“Public R&D support, financial instruments, and energy start-up ecosystems in Europe: Evidence on non-linear and delayed effects”

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PUBLIC R&D SUPPORT, FINANCIAL INSTRUMENTS, AND ENERGY START-UP ECOSYSTEMS IN EUROPE: EVIDENCE ON NON-LINEAR AND DELAYED EFFECTS

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Abstract

The transition to climate neutrality in Europe increasingly depends on the capacity of public policy to stimulate innovation, entrepreneurship, and investment in the energy sector. This study aims to examine whether, and under what conditions, public R&D support and finance-related policy instruments are associated with energy-related start-up activities and financing across European and neighboring economies, while accounting for delayed, non-linear, and country-specific effects. The analysis is based on panel data for 37 countries over the period 2018–2023. The study employs fixed-effects, PPML, lagged, and quadratic specifications. The findings suggest weak short-term associations between policy support and energy start-up outcomes, while several delayed and non-linear patterns emerge. Two-year lagged estimations reveal significant delayed associations: government support is negatively associated with green start-ups (–0.0072) and digital start-ups (–0.0114), which may reflect crowding-out mechanisms or reactive policy behaviour, although these explanations are not directly tested. In contrast, finance-related support is positively associated with digital energy start-ups after two years (0.0225). Funding models show weaker transmission effects, although government support is negatively associated with early-stage green funding (–0.0605). Quadratic specifications reveal meaningful thresholds for government support at 51.33, 93.71 and 107.39 in baseline models and between 80.80 and 158.28 points in lagged models. The results suggest that policy–start-up relationships vary by timing, intensity, support type, and start-up segment. This highlights the scientific value of analyzing public support as a delayed, non-linear and context-dependent mechanism rather than as a simple direct stimulus.

Keywords climate neutrality, energy start-ups, European economies, financial support, lagged effects, non-linear effects, public R&D support

JEL Classification O38, Q42, Q55, G28, C23

INTRODUCTION

This study is relevant because the transition towards climate neutrality requires a better understanding of how public R&D support and finance-related policy instruments influence the development of energy start-up ecosystems. In this article, energy start-ups are understood as a broad category that includes both green energy start-ups, focused on clean and sustainable energy solutions, and digital energy start-ups, focused on the application of digital technologies to energy systems. These categories are derived from the International Energy Agency's classification framework and are analyzed as separate segments of the energy start-up ecosystem; potential overlap at the firm level cannot be excluded.

The transition to climate neutrality has become a key priority for Europe, increasing the importance of innovation and entrepreneurial ecosystems. Clean energy start-ups are essential for accelerating the development and deployment of net-zero technologies (IEA, 2024), while Europe's competitiveness depends on scaling green and digital firms across sectors such as renewable energy, hydrogen, and smart energy systems (European Commission, 2025). However, differences in institutional capacity and access to risk finance still create unequal start-up conditions across advanced and transition economies (European Commission, 2024; EIB, 2024).

Public R&D support and financial instruments are key tools for energy-sector innovation, especially in early-stage clean technologies where market failures are most pronounced (IRENA, 2024; IEA, 2024). Their effectiveness depends on policy design, scale, institutional quality, and financial system maturity, which can create both crowding-in and crowding-out effects (OECD, 2024; EIB, 2024). Despite REPowerEU and the European Green Deal Industrial Plan, European finance remains fragmented, with transition economies still facing limited access to venture capital for scaling energy start-ups (European Commission, 2025).

Understanding how public R&D support and financial instruments are associated with energy start-up activity is increasingly important for European integration and global competition. However, evidence remains limited on their delayed, dynamic, and non-linear effects across different national contexts. Addressing this gap is essential for assessing their contribution to climate neutrality, economic convergence, and Europe's role in the global innovation system (IEA, 2024; European Commission, 2025).

The contribution of this study is threefold. First, unlike previous research that mainly examines general determinants of start-up development, entrepreneurial ecosystems, or innovation performance, this article focuses specifically on public R&D support and finance-related policy instruments as drivers of energy start-up formation and financing. Second, the study moves beyond immediate, linear policy effects by explicitly testing delayed and nonlinear relationships, including one- and two-year lags, quadratic specifications, and turning-point analysis. Third, by distinguishing between green and digital energy start-ups and between early- and later-stage funding, the article provides a more differentiated understanding of how policy instruments operate across different segments of the energy start-up ecosystem. In this way, the study complements existing literature by examining how the associations between public support and start-up outcomes vary across policy timing, policy intensity, and different segments of the energy start-up ecosystem.

Therefore, this article aims to examine whether, and under what conditions, public R&D support and finance-related policy instruments are associated with energy-related start-up activity and financing across European and neighboring economies, while accounting for delayed, non-linear, and country-specific effects. To achieve this aim, the study analyses the formation of green and digital energy start-ups, early- and later-stage funding, and the roles of policy timing and intensity using cross-country panel data methods.

1. LITERATURE REVIEW

The development of energy start-up ecosystems is increasingly recognized as a key driver of sustainable economic transformation, particularly in the context of climate neutrality and the green transition. Innovation and entrepreneurship are central to economic growth, as they facilitate the diffusion of new technologies and enhance competitiveness within the global economy. Start-ups support growth by developing and commercializing innovations in uncertain and capital-intensive energy sectors (Ziane et al., 2025; Dadkhah et al., 2024). Their performance depends on institutional frameworks, digitalization, and collaborative networks that shape innovation dynamics (Mursalov et al., 2023; Zhuravka et al., 2025).

Public policy instruments, especially R&D support and financial mechanisms, are important for innovation and entrepreneurship, particularly when early-stage financing is characterized by high uncertainty and risk. Targeted support can stimulate eco-innovation and green entrepreneurship, but its effectiveness depends on design and implementation (Juracka et al., 2024; Burrell et al., 2025). Public finance may also crowd in or crowd out private capital depending on institutions and market maturity, showing that policy effects are non-linear and context-specific (Streimikiene et al., 2024; Benlefki et al., 2024). These findings suggest that the impact of policy instruments is not linear and may vary across countries and sectors.

Access to finance remains a major constraint for energy start-ups, especially in transition and emerging economies. Limited credit, weak investor protection, and underdeveloped financial markets hinder start-up growth (Artyukhov et al., 2024; Halynskyi & Telizhenko, 2024). Regulatory burdens and complex market-entry procedures further constrain clean and digital energy start-ups (Podosynnikov et al., 2024; Myroshnychenko et al., 2024). Entrepreneurial decisions are also shaped by financial perceptions and risk attitudes in uncertain environments (Civelek et al., 2025; Dorusincova et al., 2025).

