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Discussion Paper

Sectoral Clustering and Climate-Tech Startup Financing Through Venture Capital and Private Equity

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Abstract

In this study, I investigate the climate-tech startup financing of venture capital (VC) and private equity (PE) investments across different sectors worldwide for the 2022-2024 period. I find that the total funding provided to climate-tech startups and the number of deals vary significantly across countries and sectors. Via a cross-sectional analysis, I find that climate-tech startups in sectors with higher deal activity receive greater funding than their counterparts in sectors with lower deal activity. The results indicate that some sectors not only complete more deals during this period but also receive greater private capital on average per startup, suggesting a sectoral clustering of private capital in climate-tech startups. As the VC/PE financing of climate-tech startups is not uniformly distributed across sectors, I also discuss the potential reasons for sectoral clustering in such startups. Policymakers can provide additional public funding to sectors with high-level risk, ease administrative processes for investors while strengthening intellectual property (IP) rights, reduce information asymmetry by encouraging information disclosure, and improve and support the activities of incubator centers for entrepreneur education and training.

Keywords: Climate Tech, Venture Capital (VC), Private Equity (PE), Startup Financing

1. Introduction

Tackling climate change requires the rapid development and deployment of climate-tech solutions that can mitigate emissions and adapt to the consequences of global warming. Startups are often at the forefront of disruptive innovations and the development of cutting-edge technologies. Given their entrepreneurial spirit, startups are considered the most suitable organizations for bringing disruptive innovations and technologies, which are needed to obtain climate solutions, to the market.

By backing early- and growth-stage startups, venture capital (VC) and private equity (PE) firms play pivotal roles in funding climate-tech startups, which require the scaling of significant amounts of private investment. VC and PE are forms of equity investment in which the investors hold a degree of ownership of a venture in exchange for providing capital.[1] These investors invest in ventures with innovative solutions that have high potential for growth and profitability, coupled with a high degree of risk.[2] In VC/PE firms, limited partners (LPs; investors) provide investment capital, and managing partners invest in the venture and manage the investment of the capital received from LPs. By acting as intermediaries between lenders (LPs) and borrowers (managing partners), VC/PE firms reduce the amount of asymmetric information (adverse selection), administrative costs, and search and monitoring efforts (Lerner and Nanda 2020; Janeway, Nanda, and Rhodes-Kropf 2021).

A significant amount of investment is needed to achieve the transformation to a sustainable economy globally. Innovations, new technologies, and the creation and adaptation of sustainable business models play critical roles in overcoming the unprecedented challenges associated with global warming. However, innovations incorporate high-level risks and often require large amounts of capital. Thus, addressing the challenges inherent in financing innovation is essential to ensure technological advancements, as innovation activities are vulnerable to capital market conditions such as economic outlook, liquidity, market volatility, and interest rates and regulations (e.g., Hall and Lerner 2010; Kerr and Nanda 2015; Hardy and Sever 2021). The optimal financing of startups is vital for bringing clean technologies into the market because the overfunding of startups leads to the inefficient allocation of capital, whereas a decline in the capital supply of private investors can leave innovative solutions unfunded. Many startups are not able to obtain financing from conventional financial institutions such as banks because startups are considered too risky.[3] In contrast, VC and PE companies have sufficient risk capital and expertise to identify the most promising businesses. With their specialized experience, VC/PE investors have the appetite to transform the majority of promising entrepreneurial activities into efficient and profitable businesses, and this is particularly relevant for climate tech, which often involves novel innovations that lack proven commercial viability.

VC/PE activities have played a critical role in financing the majority of innovative entrepreneurial activities and helping accelerate the development and deployment of new technologies during recent decades (Lerner and Nanda 2020; Janeway, Nanda, and Rhodes-Kropf 2021). Empirical evidence suggests that VC/PE firms can facilitate the innovation, diffusion, and commercialization of new technologies (Nanda and Rhodes-Kropf 2017). These firms can increase innovation activities (Lerner and Kortum 2000) and stimulate entrepreneurial activities and job creation, and aggregate income in their local economies (Samila and Sorenson 2011). Even though VC and PE investors have limitations in terms of financing innovative activities, they have financed many of the most valuable companies in the world today, such as

Alphabet, Microsoft, Meta, Amazon and Nvidia (Lerner and Nanda 2020).

While many studies have investigated the impact of VC/PE investments on innovation, there is a notable gap in terms of understanding how financing is distributed across sectors within the climate-tech sector. Previous studies have suggested that clean energy startups have not been attractive to VC/PE investors (Gaddy et al. 2017; Van den Heuvel and Popp 2023), even though VC activities in clean-tech firms have been increasing over time (Hegeman and Sørheim 2021), and various factors, such as environmental policies (Bianchini and Croce 2022), oil prices, and stakeholder awareness (Cumming, Henriques, and Sadorsky 2016), can affect VC activities. However, how and why specific climate-tech sectors attract more capital than others have not yet been thoroughly explored.[4]

In this paper, I investigate whether market conditions can explain the amount of financing of startups. Do startups in more active sectors receive greater financing than those in less active sectors? Using a dataset on climate-tech startup funding activities worldwide between January 1, 2022, and July 1, 2024, I discover that startups in sectors with greater dynamism (i.e., completing more deals) receive a greater amount financing than those in sectors with less dynamism, which suggests that sectoral clustering exists in the climate-tech sector. I use deal activity as a proxy for sectoral dynamism in a cross-sectional setting since dynamic firms have greater market confidence and growth potential than nondynamic firms.[5] This relationship remains robust when I control for investor type (VC or PE), stage of funding, and startup home country. I show that financing across various climate-tech sectors is not uniformly distributed. The total funding provided to climate-tech startups and the number of deals vary significantly across countries and sectors. Further descriptive evidence suggests that aggregate startup financing is greater in countries with more climate policy initiatives and lower climate risk than in other countries. Previous studies have focused on clean tech and clean energy, while this work examines various sectors in terms of climate tech.[6] More specifically, I contribute to the literature by revealing sectoral clustering in climate-tech sectors and discussing the potential reasons for such clustering in detail.

Understanding the changes in private capital markets is critical because not only do innovations and the emergence of novel technologies reinvigorate financial market activities, but financial markets also spur innovative activities (Nanda and Rhodes-Kropf 2017). Discovering the patterns of VC and PE investments in climate tech and the reasons for the uneven distribution across various sectors is particularly needed to accelerate the transition to a sustainable economy. The distribution of capital across sectors can significantly influence the effectiveness of global climate action, and identifying the factors affecting investment flows can help stakeholders better align capital with climate priorities.

The remainder of the paper is organized as follows. Section 2 introduces the data and provides descriptive evidence of climate-tech startup financing across sectors and countries. Section 3 presents the cross-sectional regression analyses and results. Section 4 discusses the potential mechanisms behind the findings. Finally, Section 5 concludes the paper and provides policy recommendations.

2. Data and Descriptive Analysis

In this section, I introduce the data and provide some descriptive evidence. First, I explain the details of the various datasets used in the analysis. In Section 2.1, I then show how VC/PE funding for climate-tech startups is distributed across countries. In Section 2.2, I present the changes in climate-tech funding for startups that evolved from the first half of 2022 (January 1, 2022) until the second half of 2024 (July 1, 2024).

