members; 4 = With employees; 5 = With contract work only; 6 = Other forms of management.

[9] The farming Code in FADN dataset are: 1 = Specialist field cropss; 2 = Specialist horticulture; 3 = Specialist permanent crops; 4 = Specialist grazing livestock; 5 = Specialist granivores; 6 = Mixed cropping; 7 = Mixed livestock holdings; 8 = Mixed crops-livestock.

holding according to its main production activity; UAA is the logarithm of the utilised agricultural area.

Equation (1) includes the independent variable BD, a dummy representing whether the farm lies in a Municipality inside a biodistrict used as a proxy for agglomeration effects and potential economies of scale generated by biodistricts. Equation (2) controls for a set of territorial and farmer characteristics that interact with BD membership (BD_CHAR): a) if the farm within a BD exhibit positive growth in renewable energy use (BD_rin), to account the energy-related technical efficiency; b) if the farm belongs to a BD that is not located in Less Favoured Areas (LFAs)[10] (BD_nozsva); c) if the BD is located in the North-Central regions (BD_CN) or in the South and Sicily (BD_MZ); d) if the farm within a BD is managed by a young farmer under 40 (BD_young) for testing the role of younger farmers in fostering innovation and sectoral sustainability, as they introduce novel perspectives, drive innovation, and inject vitality (Goulas & Papachatzis, 2024); e) the BD experience and the accumulated tacit knowledge (Exp), measured as the logarithm of the difference between the year of observation and the year of its establishment.

Estimating the agglomeration effects on labour productivity requires addressing endogeneity arising from potential reverse causality (Graham et al., 2010). To address this problem, this empirical analysis employs the system generalised method of moments (GMM-SYS) approach (Blundell & Bond, 1998), which accounts for individual fixed effects and the past dependency of the dependent variable, as well as the potential endogeneity resulting from reverse causality between regressors and the dependent variable (Garofalo et al., 2020). All continuous covariates and BD are treated as potentially endogenous and instrumented using the lagged covariates and dummies related to the farm's

[10] LFAs are classified, according to EU Regulation No. 950/97 (Articles 22–24) in: 1) no disadvantaged; 2) partially disadvantaged by natural conditions; 3) totally disadvantaged by natural conditions; 4) partially disadvantaged for socio-economic inequalities; 5) totally disadvantaged for socio-economic inequalities.

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characteristics, regions and years as instruments. This GMM-SYS is particularly suitable for unbalanced panel data, enhancing efficiency through an expanded instrument set (Roodman, 2009).

4. Results and discussion

4.1. Main results

This section shows and discusses the empirical evidence regarding the impact of BD location on farm labour productivity dynamics (see Table 1), and further examines this effect in relation to specific characteristics of BDs and farms (see Table 2).

In Table 1, columns 1 and 4 show the baseline model without and with the biodistrict (BD) dummy, respectively, estimated on the whole sample of farms. Columns 2 and 3 present the baseline model estimated on subsamples of farms located outside and inside BDs, respectively. Column 5 replicates the specification in column 4, treating BD membership as potentially endogenous to account for the unobserved factors that connect farmers' participation in a BD and higher productivity rates. The baseline model is confirmed in all the equations, both for the whole sample as well as for "inside" and "outside" BD subsamples (see columns 1-3 of Table 1). The overall negative and significant coefficient of the lagged variable $dPROD_{it-1}$ shows a negative dependence of labour productivity dynamics on the past. Consistent with the post-Keynesian literature, Value Added growth rate (dVA_{it}) shows a positive and significant coefficient at 1% (5% in column 2), suggesting the positive effect of economies of scale for labour productivity in agriculture. The significant (at 1%) and positive coefficients of dKL_{it} support the validity of the mechanisation effect also for the agricultural sector, although its significance decreases to 10% in column 3.

Table 1 reveals that BD participation positively impacts farm-level labour productivity, as indicated by the significant at 5% positive coefficient of the BD dummy in column 4. In column 3 (farms inside BDs), variable UAA_{it} is significant (5%) with a negative coefficient, consistent with the inverse relationship between innovation capacity and land size typically observed in more traditional farms

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with a lower propensity to innovate (Helfand & Taylor, 2021). Since BDs primarily target farms that benefit most from cooperation initiatives (RRN, 2019), this evidence, together with the positive and significant coefficient of "being in a BD" in column 4, suggests that the observed productivity gains are driven by agglomeration (Marshallian) externalities associated with spatial proximity. When BD participation is treated as potentially endogenous (column 5), its coefficient remains positive and statistically significant, confirming the robustness of the BD–productivity relationship to endogeneity bias.