The role of entrepreneurial ecosystems and institutional support structures has been widely emphasized in the literature. Start-up success depends on finance, ecosystem resources, entrepreneurial competencies, and networks (Imo & Makanjuola, 2025; Jurgelevičius & Raišienė, 2025). University–industry collaboration and knowledge transfer support innovation in technology-intensive sectors (Kuzior et al., 2024a; Samoilikova et al., 2023; Zhylinska & Sitnitskiy, 2018), while digital development strengthens knowledge exchange (Kuzior et al., 2024b). Leadership, decision-making, and adaptability also enhance start-up resilience and performance (Arfara & Karasavvoglou, 2026; Saba et al., 2025).

Recent studies also highlight the importance of contextual factors, including regional development, post-crisis recovery, and socio-economic conditions, in shaping entrepreneurial ecosystems. Transition and post-war economies face specific innovation challenges, requiring targeted policy and institutional reforms (Khymych & Masurel, 2025; Sitnicki et al., 2024). Ensuring economic freedom is crucial amidst the rapid development of entrepreneurial ecosystems (Sitnicki et al., 2026). Crisis experience, including COVID-19, shows the importance of timely government support for SMEs (Kornyliuk et al., 2022). Sustainability awareness and energy-related attitudes also shape energy entrepreneurship and innovation ecosystems (Sardianou & Kougias, 2025; Urmanaviciene, 2025).

Knowledge management, leadership, and decision-making processes also shape entrepreneurial outcomes. Effective knowledge and leadership practices strengthen innovation and performance in uncertain environments (Alemu, 2025; Behar Villegas et al., 2024), while cost management and decision-making tools improve start-up efficiency and sustainability (Daowadueng, 2024; Raišienė & Raišys, 2024). Digital technologies and innovation systems further support resilient entrepreneurial ecosystems (Zahidi et al., 2025; Yassin et al., 2024).

Despite the growing literature on start-up ecosystems, green entrepreneurship, innovation policy, and sustainable finance, several important gaps remain. First, many existing studies focus on broad entrepreneurial conditions, institutional quality, access to finance, or university–industry collaboration. In contrast, fewer studies isolate the specific effects of public R&D support and finance-related policy instruments on energy start-up ecosystems. Second, previous empirical research often assumes immediate and linear effects. In contrast, policy support may influence start-up formation and venture financing only after a time lag and only within certain intensity thresholds. Third, limited attention has been paid to differences between green and digital energy start-ups and between early- and later-stage funding. This study addresses these gaps by applying a cross-country panel framework with fixed effects, PPML models for start-up counts, log-linear models for funding variables, lagged specifications, and quadratic turning-point analysis. Therefore, the article contributes to the literature by integrating policy timing, policy intensity, and start-up segment heterogeneity into a single empirical framework.

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2. METHODOLOGY

This study employs a quantitative panel-data approach to examine the relationship between policy support mechanisms and the development of energy-related start-up ecosystems. The empirical analysis is based on a cross-country dataset covering 37 European and neighboring economies, including Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Netherlands, North Macedonia, Norway, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom, over the period 2018–2023, yielding 222 country–year observations. This sample ensures broad heterogeneity in economic development, institutional capacity, and innovation performance, enabling a comprehensive assessment of policy impacts across diverse national contexts. The sample includes EU member states, non-EU European countries, and neighboring economies. These countries were analyzed jointly because they participate in a broadly interconnected European innovation and energy-transition environment while displaying substantial variation in institutional quality, financial-market development, and innovation-system characteristics. Such heterogeneity increases the dataset's analytical variation and enables the identification of broad cross-country patterns. Country fixed effects are employed to account for time-invariant national differences.

Importantly, the sample includes both EU member states and non-EU European and neighboring economies, enabling interpretation of the results across different levels of economic development, institutional maturity, and public policy frameworks.

The dependent variables capture both the scale of entrepreneurial activity and the availability of financial resources within energy-related innovation ecosystems. Specifically, the analysis includes the number of energy and green start-ups, energy and digital start-ups, as well as early- and later-stage funding volumes for both categories. In this study, the term "energy start-ups" refers to young, innovative firms whose products, services, or business models are related to the energy sector. Within this broader category, two segments are distinguished. Green energy start-ups are firms developing technologies, products, or services that directly support the clean energy transition, decarbonization, renewable energy deployment, energy efficiency, storage, or other environmentally sustainable energy solutions. Digital energy start-ups are firms whose activities are based on digital technologies, data-driven services, software, artificial intelligence, smart grids, digital platforms, demand-side management, or other digital tools applied to energy systems. This distinction is important because green and digital energy start-ups may respond differently to public R&D support and financial instruments: green start-ups are often more capital-intensive and technology- and infrastructure-dependent, whereas digital start-ups may scale faster but require stronger digital infrastructure, data access, and market integration. These data are sourced from the International Energy Agency's Energy Start-up Data Explorer (IEA, n.d.), which provides harmonized and comparable cross-country indicators of start-up ecosystems. To address strong right skewness and the presence of zero values in funding variables, logarithmic transformations of the form log(x+1) are applied in linear specifications. In contrast, count variables are analyzed using Poisson-based models. Different estimation approaches are applied because the dependent variables differ in their statistical properties. Start-up activity is measured as count data and is therefore analyzed using PPML estimators. In contrast, funding outcomes are measured as continuous financial variables and are analyzed using log-linear fixed-effects specifications after logarithmic transformation.

The key explanatory variables, namely direct and indirect government support for business R&D and finance and support, are obtained from the European Innovation Scoreboard (European Commission, n.d.). These variables are composite index indicators reported by the European Commission (n.d.) and expressed as performance scores rather than monetary values. Higher values indicate stronger relative performance in the corresponding policy dimension compared with the benchmark framework used in the European Innovation Scoreboard. Consequently, values such as 50, 100, or 150 should be interpreted as positions on the European Innovation Scoreboard indicator scale rather than as percentages, monetary units, or direct measures of public expenditure. To control for broader macroeconomic and technological conditions, the models include GDP per capita (PPP, constant 2021 international dollars) from the World Bank (n.d.) and research and development expenditure as a percentage of GDP from the United Nations Economic Commission for Europe (UNECE, n.d.). These variables capture differences in economic development and innovation capacity that may influence both entrepreneurial activity and access to funding. The objective is not to estimate country-specific policy effects but to examine average cross-country associations within a diverse set of European and neighboring economies.