I obtain cross-sectional data on climate-tech startups and VC/PE investors from the Climate-Tech VC/PE Investment Database (1.4) of Bloomberg NEF. Since the release of the first version, v1.0, various information has been added to the dataset. The dataset covers deals worldwide from January 1, 2022, to July 1, 2024. The information on deals is collected on a quarterly basis. Sectors are categorized as follows: buildings, industry, carbon and nature, agriculture, clean molecules, energy storage, transport, and clean power.[7] Funding stages are categorized as follows: the seed stage, Series A, Series B, Series C, Series D, Series E, and unclassified VC/PE.[8]

On the climate-tech project side, 2,229 startups are recorded. The dataset includes the names of the startups, the completion date of deals, their last financing amount in USD, their sector, and their location (city and country). The startup data also incorporate information on the attributes of these startups, such as additional stake purchases, minority purchases, whether the project is funded by PE or VC, whether financing is a cross-border activity, and the round of financing. Panel A in Table 1 presents the summary statistics of the climate-tech startups in the sample, and the right panel of Figure A1 in Appendix A displays the distribution of funding received by these startups.[9]

Table 1. Summary statistics.

Variables	Mean ± SD	Min.	Max.	Obs.
Panel A: Climate-Tech Startups				
Total financing (log)	16.460 ± 1.541	13.688	21.810	2,229
Sector-level deals	317.01 ± 102.76	144	444	2,229
VC financed	0.929 ± 0.257	0	1	2,229
PE financed	0.953 ± 0.211	0	1	2,229
Seed stage	0.167 ± 0.373	0	1	2,229

(Continued)

Variables	Mean ± SD	Min.	Max.	Obs.
Series A stage	0.210 ± 0.407	0	1	2,229
Series B stage	0.097 ± 0.297	0	1	2,229
Series C stage	0.036 ± 0.187	0	1	2,229
Series D stage	0.016 ± 0.124	0	1	2,229
Series E stage	0.006 ± 0.079	0	1	2,229
Panel B: VC/PE Investors				
Investment amount in climate-tech startups (log)	18.645 ± 1.431	15.279	22.484	639
Deals in clean power	0.986 ± 1.419	0	11	639
Deals in clean molecules	0.399 ± 0.848	0	7	639
Deals in energy storage	0.712 ± 1.302	0	10	639
Deals in transport	0.859 ± 1.196	0	8	639
Deals in buildings	0.379 ± 0.806	0	7	639
Deals in industry	0.818 ± 1.418	0	16	639
Deals in agriculture	0.720 ± 1.383	0	10	639
Deals in carbon and nature	0.773 ± 1.280	0	14	638

Notes: This table presents the summary statistics of climate-tech statistics (shown in Panel A) and for VC/PE investors (shown in Panel B). In Panel A, total financing denotes the funding received by startups, sector-level deals indicate those deals completed in each sector during the sample period, and VC financed and PE financed denote whether the startup received funding from VC and PE investors, respectively. The remaining indicators represent the funding stage of the startups. In Panel B, investment amount in climate-tech startups denotes how much financing VC/PE investors provided to climate-tech startups; the remaining indicators represent the deals completed by the VC/PE investors in various sectors.

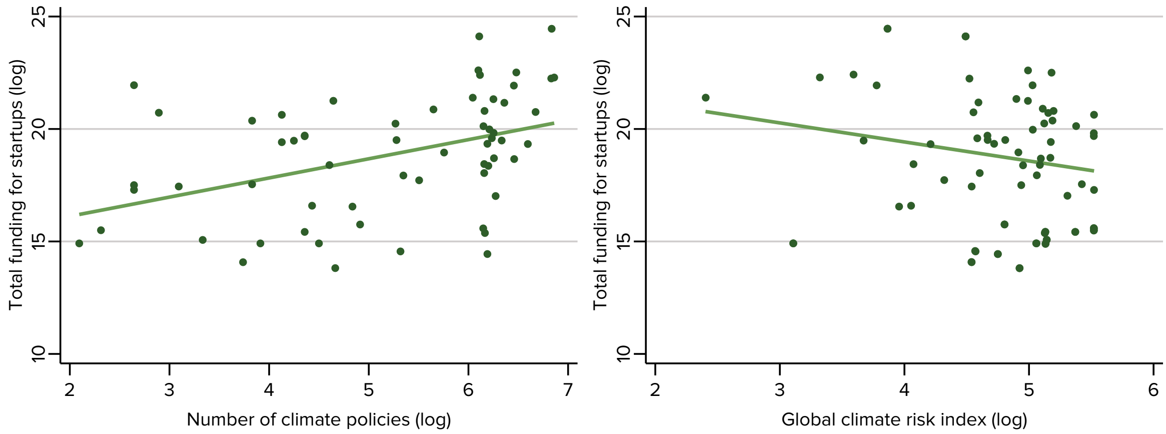
On the investor side, 639 VC and PE investors are recorded. The dataset includes the names of investors, the total number of deals they closed, the number of deals by sector, the average deal amount in USD, and the investor ranking by the number of deals. Although startups and VC and PE companies have identification information, the structure of the dataset does not allow us to match startups with VC and PE companies. Panel B in Table 1 presents the summary statistics for VC/PE investors in the sample, and the left panel of Figure A1 in Appendix A displays the distribution of funding received by startups.

2.1 Startups and Venture Capital/ Private Equity Investment Activities in the Climate-Tech Sector Across Countries

I initially analyze in which countries startup activities are clustered. I use the Climate Policy Database to determine whether the number of startup funding activities in the climate-tech industry are greater in countries initiating more climate policies than in those initiating fewer. Climate policy initiatives and regulations can create new business opportunities and encourage entrepreneurs to establish new ventures. In fact, the left panel in Figure 1 demonstrates that there has been a larger amount of climate-tech startup financing in countries with more climate policies than in those with fewer climate policies.

I use the Global Climate Risk Index from Resource Watch to determine the relationship between the emergence of startup activities and climate risk in the startups' home countries. The right panel in Figure 1 displays a negative relationship, with climate-tech startup funding tending to be greater in countries with low levels of climate risk than in those with high levels of climate risk. Worldwide, poorer countries that have not particularly contributed to the world's greenhouse gas (GHG) emissions compared to richer countries face the most serious climate change consequences. The right panel of Figure 1 is consistent with this statement. Countries facing greater climate risk are typically less developed economies in which startups are less likely to be financed. Therefore, startups in countries that are more actively introducing climate policies and are exposed to less climate risk receive greater funding from VC/PE investors than startups in other countries.

Figure 1. Startup financing, climate policies, and climate risk.

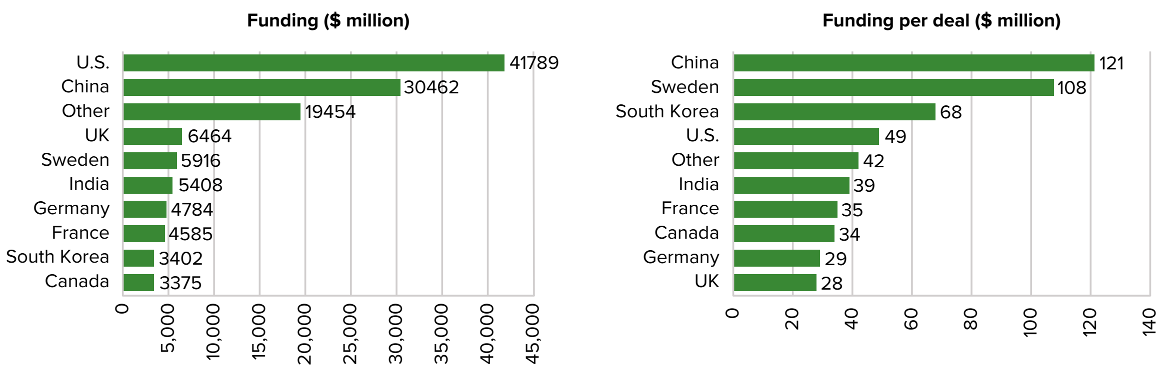


Source: Author.
Note: This figure shows the relationship between the amount of investment per deal (in USD million) provided by VC and PE companies to climate-tech startups across countries for the whole sample period from first half (1H) 2022 to 1H 2024, as well as the climate policies in their countries.