Table 1. The impact of BD participation on a farm's labour productivity

	(1)	(2)	(3)	(4)	(5)
	$dPROD_{it}$	$dPROD_{it}$	$dPROD_{it}$	$dPROD_{it}$	$dPROD_{it}$
	All farms	*Farms outside BD*	*Farms inside BD*	*All farms (Exogenous BD)*	*All farms*
$dPROD_{it-1}$	-0.104***	-0.0339	-0.174***	-0.0832*	-0.0832*
	(-3.02)	(-0.28)	(-5.29)	(-1.94)	(-1.93)
dVA_{it}	0.604***	1.309**	0.689***	0.618***	0.593***
	(4.46)	(2.18)	(4.07)	(3.48)	(3.35)
dKL_{it}	3.627***	7.585***	1.517*	3.965***	3.926***
	(3.02)	(2.98)	(1.74)	(2.79)	(2.76)
BD				5.550**	3.689**
				(2.27)	(2.09)
UAA_{it}	0.168	0.109	-0.830**	-0.00634	0.0763
	(0.57)	(0.47)	(-2.54)	(-0.03)	(0.34)
Constant	1.646*	-0.191	2.242***	-0.561	-0.527
	(1.68)	(-0.37)	(3.09)	(-0.82)	(-0.82)
LEGAL_FORM Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
MANAG_SYS Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
OTE_CODE Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Regional Dummies	*Yes*	*yes*	*yes*	*yes*	*yes*
Year Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	62777	52125	10652	62777	62777
Hansen test (p-value)	0.522	0.428	0.681	0.236	0.242
AR (1) (p-value)	0.00000219	0.00000115	2.71e-13	0.0000273	0.0000277
AR (2) (p-value)	0.392	0.0759	0.522	0.199	0.200

Note: t statistics in parentheses; * p<0.1, ** p<0.05, *** p<0.01

Table 2 expands the analysis by interacting BD membership with farm and territorial characteristics to explore sources of the competitive advantage (treating BD dummy as endogenous). While baseline model is confirmed in all equations with consistent effects, the interaction variables reveal a mutually reinforcing impact of farms and territorial characteristics and BD presence on labour productivity dynamics. Although the coefficient of UAA_{it} remains insignificant, its inclusion its inclusion

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strengthens model robustness as a key control. Column 1 reports the interaction of BD membership with the adoption by farmers of renewable energy (BD_rin), representing eco-innovations. The positive and significant at 5% coefficient of BD_rin suggests that BD environments foster conditions conducive to sustainable innovation; since renewable resources are widely available within the farm sector, effective energy-efficient practices and on-farm renewable energy sources can reduce farmers' energy costs.

In column 2, the positive and significance (5%) coefficient of BD_nozsva indicates that the competitive advantage from BD participation is not driven by marginality because it focuses on municipalities without physical or social disadvantage (Reg EC 950/97). Columns 3 and 4 report the coefficients of the interactions between BD membership and the geographical area: Centre-Northern (CN) and Southern (MZ) Italy, whose coefficients are both positive and significant at 10% and 5% respectively. Both variables grasp the interaction between BD and territorial features not captured by other covariates, suggesting that BD's action depends on the local socio-economic context. While organic farming and cooperation are prevalent in Southern Italy, some Centre-Northern regions have introduced specific regional legislation[11] regulating BDs, eventually providing for financial support (Assiri et al., 2021).

Column 5 evaluates the interaction between BD membership and the young farmer status. The significant at 5% and positive coefficient of BD_young variable indicates that younger farmers' greater propensity for innovation contributes to labour productivity growth, reflecting their higher openness to new initiatives and stronger inclination toward organic agriculture and participation in biodistricts (Mazzocchi et al., 2020). Lastly, column 6 reports a positive and significant at 5% impact of BDs experience (Exp) on labour productivity, supporting the presence of a "district effect" in agriculture.

[11] Liguria (L.R. 66/2009); Lazio (L.R. 22/2019) and Toscana (L.R. 16/2014).

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Table 2. The impact of biodistricts' characteristics on labour productivity.