The analysis is conducted at the ecosystem level using aggregated indicators reported by the IEA Energy Start-up Data Explorer. Therefore, green and digital energy start-ups should be interpreted as analytical categories within the database rather than necessarily mutually exclusive groups of firms. Some start-ups may possess both green and digital characteristics; however, the study follows the classification framework of the underlying data source and analyzes the reported categories separately.

The empirical strategy is based on two-way fixed-effects (TWFE) models that control for unobserved country-specific heterogeneity and common time shocks. For start-up count variables, Poisson pseudo-maximum likelihood (PPML) estimators are employed because the dependent variables are non-negative counts and include many zero observations. Funding variables are continuous monetary measures characterized by strong right-skewness and occasional zero values. Therefore, they are transformed using log(x+1) and estimated using log-linear fixed-effects models. Complementary log-linear fixed-effects models are estimated as robustness checks for funding variables. To account for potential delayed policy effects and mitigate reverse causality, the analysis incorporates lagged specifications (t–1 and t–2) of the explanatory variables. Furthermore, to capture potential threshold and diminishing-return effects, quadratic specifications based on mean-centered variables are estimated. The turning-point analysis is used as an exploratory tool to assess the economic relevance of estimated curvature and should not be interpreted as identifying precise optimal policy levels. Standard errors are clustered at the country level to account for serial correlation and heteroskedasticity. This multi-step modelling framework allows for a comprehensive assessment of linear, non-linear, and dynamic policy effects on energy start-up ecosystems. Given the relatively short time dimension of the panel, model complexity is limited by estimating each specification separately rather than combining lagged and non-linear structures within a single comprehensive model.

The modelling strategy follows a sequential rather than cumulative logic. Baseline TWFE and PPML models are first estimated to examine contemporaneous associations. Lagged specifications are subsequently introduced to assess delayed relationships, while quadratic terms are estimated separately to explore potential non-linear patterns. Turning-point calculations are derived from the quadratic models and are used solely to assess the economic relevance of the estimated curvature. Therefore, the empirical framework consists of complementary model specifications that address different analytical questions rather than a single, highly parameterized model.

The empirical framework is designed to identify statistical associations between policy variables and start-up outcomes rather than establish causal effects. Consequently, the estimated coefficients should be interpreted as conditional relationships after controlling for observed covariates and fixed effects. All data processing, model estimation, and statistical analyses were conducted in RStudio, ensuring reproducibility and consistency of the empirical results.

3. RESULTS

Table A1 (Appendix A) shows substantial cross-country heterogeneity across 222 observations from 37 countries during 2018–2023. Energy and green start-ups are more numerous on average than energy and digital start-ups, but both variables are highly dispersed and right-skewed, with medians far below means. This indicates that start-up activity is concentrated in a few innovation hubs.

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Funding variables are even more asymmetric. Average early- and later-stage funding is high, but medians are much lower, and some later-stage observations are zero. Extreme skewness and kurtosis show that venture capital is concentrated in selected countries and periods. These patterns justify the use of Poisson/PPML models and logarithmic transformations in the econometric analysis.

GDP per capita varies widely across countries, from about USD 13,500 to over USD 136,000, while R&D expenditure averages 1.62% of GDP. Government support for business R&D and financial support instruments also differ substantially, with mean values of 68.28 and 80.11. The data show strong heterogeneity, non-normality, and extreme values. This supports the use of fixed-effects panel models and robust estimation methods.

The results are presented sequentially, beginning with baseline specifications and then extending the analysis to lagged and non-linear models to evaluate the robustness and dynamics of the observed relationships. PPML estimations are reported for start-up count variables, whereas log-linear fixed-effects models are reported for funding outcomes. Table 1 shows that, after controlling for country- and time-fixed effects, none of the explanatory variables has a statistically significant effect on the number of energy-related start-ups. For green start-ups, government support for business R&D, financial support, GDP per capita, and R&D expenditure are insignificant, although GDP per capita has a weak positive sign. The results are similar for digital energy start-ups, where all coefficients are close to zero and insignificant. However, high pseudo R^2 values indicate that variation is mainly explained by country- and time-specific factors rather than short-term policy changes.

Table 2 shows delayed associations between policy variables and energy-related start-ups. One-year lag models are insignificant, while two-year lag models reveal significant effects. Government support for business R&D is negatively associated with start-up activity after a two-year lag on both green and digital start-ups, which may be consistent with crowding-out mechanisms or reactive policy behavior. However, these explanations are not directly tested in the present study. In contrast, financial support is positively associated with digital start-ups after a two-year lag. GDP per capita and R&D intensity also become significant for digital start-ups, showing the importance of broader structural conditions.

Table 3 shows that government support for business R&D has a significant negative effect only on early-stage green start-up funding, suggesting possible crowding-out of private venture capital or stronger support for weaker ecosystems. Other variables, including financial support, GDP per capita, and R&D expenditure, are not significant. For later-stage green funding and both digital funding categories, no significant effects are found. Low R^2 values indicate that short-term policy and macroeconomic changes explain little

Table 1. Poisson fixed-effects estimation results for energy start-ups

Source: Author's calculations in R Studio.

Variables	Green start-ups	Digital start-ups
Government support of business R&D	–0.000862 (0.001632)	0.000221 (0.002217)
Finance and support	0.004708 (0.005250)	0.001409 (0.005442)
Log GDP per capita	0.682731 (1.295452)	–0.147587 (1.313499)
R&D expenditure (% of GDP)	–0.160123 (0.279146)	–0.169163 (0.406161)
Observations	204	204
Country FE	Yes	Yes
Year FE	Yes	Yes
Adj. Pseudo R^2	0.8296	0.7363

Notes: Poisson pseudo-maximum likelihood estimations with country and year fixed effects. Standard errors clustered at the country level are reported in parentheses. No coefficients are statistically significant at conventional levels.

Table 2. Lagged Poisson fixed-effects estimation results for energy start-ups

Source: author's calculations in R Studio.