Figure 2 shows the VC and PE financing provided to climate-tech startups across countries between January 1, 2022, and July 1, 2024. Startups from 65 countries are included in the dataset, but only the 10 locations with the largest size are selected in the chart. The left panel shows that the U.S. raised the most VC/PE funding for climate-tech startups followed by China, the UK, Sweden, and India during the study period. However, as shown in the right panel, China has been the leader in terms of funding per deal, followed by Sweden, South Korea, and the U.S. Thus, even though the U.S. had the largest market size in terms of climate-tech startup financing by VC/PE investors, China had the most generous investors.

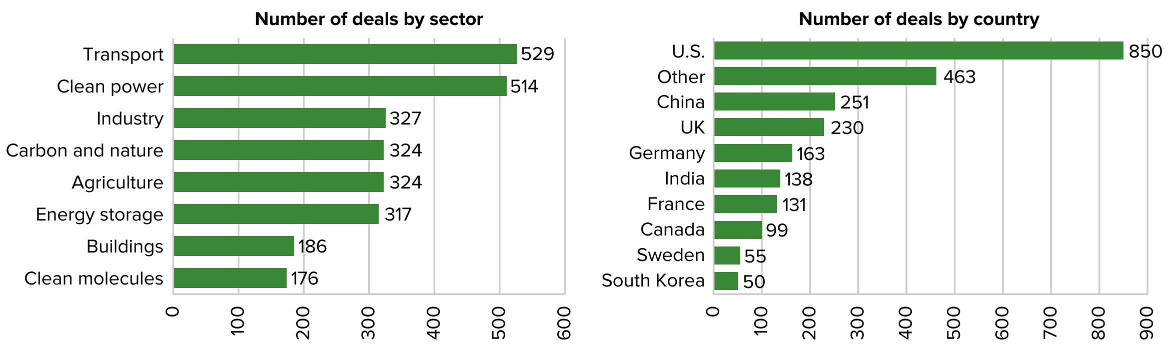
Figure 3 displays the number of deals for climate-tech startups across sectors and countries in the left panel and the number of deals across countries in the right panel. Considerable differences in the number of deals across sectors are prevalent. The transport and clean power sectors had the highest number of deals during the sample period, followed by industry, carbon, and nature, agriculture, and energy storage sectors. Buildings and clean molecules are those sectors with the fewest number of deals. Finally, the U.S. had the largest number of deals, followed by China, the UK, and Germany.

Figure 2. VC and PE investments across countries.



Source: Author.
Note: This figure shows the amount of investment per deal (in million USD) provided by VC and PE companies to climate-tech startups across countries for the whole sample period from 1H 2022 to 1H 2024. The left panel shows the total funding provided in each country, and the right panel shows the amount of funding per deal across countries.

Figure 3. Number of VC and PE deals.

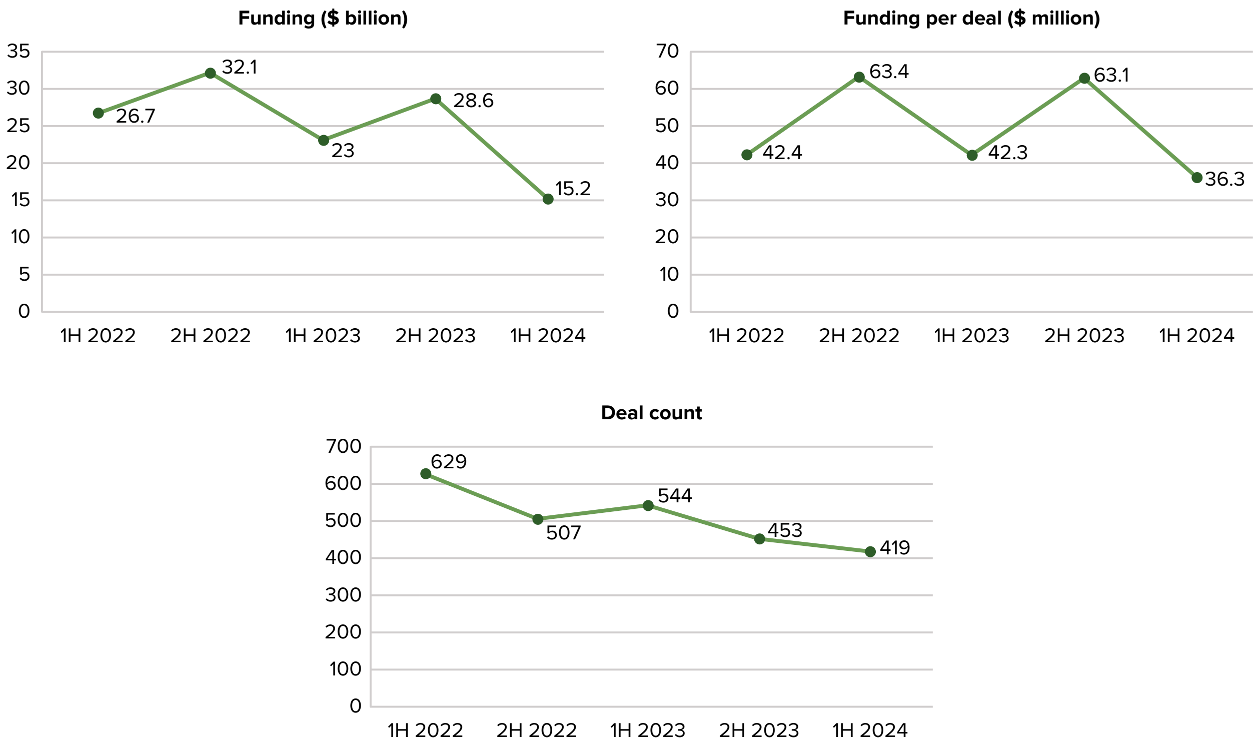


Source: Author.
Note: This figure shows the completed funding deals between climate-tech startups and VC/PE companies across various sectors and countries in the sample period.