	(1) $dPROD_{it}$	(2) $dPROD_{it}$	(3) $dPROD_{it}$	(4) $dPROD_{it}$	(5) $dPROD_{it}$	(6) $dPROD_{it}$
dPROD_{it-1}	-0.0837*	-0.0814*	-0.0818*	-0.0832*	-0.0932**	-0.169*
	(-1.94)	(-1.88)	(-1.89)	(-1.93)	(-2.19)	(-1.83)
dVA_{it}	0.596***	0.650***	0.625***	0.593***	0.587***	0.522
	(3.37)	(3.48)	(3.48)	(3.35)	(2.95)	(0.99)
dKL_{it}	3.927***	3.953***	4.014***	3.926***	3.580**	3.106***
	(2.77)	(2.83)	(2.80)	(2.76)	(2.56)	(3.49)
BD_rin	3.909**					
	(2.25)					
BD_nozsva		4.763**				
		(2.10)				
BD_CN			4.336*			
BD_MZ			(1.75)			
				3.689**		
				(2.09)		
BD_young					1.190**	
					(1.96)	
Exp_{it}						0.359**
						(1.99)
UAA_{it}	0.0630	0.0653	0.0760	0.0763	0.362	
	(0.28)	(0.29)	(0.33)	(0.34)	(1.08)	
Constant	-0.521	-0.240	-0.573	-0.527	1.648	-0.0843
	(-0.83)	(-0.43)	(-0.79)	(-0.82)	(1.46)	(-0.43)
LEGAL_FORM Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*
MANAG_SYS Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*
OTE_CODE Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*
Regional Dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	62777	62777	62777	62777	62777	2584
Hansen test (p-value)	0.291	0.165	0.0823	0.242	0.930	0.0732
AR(1) (p-value)	0.0000276	0.0000292	0.0000290	0.0000277	0.00000910	0.00676
AR(2) (p-value)	0.200	0.197	0.196	0.200	0.394	0.744

Note: t statistics in parentheses; * p<0.1, ** p<0.05, *** p<0.

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4.2. Discussion of results

Evidence from Tables 1 and 2 suggests that the competitive advantages derived from BD membership could stem from its place-based development approach, which activates external economies of scale. Consistent with the post-Keynesian literature (e.g., Blecker & Setterfield, 2019), findings confirm the key role of economies of scale in enhancing labour productivity in agriculture. As output increases, average costs decline, improving efficiency and supporting farm labour productivity growth through innovation and specialisation. Empirical evidence from a group of farms in the Salzburg region specialising in milk production shows that the pursuit of scale economies increases production intensity, labour productivity, and reduces production costs. In addition, the mechanisation effect aligns with previous studies, describing how mechanisation in labour-intensive agriculture enhances labour productivity by complementing labour (De Roest et al., 2018).

Cooperation and knowledge sharing, either formal or informal, are central in BD strategies (Passaro & Randelli, 2022b). Results suggest how the territorial clustering of specialised farms generates agglomeration advantages, lowering per-unit costs and intensifying regional specialisations, as observed in other agricultural districts. While this supports a competitive advantage from BDs, its exact source remains difficult to identify. It may reflect the activation of aggregation economies and the emergence of dynamic increasing returns and learning processes related to cooperation initiatives. However, the presence of economies of scope due to diversification cannot be excluded, as highlighted in similar experiences (De Roest et al., 2018).

A further contribution of the empirical study is that positive impacts on BDs' participation also extend to conventional farmers, reflecting the "industrial atmosphere" generated by specialisation, which benefits not just organic farmers (Becattini, 1991). The Biovallee case in France shows that BD's atmosphere supports the adoption of environmentally friendly practices by local conventional farmers. Consistent with the open eco-innovation mode, complementarities between standard and new institutional innovations, such as BDs conceived as "*instruments of knowledge*" (Stefanovic & Agbolosoo-Mensah, 2023), generate knowledge spillovers and economies of scope. This context is characterised by trust, networking, and institutional arrangements, reflecting the embeddedness of local economic activities (Granovetter, 1985).

Rising concerns over climate change and industrial sustainability have intensified focus on the environmental performance, particularly on energy efficiency due to its link to innovation and competitiveness (Tripathy et al., 2024). This connection is particularly evident in agriculture, where

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energy productivity remains volatile, indicating limited farmers' ability to optimise energy use through technological upgrading and energy-saving practices (Ball et al., 2015). Findings suggest that BDs can activate inter-organisational networks and innovative governance for greater productivity and sustainability, driving improvements in energy efficiency and circular-economy initiatives (Poponi et al., 2021), consistent with Law 23/2022's call for "*pursuing resource-conserving development*" (Art 13). Indeed, BDs actively promote networks for rational and sustainable energy use with the double objective of curbing CO_2 emissions while lowering production costs (Lasorella, 2024).

Consistent with existing literature, yet at odds with the perceived mission of BDs, the association between BD-related competitive advantages and territorial marginality suggests that benefits tend to concentrate in municipalities lacking significant physical or social disadvantages, despite BDs being intended as instruments for rural revitalisation. Therefore, the BD effectiveness seems closely conditioned by the local socio-economic context, particularly the availability of supporting services and infrastructure (Assiri et al., 2021). Furthermore, the long-standing experience of BDs can stimulate alternatives to mainstream agricultural regimes by enabling new business models and organisational routines, thereby enhancing the attractiveness of rural areas for younger farmers, who are more likely to adopt innovative practices, undertaking higher levels of risk for establishing and expanding their enterprises (May et al., 2019). The Val di Vara biodistrict exemplifies this dynamic: sustained collective action in organic farming has restructured local meat and dairy supply chains, increasing employment opportunities and areas' appeal to younger farmers (Viganò & Sturla, 2013).