Variables	Green start-ups (t – 1)	Digital start-ups (t – 1)	Green start-ups (t – 2)	Digital start-ups (t – 2)
Government support (lag)	–0.001533 (0.001678)	–0.003022 (0.002640)	–0.007218*** (0.002228)	–0.011364** (0.004152)
Finance and support (lag)	0.006800 (0.004894)	0.001610 (0.005006)	0.011062 (0.007992)	0.022514*** (0.007169)
Log GDP per capita (lag)	0.129539 (1.407510)	1.107244 (1.381325)	1.308439 (2.004059)	4.892767** (2.124190)
R&D expenditure (lag)	–0.127635 (0.456447)	0.363741 (0.474760)	0.082288 (0.532774)	0.880441** (0.381949)
Observations	165	160	128	128
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adj. Pseudo R^2	0.8178	0.7172	0.8088	0.7004

Notes: Poisson pseudo-maximum likelihood estimations with country and year fixed effects. Standard errors clustered at the country level are reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

variation, while country- and year-fixed effects dominate. Policy effects on funding appear weak in the short run and may operate through delayed or indirect channels.

Table B1 shows that one-year lagged policy effects on start-up funding are mostly insignificant, confirming weak short-term impacts. R&D expenditure is weakly negative for early-stage green and digital funding, suggesting a possible initial reallocation of resources towards internal innovation rather than venture financing.

Two-year lag models reveal stronger but still limited effects. R&D expenditure significantly reduces early-stage green funding, while financial support is weakly negative for early digital funding. Most effects remain insignificant, indicating that funding dynamics depend more on persistent country-specific structural and institutional factors than on short-term policy changes.

The funding models suggest that public policy instruments have a weaker and less direct impact on venture financing than on start-up formation. The predominance of insignificant coefficients should not be interpreted as evidence that public R&D support and financial instruments are unimportant. Rather, it indicates that their short-term average effects are limited after controlling for country- and year-specific factors. Venture financing appears to depend more strongly on persistent

Table 3. Log-linear fixed-effects estimation results for funding variables

Source: Author's calculations in R Studio.

Variables	Early green funding	Late green funding	Early digital funding	Late digital funding
Government support of business R&D	–0.060516** (0.022284)	0.032946 (0.037883)	0.019616 (0.020717)	0.018413 (0.028933)
Finance and support	0.009846 (0.032887)	0.007269 (0.022238)	–0.014549 (0.038219)	–0.002844 (0.016125)
Log GDP per capita	–8.573798 (8.737128)	2.467492 (7.145191)	–2.962777 (10.053532)	–4.351619 (5.859534)
R&D expenditure (% of GDP)	–0.931335 (3.010781)	–2.879449 (4.369167)	–3.498043 (3.769081)	–2.281630 (2.909695)
Observations	222	222	222	222
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adj. R^2	0.6830	0.6692	0.6255	0.6534
Within R^2	0.0503	0.0176	0.0087	0.0081

Notes: Linear fixed-effects estimations with log(x+1) transformation of funding variables. Standard errors clustered at the country level are reported in parentheses. Significance levels: ** $p < 0.05$.

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ecosystem conditions, such as the maturity of financial markets, the availability of private investors, the quality of the start-up pipeline, regulatory predictability, and the capacity of firms to absorb external capital. Therefore, public support may influence funding indirectly by improving the broader innovation environment, but this effect is unlikely to appear immediately in aggregate funding volumes.

Table 4 presents weak, uneven evidence of non-linear policy effects on start-up activity and funding. Most linear and squared terms for government support and financial instruments are statistically insignificant, suggesting limited short-term non-linearity. However, early-stage green funding shows a weakly significant negative squared effect of government support. This suggests a possible inverted U-shaped relationship: moderate support may help, but excessive intervention may crowd out private funding or lead to inefficient allocation.

For late-stage green, early digital, and late digital funding, insignificant quadratic terms show no clear thresholds or diminishing returns. This is consistent with the interpretation that short-term policy changes poorly explain funding dynamics and are more strongly influenced by structural and institutional factors.

Stronger non-linear effects appear in PPML start-up models, especially for digital start-ups, where government support shows a significant inverted U-shaped relationship. This means support initially stimulates entry, but excessive support may become ineffective or counterproductive. No similar effect is found for green start-ups.

Table 5 suggests that only some turning points are economically meaningful. Valid turning points appear at approximately 51.33, 93.71, and 107.39 points on the European Innovation Scoreboard indicator scale within the observed range, suggesting the presence of potential non-linear relationships. These values should not be interpreted as precise optimal policy levels. Other extreme or negative turning points are not practically interpretable.

A similar pattern appears for finance and support variables. Only two models show valid turning points within the observed range, around 78.72 and 117.86, suggesting potential threshold-like patterns in the association between support intensity and observed outcomes.

Most other turning points are outside the empirical range or below zero, so they should be interpreted cautiously. Table 4 shows that non-linear ef-

Table 4. Quadratic fixed-effects estimation results

Source: Author's calculations in R Studio.

Variables	Early Green (log)	Late Green (log)	Late Digital (log)	Early Digital (log)	Green Start–ups (PPML)	Digital Start–ups (PPML)
Gov. support (centered)	–0.0129 (0.0323)	0.0330 (0.0519)	0.0114 (0.0329)	0.0320 (0.0367)	0.0026 (0.0037)	0.0054 (0.0045)
Gov. support²	–0.0004* (0.0002)	–0.000002 (0.0004)	0.000055 (0.0002)	–0.0001 (0.0002)	–0.000050 (0.000037)	–0.000069** (0.000032)
Finance & support (centered)	0.0009 (0.0372)	0.0067 (0.0216)	–0.0022 (0.0145)	–0.0194 (0.0364)	0.0070 (0.0061)	0.0035 (0.0071)
Finance & support²	0.0003 (0.0003)	0.000037 (0.0004)	0.000002 (0.0003)	0.0003 (0.0004)	–0.000017 (0.000040)	–0.000014 (0.000044)
Log GDP per capita	–8.158 (7.915)	2.756 (6.994)	–4.024 (6.606)	–1.487 (9.804)	0.1715 (1.371)	–0.8887 (1.334)
R&D expenditure	–0.8647 (2.824)	–2.825 (4.280)	–2.218 (2.867)	–3.222 (3.765)	–0.1896 (0.2746)	–0.2172 (0.4014)
Observations	222	222	222	222	204	204
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Model	OLS	OLS	OLS	OLS	PPML	PPML
Pseudo / Adj. R²	0.198	0.190	0.186	0.173	0.847	0.767

Notes: Linear fixed-effects (log(x+1)) and Poisson pseudo-maximum likelihood estimations with country and year fixed effects. Standard errors clustered at the country level are reported in parentheses. Significance levels: ** $p < 0.05$, * $p < 0.1$.