2.2 Changes in Climate-Tech Startup Financing over Time

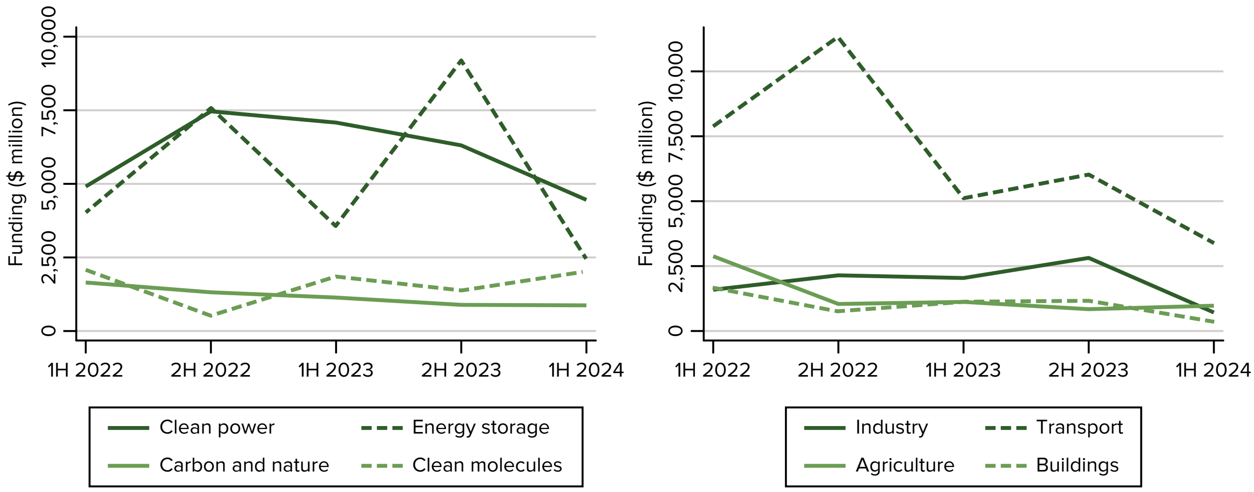
The last two years have seen a steady decline in the aggregate funding of VC and PE activities. The upper-left panel of Figure 4 shows that the total amount of the funding activity has been declining from 1H 2024 to the end of 1H 2024. During this period, VC/PE financing activity fell by approximately 43%, from 26.7 billion USD to 15.2 billion USD. However, the decline in funding received by startups per deal is not apparent, as presented in the upper-right panel, corresponding to an approximately 14% decrease, from 42.4 million USD to 36.3 million USD. In fact, similar to the decline in the amount of total financing, the panel at the bottom displays a drop in the total number of deals of approximately 33% over time, from 629 to 419 completed deals, and this explains the change in the amount of total funding. Hence, we can assess the amount that total funding has declined due to the decrease in the number of completed deals, as the amount of funding per deal has remained largely stable.

Figure 4. Aggregate VC and PE funding and deals over time.



Source: Author.
Note: This figure shows the investments and deals in aggregate over half-year periods from 1H 2022 to 1H 2024. The upper-left panel displays the aggregate VC/PE funding, the upper-right panel displays the aggregate VC/PE funding per deal, and the bottom panel displays the aggregate number of deals.

Figure 5. VC and PE investments across sectors.



Source: Author.
Note: This figure presents the VC/PE investments across various sectors from 1H 2022 to 1H 2024.

Figure 5 presents the sectoral distributions of investments in million USD between 1H 2022 and 1H 2024. There are considerable differences across sectors both in terms of the amount of aggregate funding and changes in funding amount over time. The buildings, agriculture, transportation, industry, carbon and nature, and energy storage sectors decreased by 79%, 66%, 57%, 55%, 47%, and 40%, respectively. The reduction in the amount of funding provided to clean power (i.e., clean power development and power equipment and technology) and clean molecules (i.e., hydrogen, renewable fuels, and oil and gas decarbonization) was relatively small at 9% and 3%, respectively.

Each climate-tech sector may have different characteristics, which vary according to their cost of capital, the presence and ability of skills and labor supply, policy/regulatory hurdles, innovation capabilities, market dynamics, and the demand for their products and services. In the next section, I evaluate the role of sectors in climate-tech fund flows from the VC/PE ecosystem.

3. Empirical Analysis of Startup Financing

As previously shown, the decrease in the number of VC/PE activities is largely due to the smaller number of deals completed, and there is noticeable heterogeneity across sectors. In this section, I attempt to further understand whether there is a positive relationship between the amount of startup financing and the number of deals in the associated sector. Can the amount of financing of startups be explained by market conditions? Do startups in sectors with a greater number of completed deals receive greater financing than those in sectors with fewer completed deals? Here, I examine whether the size of those startups financed is larger in sectors with a greater number of deals than in those with fewer deals. Section 3.1 introduces the cross-sectional regression analysis, and Section 3.2 presents the results.

3.1 Methodology

I estimate the following equation in a cross-sectional setting:

$$\ln(\text{financing})_{sj} = \alpha + \eta \ln(\text{Deals})_{\text{j}} + \textstyle\sum_f \rho_f FundingType_{sj} + \sum_m \lambda_m Stage_{sj} + \gamma\, Country_{sj} + \epsilon_{sj} \quad (1)$$

where s denotes the startup and j denotes the industry. $Financing_{sj}$ is the dependent variable indicating the financing received by startups via the natural logarithm. $Deals_j$ denotes the number of completed deals in sector j in natural logarithm.

VC investors typically invest in startups in the early stages, whereas PE investors tend to invest in mature companies. A venture financed by a PE investor would likely have a longer history of operating and receiving greater financing, and in contrast, VC investors would provide less funding to startups in the early stages, as they would perceive such investment as too risky. To control for this variation, I include $FundingType_{sj}$, a dummy variable indicating whether the startup received financing from a VC or PE firm, in the regression. Additionally, early-stage startups typically receive less funding from VC/PE investors because of the unproven profitability or commercialization of their products or services compared to mature startups. To control for this factor, and, therefore, different amounts of financing for startups, I include $Stage_{sj}$ as a dummy variable indicating in which financing stage the startup was during the sample period. Previous studies have documented a geographic concentration, i.e., local bias, of VC/PE investment activities (Sorenson and Stuart 2001; Chen et al. 2010; Cumming and Dai 2010; Colombo, d'Adda, and Quas 2019). The financing functions of these activities are best in locations with universities, incubator centers, and successful tech companies, and where investment exists. Moreover, the availability of capital and the emergence of entrepreneurial activities vary significantly across countries for various reasons. I control for the location of the ventures, denoted by $Country_{sj}$, because entrepreneurs in some locations may be more likely to search for investors through equity financing if there is greater availability of VC companies. ε_{sj} denotes the standard error.

3.2 Results

In this section, I present the results from estimating the cross-sectional regression shown in Equation (1) in Table 2. The coefficient on "Deals" is positive and significant at the 1% level across all models. This finding indicates that sectors with higher deal activity tend to have larger financing amounts, whereas startups in sectors experiencing a decline in dynamism between 2022 and 2024 receive less financing.

In Column (1), a 1% increase in the number of deals is associated with a 0.385% increase in the amount of financing on average. In Column (2), I include country fixed effects to control for the geographic concentration of VC/PE activities. The magnitude of the relationship between the funding received by the startup deals and sector-level deals only slightly changes. The model in Column (3) controls for investor type. The coefficient on deals increases slightly in magnitude to 0.397. As expected, being funded by VC investors is negatively associated with the amount of funding (the coefficient magnitude is -1.082), whereas being funded by PE investors is positively associated with the amount of funding (the coefficient magnitude is 1.031).

Table 2. Startup financing and sector-level deals.

Variables	(1)	(2)	(3)	(4)
Deals (log)	0.385 (0.092)***	0.382 (0.093)***	0.397 (0.093)***	0.315 (0.082)***
VC backed			−1.082 (0.219)***	−1.162 (0.223)***
PE backed			1.031 (0.276)***	0.987 (0.278)***
Seed stage				−1.017 (0.061)***
Series A stage				0.157 (0.060)***
Series B stage				1.143 (0.087)***
Series C stage				1.606 (0.143)***
Series D stage				1.884 (0.214)***
Series E stage				2.273 (0.288)***
Country ID controls	No	Yes	Yes	Yes
Observations	2,229	2,229	2,229	2,229
R-squared	0.008	0.083	0.096	0.282
Adjusted R-squared	0.007	0.055	0.068	0.258

Notes: This Table presents the relationship between the funding amount received by the startups and the deal amount in their corresponding sectors. The dependent variable is funding amount in natural logarithm, and the explanatory variable is total sector-level deal amount in natural logarithm. Eight sectors are included as controls in Columns 3 and 4, whereas 66 countries are included as controls in Columns 2 and 4.