By bridging the industrial district and agricultural economics literature, this study shows that a "district effect" on labour productivity emerges once BD activity becomes significant, typically over the medium term. Time is crucial for the development of the district atmosphere and the activation of external economies. Technological progress is a cumulative learning process, underpinning the knowledge accumulation and the emergence of innovation (Winter et al., 2000). Accordingly, regions

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with a longer history of specialisation tend to endow firms with greater stocks of intangible assets, such as tacit knowledge and institutional capabilities, than less developed regions (Gustavsson, 2003).

5. Conclusions

This paper estimates the effects of BDs on farm labour productivity growth using a dynamic panel GMM model on the Italian FADN dataset. Findings highlight that BD membership positively affects innovation and competitiveness, supporting the economic viability of sustainability-oriented networking. By framing BDs within a post-Keynesian framework, the BDs' impact on labour productivity is interpreted as arising from their intrinsic nature, whereby development processes involve civil society and sustainability principles generate competitive advantages, indicating their capacity to activate dynamic returns to scale as a key mechanism shaping local growth.

Findings support integrating a territorial perspective into post-Keynesian economics by combining the economies of scale analyses (dynamic increasing returns, learning by doing, network externalities) with place-based drivers and barriers, concerning institutional, geographical and social dimensions, and the evolutionary path of local economic and technological relations. In line with the quintuple helix model, considering BDs as institutional innovation where science, business, policy, society, and nature interact underscores their nature of collective innovation, in which local demand sustains labour productivity and collective action generates spillovers diffusing sustainable farming practices (Kreft et al., 2023).

Empirical analysis provides interesting policy implications. From the lenses of Porter's strong hypothesis, organic farming principles can act as institutional drivers of efficiency and product diversification. Evidence from BD practices supports this view: municipalities within the *Biodistretto della Via Amerina e delle Forre* issued regulations limiting pesticide use in hazelnut orchards, alongside technical support - provided in collaboration with regional authorities - to facilitate

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compliance among conventional farmers[12]. Findings suggest that BD initiatives generate indirect benefits for conventional farms. BDs' policies should aim to stimulate at least the adoption of sustainable practices by conventional farms because strengthening the 'district atmosphere' through enhanced social capital and knowledge diffusion can foster their uptake of sustainable practices. As in the Parma Biodistrict (Guareschi et al., 2023), progressive labelling or participatory certification systems could be supportive.

Findings show that BDs can be conceptualised as territorial systems in which labour productivity benefits from governance structures reinforcing environmental policies (such as incentives for renewable energy adoption) through the cooperative and knowledge-sharing dynamics typical of the district approach, as observed in local food systems. Nevertheless, this "district effect" rises in non-marginalised areas, underscoring the role of rural-urban interaction in fostering innovation (Packer & Zanasi, 2023) and the influence of socio-territorial factors partly beyond BDs' control. This needs to complement BD initiatives with policies aimed at reducing territorial disparities. Consistent with the 2025 European Commission's "A Vision for Agriculture and Food"[13], the positive impact of the Common Agricultural Policy must be complemented with cohesion policies supporting economic diversification, infrastructure and services provision.

The study's limitations provide avenues for future research. The main constraint concerns the absence of explicit consideration of spatial interactions, which could generate spillovers and spatial dependence, thereby limiting agglomeration dynamics' analysis. This limit stems from the nature and size of the data, which preclude robust spatial regression analysis. Approximately 20% of observations are not georeferenced, leading to an information loss in the GMM model, and only a small share of farms in the FADN dataset are located in municipalities within BDs, weakening the identification of meaningful spatial linkages. Moreover, the unbalanced panel, covering nearly

[12] https://biodistrettoamerina.com/pan-pesticidi/.

[13] https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

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100,000 farms, pose significant computational challenges for a spatial regression. Future research will develop datasets suitable to measure potential BDs' spatial spillovers. The analysis does not differentiate between organic and conventional farms, preventing the assessment of heterogeneity in BD effects. While this does not undermine the research question, since BD-related benefits appear to extend to conventional farms, likely through district "atmosphere" effects, "physical" endowments (such as local specialisation, supply chain infrastructures, knowledge spillovers emerging within districts, and access to the shared networks), establishing a stronger relationship between labour productivity enhancement and spillovers between organic and conventional farms remains necessary. Finally, the dataset prevents identifying BD membership among organic farms. As members' farms benefit from dedicated market arrangements, technical assistance, marketing initiatives and cooperation projects, distinguishing membership status would allow a more robust assessment of differential impacts between 'inside' and 'outside' BDs.

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