Table 5. Turning point analysis of quadratic models

Source: Author's calculations in R Studio.

Variable	β_1	β_2	Turning point (original)	Min	Max	Within range
Government support	–0.0129	–0.000381	51.33	0	207.57	Yes
Government support	0.0330	–0.000002	8009.10	0	207.57	No
Government support	0.0114	0.000055	–35.72	0	207.57	No
Government support	0.0320	–0.000105	220.21	0	207.57	No
Government support	0.0026	–0.000051	93.71	0	207.57	Yes
Government support	0.0054	–0.000069	107.39	0	207.57	Yes
Finance & support	0.0009	0.000319	78.72	0	191.83	Yes
Finance & support	0.0067	0.000037	–10.39	0	191.83	No
Finance & support	–0.0022	0.000002	586.49	0	191.83	No
Finance & support	–0.0194	0.000257	117.86	0	191.83	Yes
Finance & support	0.0070	–0.000017	289.92	0	191.83	No
Finance & support	0.0035	–0.000014	203.37	0	191.83	No

Notes: Turning points are calculated as $-\beta_1/(2\beta_2)$ and adjusted for mean-centering. Turning-point values are expressed on the original European Innovation Scoreboard indicator scale of the corresponding policy variable. "Within range" indicates whether the turning point lies within the observed range of the corresponding variable. Only turning points within the observed range are considered economically meaningful.

fects are selective rather than universal, and that only a few policy relationships have economically meaningful thresholds.

Table 6 shows that lagged non-linear effects remain weak for funding variables. Neither lagged government support nor financial instruments have robust, significant linear or squared effects on early- or later-stage funding for green and digital start-ups. This suggests that delayed policy effects do not create clear thresholds or diminishing returns in venture financing. However, R&D expenditure has a marginal negative effect on early-stage green and digital funding, possibly reflecting a temporary shift of resources away from external venture funding.

In PPML start-up models, clearer effects appear for green start-ups. Lagged government support is weakly positive, while its squared term is weakly

Table 6. Lagged quadratic fixed-effects estimation results (t – 1)

Source: Author's calculations in R Studio.

Variables	Early Green (log)	Late Green (log)	Late Digital (log)	Early Digital (log)	Green Start–ups (PPML)	Digital Start–ups (PPML)
Gov. support (lag, centered)	–0.0583 (0.0528)	0.0721 (0.0789)	–0.0046 (0.0579)	–0.0164 (0.0514)	0.0091* (0.0039)	0.0021 (0.0059)
Gov. support² (lag)	0.0002 (0.0005)	–0.000056 (0.0006)	0.0003 (0.0004)	0.0004 (0.0003)	–0.0001* (0.000044)	–0.00007 (0.000055)
Finance & support (lag)	–0.0067 (0.0344)	–0.0305 (0.0361)	–0.0153 (0.0259)	–0.0490 (0.0417)	0.0013 (0.0068)	0.0039 (0.0091)
Finance & support² (lag)	–0.0003 (0.0003)	–0.0001 (0.0006)	–0.0003 (0.0005)	–0.0003 (0.0004)	0.000073 (0.000049)	–0.000009 (0.000059)
Log GDP per capita (lag)	–5.748 (7.272)	1.693 (8.045)	–1.556 (6.498)	–15.25 (10.62)	0.0419 (1.568)	0.3513 (1.498)
R&D expenditure (lag)	–5.486* (3.067)	2.532 (5.379)	3.680 (3.971)	–8.105* (4.183)	–0.1949 (0.4152)	0.3219 (0.4333)
Observations	185	185	185	185	165	160
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Model	OLS	OLS	OLS	OLS	PPML	PPML
Pseudo / Adj. R^2	0.214	0.198	0.196	0.197	0.841	0.755

Notes: Lagged quadratic fixed-effects estimations with log(x+1) transformation for funding variables and Poisson pseudo-maximum likelihood for start-up counts. Standard errors clustered at the country level are reported in parentheses. Significance levels: * $p < 0.1$.

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negative, indicating an inverted U-shaped relationship: moderate support encourages entry, but excessive support may reduce effectiveness. For digital start-ups, no significant lagged non-linear effects are found. Table 6 suggests that policy effects are delayed, heterogeneous, and context-dependent. Non-linearity is more visible in start-up formation than in funding, while high pseudo R^2 values suggest that unobserved structural and institutional factors remain dominant.

Table 7 provides additional evidence of delayed non-linear effects, especially for start-up formation and, to a lesser extent, for early-stage funding. Funding results remain weak overall, but early-stage green funding shows a weakly significant U-shaped effect of lagged government support: low and high levels of support are associated with higher funding, while intermediate levels are less effective. Lagged financial support has a weak negative effect after two years, suggesting possible crowding-out or inefficient capital allocation. R&D expenditure also remains negative, supporting the view that public R&D intensity may substitute for private early-stage investment in the medium term.

PPML start-up models show stronger effects. Lagged government support has a significant U-shaped effect on digital start-ups, with higher activity at low and high support levels and weaker effects at moderate levels. For green start-ups, government support has only a weak negative linear effect. GDP per capita and R&D expenditure also significantly support the formation of digital start-ups after 2 years. Policy effects become clearer when lagged and non-linear models are combined, especially for start-up formation rather than funding. The limited significance of funding models suggests that venture financing depends more on structural and institutional conditions than on short-term policy changes.

Table 8 shows that meaningful non-linear effects in one-year lagged models are selective. For government support, valid turning points appear mainly for digital funding and both green and digital start-ups, suggesting potentially meaningful threshold-like patterns. In contrast, green funding turning points fall outside the observed range and are not economically meaningful. For finance and support variables, some valid thresholds are identified for early green funding, digital funding, and green start-ups, suggesting potentially meaningful non-linear patterns within the observed data range. However, several turning points remain outside the empirical range. Policy effects are non-linear but not universal, and they differ by instrument, timing, and start-up segment.

Table 7. Lagged quadratic fixed-effects estimation results (t − 2)

Source: Author's calculations in R Studio.