These findings suggest that PE-backed startups tend to receive larger financing amounts than other startups. The reason for this is that VC investors tend to back early-stage startups, which have a shorter operating history and smaller funding needs. Conversely, PE firms usually finance mature companies that require larger-scale investments. Both of the coefficients are significant at the 1% level.

In Column (4), I additionally control for the funding stage of startups. The coefficient of interest becomes 0.315. The coefficients on the controls for VC and PE are -1.162 and 0.987, respectively, remaining significant at the 1% level.[10] Moreover, the coefficients on the funding stage increase from the seed stage (-1.017) to the Series E stage (2.273), indicating that each subsequent financing stage is associated with increasingly larger amounts of funding. Startups at the seed stage receive less funding than those at later stages. The coefficients increase progressively through each subsequent funding stage from the seed stage to the Series E stage, showing that later-stage funding rounds are associated with substantially larger financing amounts. This finding is expected because startups typically secure larger rounds of financing as they mature and de-risk their technologies and business models.

These findings suggest a robust relationship between sector-level activity and the amount of funding received by climate-tech startups. Essentially, more active sectors attract more financing rounds than less active sectors. The R-squared values show that model fit improves as additional controls are added, particularly in Columns (3) and (4). However, the R-squared values remain relatively low, suggesting that the variation in the dependent variable is not extensively captured by the independent variables (i.e., other unobserved factors may contribute to financing decisions).

The dataset used in this study is limited and does not allow us to investigate which mechanisms may drive the findings, but in the next section, I discuss the potential factors specifically related to the changes in private fund flows to climate-tech startups.

4. Discussion

Considering that green technologies are newly developed and newly deployed technologies, easier pathways to commercialization for various reasons may explain the findings of this study. An important challenge for the climate-tech industry recently has been that an increasing number of industries, such as AI and military defense, are competing for funding. Investors may have found better opportunities in such sectors or asset classes that offered more attractive risk-adjusted returns during this period. Increased competition within sectors such as the transport and energy storage sectors may have led to market saturation, thus reducing the potential for high returns.

The global economy has experienced a period of high valuations in tech sectors in recent years. This situation may have induced difficulties in securing additional funding for startups or further scrutiny by investors about the performance and profitability of startups.[11] Moreover, the increasing emphasis placed on environmental, social, and governance (ESG)/sustainability criteria may discourage investments in startups with weak ESG credentials.[12] Finally, rising concerns about greenwashing can also lead investors to be more cautious and conduct deeper due diligence, thus slowing the investment process. In the remainder of this section, I discuss other potential reasons in detail.

4.1 Role of Innovation

Innovation is a risky activity, and VC investors are ideal candidates to finance innovative entrepreneurs. As a result, VC-backed startups tend to be more innovative and have relatively more patents than other startups (Howell et al. 2021). However, the current literature explains the larger number of innovative activities of VC-backed startups by selection bias among VC investors rather than by the impact of VC investments on startup innovation. More specifically, the evidence suggests that VC investors consider patents positive signals for their investment decisions and invest in more innovative ventures (Engel and Keilbach 2007; Caselli, Gatti, and Perrini 2009; Lahr and Mina 2016). Similarly, Chemmanur, Krishnan, and Nandy (2011) find that VC-backed firms tend to be more efficient than non-VC-backed firms before they receive financing from investors. With respect to the climate-tech industry, some sectors may generate more patents than others, which can lead to the concentration of capital in those sectors in which investors are more interested.[13]

While the literature identifies a selective bias in VCs' choice of more innovative ventures, some studies suggest that receiving investments from venture capitalists does not increase the patenting activities of startups (Engel and Keilbach 2007; Caselli, Gatti, and Perrini 2009; Lahr and Mina 2016), although startups tend to be more efficient after they receive funding (Chemmanur, Krishnan, and Nandy 2011). The findings indicate that VC investors prefer financing the commercialization of existing innovations than financing new innovations. Hence, investors are more inclined to fund climate-tech startups in certain sectors in which innovations may be easier or more likely to commercialize.

The innovative activities of VC-backed startups can vary on the basis of the macroeconomic conditions of the overall economy because of changes in capital supply, market demand, or operational costs. Howell et al. (2021) provide evidence that the innovation activities of VC-financed firms decline during downturns. Even more interestingly, Nanda and Rhodes-Kropf (2013) show that riskier and more innovative firms are more likely to be financed during boom periods than during bust periods. Thus, riskier and costlier companies (e.g., those that are more hardware intensive), compared to less risky and costly companies, may have received less climate-tech financing during the study period in which recession expectations increased.

4.2 Macroeconomic Conditions

With their professional expertise, VC/PE companies follow market conditions carefully and analyze the most promising ventures that can yield the highest profits in the next 5-10 years. Given that early-stage investors provide financing to ventures that typically have no record of positive cash flow, they need to predict the probability of startup success. Early-stage investors may therefore be sensitive to macroeconomic conditions that directly affect the exit performance of late-stage investors. In this context, Conti et al. (2019) find that VC investors changed their investment strategies and focused more on their core sectors during the 2008 financial crisis.

Studies show that macroeconomic conditions are one of the determinants of VC investment activities and that VC firms tend to invest more during booms and less during busts. This procyclicality occurs because there is abundant capital available for investment activities during boom periods, whereas there are declines in capital supply in the market during bust periods.

Empirical evidence suggests that during boom periods, more innovative projects are more likely to be funded (Nanda and Rhodes-Kropf 2017), the number of deals completed by investors increases, and more experienced VC investors perform better (Gompers et al. 2008). In contrast to the more active financing and better performance of investors, Nanda and Rhodes-Kropf (2013) find that VC-backed firms have a greater propensity to fail during boom periods, as they are more likely to finance riskier ventures during those periods, even though the innovative activities of VC-backed startups also increase during boom periods (Howell et al. 2021). Finally, Cumming, Henriques, and Sadorsky (2016) find a positive relationship between oil prices and VC activities in the clean-tech industry.

In times of increasing demand for efforts to address climate change, VC investors may have bias toward climate-tech companies. Interest rates increase the cost of financing large-scale investment projects and make them less desirable for investors, especially in terms of riskier companies such as startups. In recent years, central banks worldwide have raised interest rates to combat high inflation rates. Some climate-tech sectors, therefore, may have higher costs of capital, particularly if they rely more on hardware technologies, and this situation may have led to a decline in the number of deals in certain sectors during the study period.

Additionally, recent concerns about a global economic slowdown or potential recession may have led VC/PE investors to adopt a risk-averse approach. The impacts of the COVID-19 pandemic likely persisted for several years, overlapping with the study period. Strained trade relationships between major economies and geopolitical instability across many regions in the world have also impacted global energy markets and tended to reduce investor confidence. Fossil fuel energy prices increased substantially with the onset of the war in Ukraine, and the focus shifted to energy security rather than to new energy technologies. Considering that all these factors increase economic uncertainty, VC and PE firms tend to pull back on funding new ventures and focus on supporting their existing portfolio companies during periods of high economic uncertainty. The conflicts in Ukraine and the Middle East and the following energy crisis have significantly increased the uncertainty in the world economy. Hence, these shocks to the global markets correspond to the study period and reveal that VC/PE activities are vulnerable to short-term shocks in addition to boom and bust periods.

4.3 The Possibility of Investment Exits

A lack of exit mechanisms is usually considered one of the main barriers discouraging investors from financing startups in the VC/PE ecosystem. Disruptions in macroeconomic conditions and legal and regulatory hurdles can generate difficulties in terms of exit strategy development. Investors may not be interested in financing startups when they foresee that exiting those entrepreneurial activities will be difficult, and will therefore not bring sufficient financial returns in the future.