Variables	Early Green (log)	Late Green (log)	Late Digital (log)	Early Digital (log)	Green Start–ups (PPML)	Digital Start–ups (PPML)
Gov. support (lag, centered)	–0.0489 (0.0536)	0.0205 (0.0804)	–0.0635 (0.0445)	–0.0288 (0.0867)	–0.0106* (0.0059)	–0.0180** (0.0070)
Gov. support² (lag)	0.0010* (0.0005)	–0.0001 (0.0005)	0.0006 (0.0004)	0.0009* (0.0005)	0.000023 (0.000046)	0.0001* (0.000052)
Finance & support (lag)	–0.0836* (0.0370)	0.0470 (0.0571)	0.0582 (0.0372)	–0.1724* (0.0690)	0.0147 (0.0120)	0.0163 (0.0114)
Finance & support² (lag)	–0.0004 (0.0005)	0.0010 (0.0010)	0.0011 (0.0007)	–0.0011 (0.0011)	–0.000047 (0.000095)	0.000047 (0.000100)
Log GDP per capita (lag)	–0.9869 (13.02)	6.991 (29.86)	17.32 (16.59)	–32.96* (16.45)	1.041 (2.500)	6.703* (2.839)
R&D expenditure (lag)	–7.737* (3.500)	4.265 (8.406)	9.752 (5.835)	–7.164 (4.677)	0.1645 (0.5816)	0.9882* (0.4644)
Observations	148	148	148	148	128	128
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Model	OLS	OLS	OLS	OLS	PPML	PPML
Pseudo / Adj. R²	0.237	0.193	0.207	0.216	0.837	0.753

Notes: Lagged quadratic fixed-effects estimations (t−2) with log(x+1) transformation for funding variables and Poisson pseudo-maximum likelihood for start-up counts. Standard errors clustered at the country level are reported in parentheses. Significance levels: ** p < 0.05, * p < 0.1.

Table 8. Turning point analysis for lagged quadratic models (t − 1)

Source: Author's calculations in R Studio.

Model	Variable	β_1	β_2	Turning point (original)	Min	Max	Within range
Early green funding	Gov. support	–0.0583	0.000192	218.21	0	207.57	No
Late green funding	Gov. support	0.0721	–0.000056	710.19	0	207.57	No
Late digital funding	Gov. support	–0.0046	0.000314	73.64	0	207.57	Yes
Early digital funding	Gov. support	–0.0164	0.000351	89.66	0	207.57	Yes
Green start-ups	Gov. support	0.0091	–0.000100	111.99	0	207.57	Yes
Digital start-ups	Gov. support	0.0021	–0.000070	81.13	0	207.57	Yes
Early green funding	Finance & support	–0.0067	–0.000257	64.65	0	181.68	Yes
Late green funding	Finance & support	–0.0305	–0.000139	–32.26	0	181.68	No
Late digital funding	Finance & support	–0.0153	–0.000343	55.26	0	181.68	Yes
Early digital funding	Finance & support	–0.0490	–0.000339	5.34	0	181.68	Yes
Green start-ups	Finance & support	0.0013	0.000073	68.63	0	181.68	Yes
Digital start-ups	Finance & support	0.0039	–0.000009	301.62	0	181.68	No

Notes: Turning points are calculated as $-\beta_1/(2\beta_2)$ and adjusted for mean-centering. Turning-point values are expressed on the original European Innovation Scoreboard indicator scale of the corresponding policy variable. "Within range" indicates whether the turning point lies within the observed range of the corresponding lagged variable. Only values within the range are considered economically meaningful.

Table 9 provides additional evidence of potentially meaningful non-linear effects in two-year lagged models, especially for government support. Most turning points fall within the observed range across funding categories and digital start-ups. This is consistent with potential U-shaped patterns: the estimated quadratic relationships imply turning points within the observed range, suggesting possible changes in the direction of the association at different support levels. The results are consistent with the view that timing and scale may matter to influence entrepreneurial and funding outcomes.

For finance and support variables, the evidence is weaker. Only late green and late digital funding show valid turning points, suggesting selective non-linear effects in later-stage financing. Most other thresholds fall outside the observed range, so they are not economically meaningful. Government support shows clearer delayed threshold effects than financial instruments, confirming that policy effectiveness depends on timing, scale, and intensity.

The empirical results reveal three main patterns. First, the baseline models confirm that short-term

Table 9. Turning point analysis for lagged quadratic models (t − 2)

Source: Author's calculations in R Studio.

Model	Variable	β_1	β_2	Turning point (original)	Min	Max	Within range
Early green funding	Gov. support	–0.0489	0.000964	89.83	0	207.57	Yes
Late green funding	Gov. support	0.0205	–0.000109	158.28	0	207.57	Yes
Late digital funding	Gov. support	–0.0635	0.000600	117.44	0	207.57	Yes
Early digital funding	Gov. support	–0.0288	0.000881	80.80	0	207.57	Yes
Green start-ups	Gov. support	–0.0106	0.000023	292.01	0	207.57	No
Digital start-ups	Gov. support	–0.0180	0.000106	149.76	0	207.57	Yes
Early green funding	Finance & support	–0.0836	–0.000401	–29.64	0	169.09	No
Late green funding	Finance & support	0.0470	0.000988	50.83	0	169.09	Yes
Late digital funding	Finance & support	0.0582	0.001078	47.59	0	169.09	Yes
Early digital funding	Finance & support	–0.1724	–0.001054	–7.18	0	169.09	No
Green start-ups	Finance & support	0.0147	–0.000047	232.68	0	169.09	No
Digital start-ups	Finance & support	0.0164	0.000047	–100.77	0	169.09	No

Notes: Turning points are calculated as $-\beta_1/(2\beta_2)$ and adjusted for mean-centering. Turning-point values are expressed on the original European Innovation Scoreboard indicator scale of the corresponding policy variable. "Within range" indicates whether the turning point lies within the observed range of the corresponding lagged variable. Only turning points within the range are considered economically meaningful.

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policy effects are limited: public R&D support and financial instruments do not immediately increase the number of energy start-ups or funding volumes. Second, lagged specifications show that policy effects become more visible over time, especially for digital energy start-ups, where financial support has a positive effect two years later. Third, quadratic models suggest that some policy–start-up relationships may be non-linear and depend on the intensity of support. This means that neither insufficient nor excessive intervention is optimal. The weakest and least stable results are observed for funding variables, which indicates that venture financing is less sensitive to short-term policy changes and more dependent on structural ecosystem characteristics. Thus, the key empirical message is that direct short-term associations between policy variables and energy start-up outcomes are generally weak. More pronounced patterns emerge only in selected lagged and non-linear specifications, suggesting delayed and context-dependent relationships that should be interpreted cautiously.