In principle, one would expect climate-tech startups to be more valuable at exit because they inherently integrate environmental and social considerations, which have recently become very important criteria for investors.

However, climate-tech startups may generate lower returns for investors (Zerbib 2019; Choi, Gao, and Jiang 2020; Bolton and Kacperczyk 2021; Faccini, Matin, and Skiadopoulos 2023; Hsu, Li, and Tsou 2023), which would reduce their valuations and the willingness of investors to provide them with funding.

Initial public offerings (IPOs) are considered, financially, the most attractive entrepreneurial exit strategy to liquidate funds. Several studies have revealed simultaneous decreases in the number of people going public and increases in the number of people staying private (Gao, Ritter, and Zhu 2013; Ewens and Farre-Mensa 2020). Jeng and Wells (2000) find that IPOs are the main determinants of VC investment activities across 21 countries over 10 years. The empirical evidence suggests that higher IPO valuations typically increase the amount of VC funding (Gompers and Lerner 1998; Jeng and Wells 2000; Kaplan and Schoar 2005).[14] Startups in some sectors may have more commercial value or more mature technologies that can facilitate IPOs, increasing funding options for startups in return compared to those in other sectors. Therefore, early-stage technologies in different climate-tech sectors may have not yet proven their commercial value, ultimately leading to fewer IPOs and less VC/PE activity.

Mergers and acquisitions (M&As) are another highly common exit strategy among VC and PE firms. In fact, Gao, Ritter, and Zhu (2013) find that acquisitions are more profitable exit strategies than IPOs for small companies because growth becomes more important than going public, which is a result of rapid technological change. Growing as an independent venture may become less attractive for entrepreneurs aiming to commercialize products or services and grow larger more quickly through the support of larger organizations. However, M&A activities typically vary across sectors, and startups in some sectors may be more advantageous than those in other sectors.

4.4 Changing Preferences of LPs

Changing the preferences of investors and LPs may have a profound effect on the distribution of VC/PE investments in the climate-tech industry. As a coercive factor, stakeholder activism is placing increasing pressure on investors and asset managers to invest in environmentally friendly business activities. More specifically, the pro-environmental preferences and attitudes of investors and asset owners can increase their investments in environmentally friendly activities, assets, and businesses (Hong and Kacperczyk 2009; Bénabou and Tirole 2010; Riedl and Smeets 2017; Hartzmark and Sussman 2019). By investigating VC investments in the clean-tech industry across the world, Cumming, Henriques, and Sadorsky (2016) find that stakeholder awareness increases the number of VC activities.

Previous studies have documented that individual and institutional investors consider sustainability in their investment decisions and are willing to engage in sustainable investing (Bollen 2007; Hong and Kostovetsky 2012; Riedl and Smeets 2017; Hartzmark and Sussman 2019; Bauer, Ruof, and Smeets 2021; Barber, Morse, and Yasuda 2021). Furthermore, the majority of global institutional investment companies and global asset managers consider ESG considerations in their investment decisions and consider ESG a top priority (FTSE Russell 2018; Eccles and Klimenko 2019). Sectors promising greater long-term environmental benefits, enhancing resilience to climate risks and developing scalable solutions, may influence priorities and preferences, ultimately shaping the distribution of investments across sectors. Investors and LPs seeking high-impact and breakthrough innovations may be more willing to support high-risk startups than other investors and LPs.

Moreover, increasing (decreasing) the interest of investors, LPs, and asset owners in other sectors may also reduce by raising the amount of funding in the climate-tech industry. One potential explanation for the decline in financing for climate-tech companies during the last two years may be associated with the substantial increase in the level of interest in AI technologies. Excitement about the capabilities of AI may have deterred capital owners from investing in other fields. Hence, climate-tech sectors that rely more on AI technologies may have experienced less decline in deal activity than those that rely less on such technologies.

A growing body of literature shows that VC/PE activities are concentrated in a small number of investors, industries, and geographies (Lerner and Nanda 2020; Hellmann and Thiele 2022). In fact, this effect may be even more pronounced when capital is concentrated in a small number of VC/PE firms.

4.5 Historical Performance of Assets

There is a growing body of literature investigating the financial performance of green investments compared with other asset classes. The better performance of green investments can be perceived as a product of them being lower risk, which is a result of their higher sustainability profile, to a higher sustainability profile, and investors may expect higher returns over time. However, existing empirical evidence on this issue is mixed, and there is no consensus yet on whether the higher sustainability or greenness of investments has a positive effect on returns. Some studies show that the sustainability performance of firms generates superior returns (Bebchuk, Cohen, and Ferrell 2009; Derwall et al. 2005; Edmans 2011; Nagy, Kassam, and Lee 2016; Pástor, Stambaugh, and Taylor 2022), while other studies find evidence of the poorer performance of green investments compared to their counterparts (Zerbib 2019; Choi, Gao, and Jiang 2020; Bolton and Kacperczyk 2021; Faccini, Matin, and Skiadopoulos 2023; Hsu, Li, and Tsou 2023).

VC and PE companies may be associating past investment performance with future investment opportunities. Investors may analyze the past performance of some sectors, expect higher growth and higher profits and, eventually, be more willing to invest in those sectors in the future. In this context, Gompers et al. (2008) find that more experienced VC investors increase their investments in growing sectors more than less experienced VC investors.

By focusing only on green investments, Gaddy et al. (2017) find that disappointing VC activity in clean energy is related to high risks and low returns from investments, and they also provide evidence that in response to the performance of their clean-energy investments, VC investors reallocate their investments from hardware to software ventures and toward other sectors.

4.6 Role of Government and Regulatory Support

Governments have been the primary financial source of scientific and technological research and product development. Government policies can create favorable environments for VC activities and play a proactive role in fostering innovation.[15] By focusing on Organisation for Economic Co-operation and Development (OECD) countries, Bianchini and Croce (2022) show that environmental policies have effectively increased VC investments in clean-tech startups. In recent years, either a lack of or a delay in government subsidies and regulatory support in some sectors may not have materialized as quickly or extensively as anticipated, thereby dampening investor enthusiasm for climate-tech startups. In contrast, new regulations or government policies may have created uncertainties, making such investments riskier.

Government support programs have played a catalytic role in the emergence of radical innovations, but their role in stimulating VC/PE investments is still unclear. Lerner and Kortum (2000) have found that the amendment of the Employee Retirement Income Security Act in 1979 increased VC investments in pensions, which subsequently spurred patenting. Moreover, members of the Small Business Innovation Research (SBIR) program, a government funding program in the U.S. aimed at encouraging R&D activities, are more likely to receive VC investments than nonmembers (Lerner 1999; Howell 2017).

In contrast to the expected benefits of government policies and regulatory frameworks, some studies find no evidence of the positive impacts of government support and regulations on entrepreneurial activities and VC/PE investments. However, tax credits to spur entrepreneurial activities do not always lead to desired outcomes (e.g., Denes et al. 2023). Regulations have the potential to affect the decisions of ventures facing trade-offs between going public and staying private. These regulations may indirectly affect VC/PE activities via reducing the number of IPOs. However, previous studies do not find evidence of the impact of regulations on IPOs in the U.S. (Gao, Ritter, and Zhu 2013; Ewens and Farre-Mensa 2020).

Nevertheless, by studying the passage of the National Securities Markets Improvement Act (NSMIA) in the U.S. during the 1990s, Ewens and Farre-Mensa (2020) find that deregulation stimulated the private capital supply by reducing the relative cost of remaining private. Finally, designing appropriate rules for intellectual property (IP) protection can attract VC/PE investment. IP rules can limit the ability of competitors to replicate or use innovations that could reduce the profitability and long-term value of startups. Moreover, better IP protection can allow for the use of innovation outcomes (e.g., patents) as collateral, which would facilitate securing financing. Consistent with these arguments, previous studies suggest that governments play a role in driving VC investments by defining better property rights (Dushnitsky and Lenox 2005; Groh and Wallmeroth 2016). Hence, some sectors may be more intensive in terms of their IP rights or may be more exposed to the risk of IP theft and imitation than other sectors.

5. Conclusions and Policy Implications

In this paper, I have analyzed the trends in VC/PE financing of climate-tech startups and related it to sector-level deal activity. I have found that startups in sectors with greater dynamism (sectors with greater deal activity) receive greater financing than those in less dynamic sectors, and I have discussed the potential reasons for this finding. The results provided in this paper reflect clustering in certain sectors and correspond to previous findings in the literature, suggesting that VC/PE investment activities tend to concentrate in certain industries because of the knowledge accumulation and economies of scale within those sectors (Nanda and Rhodes-Kropf 2017).

I have emphasized that the dataset used in this study does not allow for a detailed causal investigation. Despite the limitations of the small dataset, the relationship between sectoral dynamism, proxied by sectoral deal activity, and the amount of financing is evident. Moreover, the findings provide considerable insights and an empirical basis for further discussions on broader investment trends.

Identifying the factors that influence sectoral variations and why certain sectors receive more or less financing for climate-tech startups is essential for policymakers to accelerate the transition to a sustainable and low-carbon economy. The allocation of public resources requires providing funding where it is most needed, and understanding where investments are concentrated can guide policymakers in designing interventions to support less-funded sectors. In particular, some climate-tech sectors may need additional public support because they are at the early stages of technological development, incorporate high levels of uncertainty, have long timelines for commercialization, and require a large amount of resources for innovation.

Through various policy tools, policymakers can help accelerate the transition to a sustainable economy and ensure that all sectors benefit from financial resources and innovations. Comprehending the factors determining financial flows across climate-tech sectors can allow policymakers to take action to prevent the concentration of investments in only a few sectors and impediments in progress toward climate goals. By understanding why certain sectors receive more or less financing, policymakers can design targeted interventions such as subsidies, grants, tax incentives, or public-private partnerships to address financing gaps. The key recommendations for policymakers can be summarized as follows:

1. Introduce mechanisms like guarantees, co-investment programs through public-private partnerships, or risk-sharing facilities, which can reduce the inherent risks associated with investing in unproven technologies.
2. Relax regulatory constraints on institutional investors and improve legal and administrative processes. Enhancing legal and administrative efficiency can facilitate the direction of capital flows toward innovative activities and ensure that private investments align with national climate targets.
3. Prioritize high-risk, high-impact sectors, and also allocate additional public funding to sectors for decarbonization projects with long-term importance but that are less attractive to investors.

4. Strengthen IP rights to safeguard climate-tech startups' innovations, which can increase investor confidence.
5. Reform bankruptcy regulations to make investment exits more predictable and reduce uncertainties in potential exit strategies.
6. Support incubation and accelerator programs for the education and training of entrepreneurs to enhance skill development.
7. Encourage transparency and improve data access to promote information disclosure and facilitate due diligence processes.

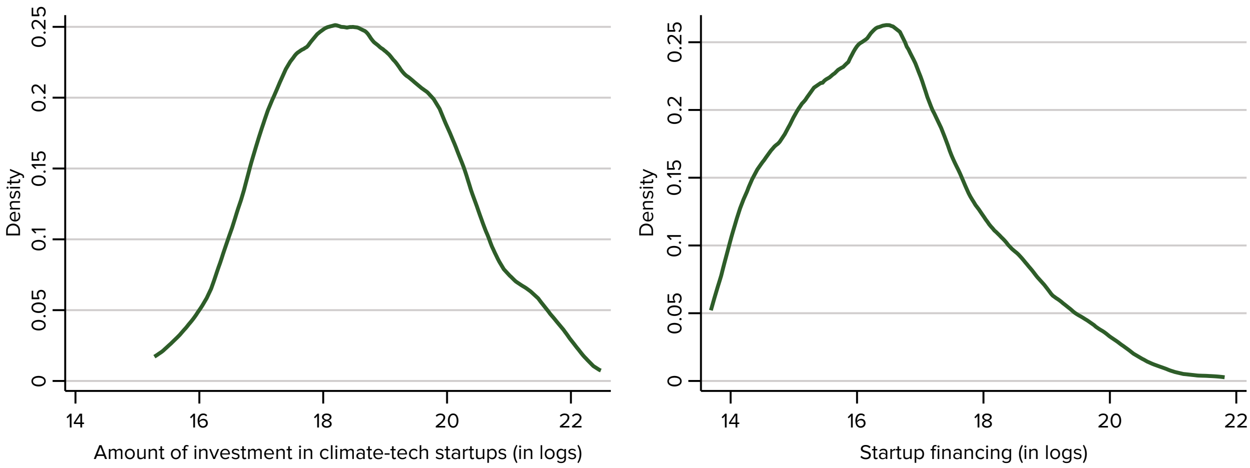
Additionally, key recommendations for VC/PE investors can be summarized as follows:

1. Diversify portfolios in climate-tech sectors to manage sector-specific risks and hedge against sector-specific vulnerabilities.
2. Align investments with the most recent empirical findings and climate objectives.
3. Incorporate sector-specific assessments to identify risks and opportunities to ensure balanced and sustainable capital allocation.
4. Discover the factors and trends leading capital flows to anticipate the sectors with the highest potential profits and make more strategic investment decisions.

Appendix

A Appendix Figures

Figure A1. Distribution of VC/PE investors' investments and startup funding amount.



Source: Author.
Note: This Figure shows the distribution of VC/PE companies' total investments in climate-tech startups (on the left) and climate-tech startups' total funding received from the VC/PE companies (on the right).

B Appendix Tables

Table B1. Climate-tech sectors, subsectors, applications, and technologies.

	Subsector	Application	Technology
Clean power	Power equipment and technology	Solar equipment and technology	Solar power equipment
			O&M/digital technologies – solar
		Wind equipment and technology	Wind power equipment
			O&M/digital technologies – wind
		Nuclear	Fission
			Fusion
		Geothermal equipment and technology	
		Hydropower equipment and technology	
		Carbon capture equipment and technology	
		Demand response, VPPs and DERMs	
		Grid	Grid hardware
			Grid software
	Clean power development	Utility-scale developer	Solar developer
			Wind developer
			Stationary energy storage
			Carbon capture developer
			Hydropower developer
			Geothermal developer
		Distributed energy development	
Clean molecules	Hydrogen	Project development	Hydrogen production developer
			Hydrogen transport and storage developer
		Equipment and technology	Hydrogen production equipment and technology
			Hydrogen transport and storage equipment and technology
			Hydrogen fuel cells
	Renewable fuels	Biofuels	
		E-fuels	
		Waste to fuels	
	Oil and gas decarbonization	Efficiency	
		GHG monitoring and management	

Notes: The table presents the sectors, subsectors together with the application and technology in those sectors.

Table B2. Climate-tech sectors, subsectors, applications, and technologies.