4. DISCUSSION

Compared with previous studies that mainly emphasize the general importance of entrepreneurial ecosystems, financial access, regulatory quality, and innovation capacity, this study provides a more specific policy-oriented explanation of energy start-up development. Its added value lies in showing that direct short-term associations between public R&D support, finance-related instruments, and energy start-up outcomes are generally weak, while selected lagged and non-linear patterns emerge. Most direct short-term associations are weak, while more pronounced patterns emerge only when delayed and non-linear relationships are considered. This finding refines earlier arguments on the roles of institutions, finance, and ecosystem resources by demonstrating that the same policy instrument may be statistically insignificant in some specifications, negatively associated in others, or linked to stronger outcomes only in selected lagged or non-linear models. Thus, the study contributes to the literature by shifting the interpretation of policy support from a simple "more support is better" logic towards a more conditional understanding based on delayed, non-linear, and segment-specific effects.

Although the models estimate average cross-country effects, the results should be interpreted in light of substantial differences in economic development, institutional maturity, and public policy frameworks across the analyzed countries. In more developed economies, public support may operate mainly through co-financing, de-risking, and scaling mechanisms. The following mechanisms should be interpreted as plausible explanations of the observed associations rather than as directly identified causal channels. In contrast, in transition and non-EU economies, its effectiveness may depend more strongly on administrative capacity, regulatory predictability, investor protection, and access to international finance.

The empirical findings of this study broadly align with the existing literature in highlighting that the impact of public R&D support and financial instruments on entrepreneurial ecosystems is complex, context-dependent, and often non-linear rather than immediate and linear. The absence of statistically significant effects in baseline models suggests that short-term policy interventions do not directly translate into increased start-up formation or funding, consistent with the view that innovation systems are shaped primarily by structural and institutional factors rather than short-run policy fluctuations. This supports prior evidence that entrepreneurial ecosystems depend on deeper determinants such as institutional quality, access to finance, and ecosystem resources (Imo & Makanjuola, 2025; Jurgelevičius & Raišienė, 2025). At the same time, the negative short-run association between government support and early-stage green funding, as well as the delayed negative effects on start-up formation, provides empirical support for the crowding-out hypothesis discussed in the literature, where public intervention may substitute for private investment or be more intensively directed towards weaker ecosystems (Streimikiene et al., 2024; Benlefki et al., 2024). These findings also resonate with studies emphasizing regulatory barriers and inefficiencies in policy design, which may limit the effectiveness of public support in clean and digital energy sectors (Artyukhov et al., 2024; Myroshnychenko et al., 2024).

At the same time, the results extend the literature by demonstrating that policy effects are not only delayed but also exhibit clear non-linear and threshold dynamics, particularly in the case of start-up formation and digital entrepreneurship. The identification of economically meaningful turning points suggests that the association between government support and start-up outcomes varies across levels of policy intensity, consistent with theoretical arguments on diminishing returns and optimal policy intensity (Juracka et al., 2024; Burrell et al., 2025). Moreover, the positive delayed effect of financial support on digital start-ups highlights the importance of well-functioning financial instruments in fostering technology-oriented entrepreneurship, in line with studies emphasizing the role of financial development and risk perceptions in shaping entrepreneurial behavior (Civelek et al., 2025; Dorusincova et al., 2025). However, the limited and inconsistent effects observed for funding variables suggest that venture financing remains largely driven by structural ecosystem characteristics, including university–industry collaboration, digitalization, and knowledge transfer mechanisms, rather than short-term policy changes (Kuzior et al., 2024a; Mursalov et al., 2023). The findings contribute to the literature by providing cross-country panel evidence suggesting that the observed relationships between policy support and start-up outcomes vary according to timing, scale, and interactions with broader institutional conditions, thereby reinforcing the need for dynamic, targeted policy design in the context of European economic integration and climate-neutral transformation. These findings represent average patterns across a heterogeneous group of European and neighboring economies and should therefore be interpreted with appropriate caution at the country level.

From a practical perspective, these findings suggest that policymakers should avoid evaluating public R&D support and financial instruments only by their immediate impact on start-up numbers or funding volumes. The weak short-term effects imply that energy start-up policy should be designed as a long-term ecosystem-building strategy rather than as a quick stimulus mechanism. For green start-ups, public support should be carefully coordinated with private finance to avoid crowding-out effects, especially at the early funding stage. For digital energy start-ups, financial instruments appear more effective when their impact is assessed with a time lag, suggesting the need for stable, predictable support schemes. The presence of non-linear effects also suggests that policy intensity should be calibrated: very low support may be insufficient to mobilize entrepreneurial activity, while excessive intervention may reduce efficiency or weaken private-sector incentives. Therefore, the practical implication is that public policy should combine financial instruments with regulatory stability, investor incentives, university–industry cooperation, and targeted support for start-up scaling.

These implications should also be interpreted in light of differences in levels of development and public policy across the analyzed countries. The sample includes both EU member states and non-EU European or neighboring economies, which differ substantially in institutional capacity, access to EU-level programs, financial-market maturity, and policy implementation mechanisms. In more developed EU economies, where venture capital markets, innovation infrastructure, and regulatory frameworks are relatively stronger, public R&D support may be more effective when it complements private investment, supports high-risk technological scaling, and reduces uncertainty for investors. In contrast, in transition and non-EU economies, the weaker short-term effects of policy instruments may reflect limited administrative capacity, fragmented financial markets, lower investor confidence, and weaker links between research institutions and private firms. For these countries, state support should not be limited to direct subsidies. However, it should also strengthen the institutional and financial conditions that enable energy start-ups to secure public support and attract private capital. Therefore, the findings suggest that policy design should be differentiated: advanced innovation systems require calibrated co-financing and scaling instruments, while less developed ecosystems need stronger institutional support, de-risking mechanisms, regulatory predictability, and capacity-building measures.