	Subsector	Application	Technology
Energy storage	Lithium batteries	Battery technology, materials and manufacturing	
		Battery recycling	
	Battery-metal mining		
	Mechanical energy storage		
	Thermal storage		
	Non-lithium electrochemical storage		
	Storage integration		
	Battery software		
Transport	Battery electric vehicles	Passenger vehicles	
		Commercial vehicles	
		Two-three-wheelers	
		Components and materials	
	Electric vehicle charging	EV charging hardware	
		EV charging software	
		Infrastructure developer	
	Fuel-cell vehicles		
	Mobility services	Ride-hailing	
		Micromobility sharing	
		Car sharing	
	Low-carbon aviation	Electrified aviation	
		Hydrogen-powered flight	
	Low-carbon shipping	Hydrogen-powered shipping	
	Transport system efficiency		
Buildings	Heat pumps		
	Cooling systems		
	Energy efficiency	Energy efficiency hardware	
		Energy efficiency software and sensors	
	Low-carbon construction		

Notes: This table is the continuation of Table B1 and presents the sectors, subsectors together with the application and technology in those sectors.

Table B3. Sectors, sub-sectors, applications, and technologies in climate-tech.

	Subsector	Application	Technology
Industry	Mining decarbonization		
	Point-source carbon capture		
	Industrial efficiency		
	Steel and aluminum	Fuel switching – metals	Electrified metal production
			Hydrogen-fired metal production
		Metals recycling	
	Cement	Fuel switching – cement	Electrified cement production
			Hydrogen-fired cement production
		Cement recycling	
		Low-carbon cement substitutes	
	Chemicals and petrochemicals	Fuel switching – chemicals	Electrified chemicals production
			Green hydrogen-derived chemicals
		Recycling and end-of-life management	Chemical recycling
			Digitalization of recycling
		Low-carbon chemicals substitutes	Bioplastics and biochemicals
			CO_2 to plastics
	Low-temperature industry decarbonization	Food and beverage decarbonization	
		Pulp and paper decarbonization	
		Textiles and clothing decarbonization	
Agriculture	Crop farming	Precision agriculture	
		Indoor farming	
		Crop inputs	
		Plant science	
	Low-carbon fats and proteins	Plant-based	
		Cultured meat	
		Precision fermentation	
	Food waste management		
Carbon and nature	Carbon removal	Direct air capture	
		Land-based carbon removal	
		Ocean-based carbon removal	
	Carbon management	Alternative carbon utilization	
		Carbon transport and storage	
	Accounting, monitoring and modeling	Carbon accounting	
		Climate monitoring	
		Climate modeling	
	Voluntary carbon market	Project developer	
		Marketplace	
	Biodiversity tech		
	Water tech		

Notes: This table is the continuation of Table B1 and presents the sectors, subsectors together with the application and technology in those sectors.

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Endnotes

[1] Equity investors hold their stakes in companies for approximately 3-7 years and realize returns for their LPs (investors) through various exit strategies, such as M&As, IPOs, and management buyout.

[2] VC investors generally tend to finance more risky, early-stage startups, whereas PE investors usually invest in more mature companies. Owing to their high-risk appetite for investing in startups, VC investors offer capital, strategic guidance, mentorship, and access to networks of industry experts in exchange for ownership and significant returns. Conversely, PE investors help more mature companies scale their proven technologies. Moreover, the management of VC and PE investors tends to vary across countries; some of these investors are actively involved in managing their investments, whereas other investors may not be involved in day-to-day management issues.

[3] Ventures at the early stages involve high risks for investors because they hold few tangible assets and a limited record of performance measures; they are also unlikely to sustain healthy cash management under debt-based finance. Therefore, conventional financial institutions providing capital based on debt financing, such as banks, are considered unsuitable for startup financing. Moreover, startups need time to test and prove the commercial viability of their products and services. Hence, a fixed repayment schedule in debt financing is less desirable for startups than is more flexible equity financing, which allows entrepreneurs to secure returns to investors over a longer-term period.

[4] Gaddy et al. (2017) is the most closely related paper to the current study, documenting a reallocation across clean-energy sectors.

[5] Sectors with higher degrees of innovation, technological advancements, market expansion, and investments attract more capital and talent than other sectors. Such factors indicate how vibrant and evolving a sector is, signaling market confidence and future growth potential, and eventually leading to higher numbers of completed deals.

[6] Clean-tech typically refers to several sectors, such as energy, transportation, water, and materials.

[7] Tables B1, B2, and B3 in Appendix B provide details regarding the subsector, technology, and application for each sector in the climate-tech field.

[8] Funding stages represent successive rounds of financing as a startup matures. In general, the seed stage is the first official funding stage, which involves financing the company's first steps, including market research and product development. Series A funding is the next round of funding after seed funding, supporting initial market entry and product development. Series B funding focuses on scaling operations and is not used for product or service development. Series C and D funding broadens the investor range, facilitates expansion across borders, and prepares the company to an exit, whereas Series E funding typically enables pre-exit funding and an exit strategy. In addition, some deals are classified simply as VC or PE financing, without a specific stage designation, which is referred to as "unclassified VC/PE" investments in the dataset.

[9] Figure A1 in Appendix A shows the distribution of VC/PE companies' investments in the climate-tech industry and climate-tech startups' total funding received from VC/PE investors.

[10] More specifically, the results suggest that VC-backed startups received less than approximately one-third of the financing compared with their counterparts (using the coefficient of 1.162 for the dummy variable of VC, exp(1.162)-1=2.196*100=219%).

[11] The increased scrutiny of startups by the investors may have occurred due to fears of a bubble or the realization or belief of overfunding (i.e., providing excess capital to) startups.

[12] See the latest European Lender Intentions Survey 2024 and European Investor Intentions Survey 2024, respectively, at https://mediaassets.cbre.com/-/media/project/cbre/shared-site/insights/reports/ european-lender-intentions-survey-2024.pdf?rev=ed57cabe9c974b57af9efb81e76555a1 and https://mktgdocs.cbre.com/2299/b48e9cae-efe5-4141-880c-0aed494004ac-968465607/v032024/ European%20Investor%20Intentions%20Survey%202024.pdf.

[13] In contrast, they may not consider the existing innovation performance of a venture and focus on potential innovation output and corresponding profitability in the future. In support of this argument and in contrast to these studies, Croce, Martí, and Murtinu (2013) find that VC-backed firms do not have higher productivity growth than their non-VC-backed counterparts before they receive funding, although they have greater productivity growth after the first round of funding.

[14] In contrast, Gompers et al. (2008) find that VC activities are responsive to IPO activities.

[15] Lerner (2013) discusses possible policy initiatives that may contribute to the growth of financing ventures.

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Notes

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About the Author

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Dr. Cilekoglu is a Postdoctoral Researcher in the Climate & Sustainability Program. His current research covers understanding sustainable finance practices, the implications of climate change, and the responses of firms to climate policy initiatives. He holds a Ph.D. in Economics from the University of Barcelona and an M.Sc. in Economics from Catholic University in Milan. He was previously a Lecturer at Istanbul Bilgi University and a Visiting Researcher at both LMU in Munich and METU in Ankara. Prior to joining KAPSARC, he worked as a Climate Policy Consultant for a political party.

About the Project

This study investigates the climate-tech startup financing of venture capital (VC) and private equity (PE) investments across different sectors worldwide for the 2022-2024 period. Cross-sectional analysis suggests that startups in sectors with greater dynamism (proxied by deal activity) received more funding than those in sectors with less dynamism. The findings reveal sectoral clustering in climate-tech sectors, with VC/PE financing not being uniformly distributed across various climate-tech sectors. The total funding provided to climate-tech startups and the number of deals vary significantly across countries and sectors. The potential reasons for sectoral clustering in climate-tech sectors are discussed, along with recommendations for policymakers. This paper contributes to a broader understanding of capital flows within the climate-tech ecosystem, offering insights for policymakers seeking to ensure efficient capital allocation for various climate solutions and accelerate the transition to a sustainable economy.

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