This study has several limitations. It uses aggregated country-level data, which may hide regional, sectoral, and start-up-type heterogeneity, while the short 2018–2023 period limits the assessment of long-term policy effects. Given the heterogeneity of the sample, the estimated relationships should be interpreted as average cross-country patterns that may not apply uniformly across all national contexts. Although lagged and non-linear models

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are applied, the results show associations rather than full causality, as unobserved institutional factors, policy design differences, and reverse causality may remain. Although lagged and non-linear models are applied, the estimates should be interpreted as conditional associations rather than causal effects, as endogeneity, omitted variables, and reverse causality may remain. Another limitation is that the study does not separately estimate country clusters by levels of economic development; future research with longer time series could apply cluster-based or group-specific models to compare advanced EU economies, transition economies, and non-EU countries more directly. In addition, composite policy indicators may not fully capture differences in policy implementation across countries. Because the study relies on aggregated ecosystem-level indicators, it cannot determine whether individual firms appear simultaneously in both green and digital start-up categories. Future research should use regional or firm-level data, extend the time horizon, and apply event-study or quasi-experimental designs to strengthen causal interpretation. Further studies could also examine interactions among policy instruments, institutional quality, technology domains, venture capital networks, university–industry collaboration, and digital infrastructure to better explain how policy support affects sustainable energy entrepreneurship.

CONCLUSIONS

This study examined how public R&D support and finance-related policy instruments influence energy start-up ecosystems in European and neighboring economies. By applying cross-country panel models with fixed effects, PPML estimations, lagged specifications, and quadratic terms, the article shows that direct short-term associations between policy variables and energy entrepreneurship are generally weak, while some delayed and non-linear relationships emerge in specific specifications.

The main empirical conclusion is that direct short-term associations between policy instruments and energy start-up outcomes are generally weak. More visible relationships appear only in selected lagged and non-linear models and should therefore be interpreted cautiously. Higher levels of public R&D support are not consistently associated with greater start-up activity. The negative associations observed in some models may be consistent with crowding-out or reactive policy behavior, but these mechanisms are not directly tested in this study. Finance-related support is more strongly associated with digital energy start-ups when assessed with a time lag. At the same time, funding outcomes appear less responsive to short-term policy changes and more dependent on structural ecosystem conditions.

The study contributes to the literature by showing that the relationship between policy support and energy start-up outcomes is conditional rather than immediate or uniform. The findings suggest that timing, support intensity, instrument type, and start-up segment matter, while threshold-like patterns should be treated as exploratory evidence rather than precise policy optima.

From a practical perspective, policy support for energy start-ups should be viewed as part of a long-term ecosystem-building strategy rather than a short-term stimulus tool. Public R&D support should be coordinated with private finance and broader institutional conditions, while financial instruments may be particularly relevant for digital energy start-ups. These implications should be interpreted cautiously, as the study identifies associations rather than causal policy effects.

From a policy perspective, the findings suggest that support for energy start-ups should be treated as part of a long-term ecosystem-building strategy rather than as a short-term stimulus tool. Public R&D and financial instruments should be designed with attention to timing, country context, and the start-up segment, while remaining coordinated with private finance, regulatory stability, and university–industry cooperation. These implications should be interpreted cautiously, as the study identifies associations rather than causal policy effects.

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APPENDIX A

Table A1. Descriptive statistics of variables

Source: Author's calculations in R Studio.

Variable	N	Mean	SD	Median	Min	Max	Skewness	Kurtosis
Energy and green start-ups (Number)	222	9.77	18.90	2.00	0.00	113.00	3.10	10.63
Energy and digital start-ups (Number)	222	5.65	10.36	2.00	0.00	66.00	3.15	11.39
Early-stage funding of energy and green start-ups (USD)	222	48,997,353.75	124,889,480.26	2,465,358.25	0.00	792,449,700.00	3.90	16.30
Later-stage funding of energy and green start-ups (USD)	222	48,652,068.22	248,237,832.75	0.00	0.00	3,397,459,000.00	11.33	146.81
Later-stage funding of energy and digital start-ups (USD)	222	36,348,018.43	238,422,771.59	0.00	0.00	3,376,590,000.00	12.57	170.99
Early-stage funding of energy and digital start-ups (USD)	222	32,790,039.93	84,136,331.61	2,266,085.00	0.00	795,792,600.00	5.05	34.53
GDP per capita, PPP (constant 2021 international $)	222	49,484.46	24,618.22	46,036.88	13,559.26	136,772.40	1.27	2.29
Research and development expenditure (% of GDP)	222	1.62	0.97	1.42	0.15	3.64	0.38	–0.99
Direct and indirect government support of business R&D	222	68.28	65.81	40.12	0.00	207.57	0.75	–0.71
Finance and support	222	80.11	48.64	78.92	0.00	191.83	0.13	–0.83

APPENDIX B

Table B1. Lagged log-linear fixed-effects estimation results for funding variables

Source: Author's calculations in R Studio.

Variables	Early green (t – 1)	Late green (t – 1)	Early digital (t – 1)	Late digital (t – 1)	Early green (t – 2)	Late green (t – 2)	Early digital (t – 2)	Late digital (t – 2)
Gov. support	–0.0369 (0.0308)	0.0652 (0.0437)	0.0231 (0.0244)	0.0306 (0.0266)	0.0512 (0.0404)	0.0166 (0.0363)	0.0573 (0.0577)	0.0093 (0.0355)
Finance & support	–0.0074 (0.0340)	–0.0318 (0.0395)	–0.0496 (0.0430)	–0.0161 (0.0289)	–0.0605 (0.0361)	0.0224 (0.0338)	–0.1353* (0.0776)	0.0416 (0.0312)
Log GDP pc	–5.1609 (6.1797)	2.9305 (7.8419)	–15.0398 (10.1227)	–1.1039 (4.9412)	–3.4830 (10.0462)	–1.2748 (25.0549)	–29.0043* (14.9741)	3.7279 (15.5777)
R&D exp	–5.0397 (3.0010)	2.8305 (6.2089)	–7.5498* (4.1046)	4.2561 (4.9006)	–8.2961** (3.8118)	4.5988 (8.8111)	–7.8723 (4.7416)	9.7846 (6.4031)
Observations	185	185	185	185	148	148	148	148
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.708	0.674	0.667	0.658	0.723	0.636	0.681	0.645
Within R^2	0.038	0.045	0.053	0.022	0.053	0.020	0.101	0.059

Notes: Linear fixed-effects estimations with log(x+1) transformation of funding variables. Standard errors clustered at the country level are reported in parentheses. Significance levels: ** $p < 0.05$, * $p < 0.1$.