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Equity Crowdfunding as a Source of Finance for Early-Stage Cleantech Firms: Exploring the Role of Patents

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Abstract. This study investigates whether European Cleantech firms with patents attract more equity crowdfunding than those without patents. We find that firms with patents indeed raise significantly more funding in crowdfunding campaigns. We also find, inter alia, that two measures of innovation —firms' intangible asset values and the number of patents pending— increase after a successful (in terms of amount raised) crowdfunding campaign. Firms with patents granted have more debt finance than firms with patents pending. A key determinant of the amount of crowdfunding raised is the number of patents pending, suggesting that equity investors are keen to invest on the promise of success. We also find that debt finance has a significant impact on the development of intangible assets, which indicates the role of capitalized intangible assets and patents to secure debt. Our findings suggest support for signaling theory, as patents reduce information asymmetries and act as a signal for equity crowdfunding investors.

Keywords: equity crowdfunding, cleantech, entrepreneurial finance, patents, innovation.

JEL Classifications G24, G32, L26, O32.

1. Introduction

In this study we investigate the resourcing of Clean Technology (Cleantech) firms. Action on Climate Change is now the top priority of governments globally. It is increasingly evident that national governments and global coalitions are required to make substantial policy and financing commitments to reducing carbon and other greenhouse gas emissions in order to contain global warming to within 1.5 degrees net increase above pre-industrial levels by achieving Net Zero emissions by 2050, or sooner. Recent UN IPCC reporting (United Nations, 2021) provides a stark perspective on this, with both Bloomberg and the International Energy Agency estimating that current global climate change investments are

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under half of the annual run-rate costs required (estimated at $2.35T). The Paris Agreement, a legally binding international treaty on climate change, has a vision of accelerating technology development and transfer (United Nations, 2015) in order to reduce harmful carbon emissions. Development of innovative disruptive technologies to enhance and reverse the harmful effects of carbon emissions is emphasised by governments and international agencies (Polzin, 2017; Owen et al., 2018).

Cleantech can be categorised into green entrepreneurship or eco-entrepreneurship. Green entrepreneurship refers to a special subset of entrepreneurship that aims at creating and implementing solutions to environmental problems and promoting social change so that the environment is not harmed (Saari and Joensuu-Salo, 2020). Eco-entrepreneurship is defined as being based on implementing innovations in the environmental sector (Rodríguez-García et al., 2019). The eco-entrepreneur is aware of the environmental impact that their business exerts on the surroundings and develops innovations that reduce this impact (Gerlach, 2003). Gaddy et al. (2017) define Cleantech firms as firms that commercialize clean energy technologies, entailing the development, integration, deployment, or financing of new materials, hardware or software, that has a focus on energy generation, storage, distribution, and efficiency. We define early-stage Cleantech firms as private for-profit Small and Medium Sized Enterprises (SMEs) less than 5 years old whose aim is to develop and adopt innovative technologies to reduce carbon dioxide emissions in their products and processes (Kenton, 2018). Our sample of Cleantech firms operate in the Energy Efficiency, Recycling and Waste Management, Renewable Energy, and Transportation sectors.

Small early-stage ventures play a significant role in innovation and invention (Owen et al., 2018) although they typically lack sufficient resources to develop and scale their business (Ghosh and Nanda, 2010; Giudici et al., 2018; Hornuf and Schwienbacher, 2018). Early-stage Cleantech firms require long horizon intensive R&D which can span from proof of concept to early-stage commercialization (Mazzucato and Semieniuk, 2018) which presents resourcing challenges, particularly at start-up. They experience *valley of death* periods along with a higher *liability of newness* compared with other new ventures (Lehner and Nicholls, 2014; Lehner et al., 2018). This is due to their hybrid business-models (Quélin et al., 2017) that aim to combine commercialization with an environmental mission (Doherty et al., 2014). Due to their long horizon R&D, Cleantech firms often struggle to obtain sufficient, frequently high, levels of private investment required to reach commercialization (Rowlands, 2009; Owen et al., 2019). As such, investors may not be rewarded for the full environmental and societal value, and the risk-reward balance is viewed as unfavourable to investors (Bocken, 2015). Efforts have focused on larger infrastructural projects (Mazzucato and Semieniuk, 2018) and far less attention has been given to early-stage Cleantech SME investment (Owen et al., 2018). There is thus a need for

greater understanding of finance for new low carbon innovations and businesses (Rizos et al., 2016).

The emergence of Crowdfunding has provided young entrepreneurial firms with an additional source of external equity finance, one that plays an increasingly important role (Ahlers et al., 2015; Bruton et al., 2015; Cumming and Vismara, 2017). Equity crowdfunding has a positive impact on innovation (Stanko and Henard, 2016; Paschen, 2017) and developing growth opportunities (Signori and Vismara, 2018; Eldridge et al., 2021). Crowdfunding is viewed as an important innovation within both developed and developing countries' innovation and finance ecosystems (Lam and Law, 2016). According to Crunchbase, of 2,967 equity crowdfunding campaigns between 2014 and 2018, 177 of these were Cleantech firms, representing 5.9% of all equity crowdfunding campaigns. Hörisch (2015) noted that in the context of environmentally oriented ventures, crowdfunding's potential is not sufficiently used but its use is increasing due to the increased focus on environmental issues at government, agency and investor levels.

Patents, as well as the amount of time and resources invested in R&D, are two of the most important proxies for technological capabilities (Baum et al., 2019). Some studies indicate that such supply-drive technological innovations are particularly important in Cleantech (Horbach, 2008). Dangelico (2017) states that new technologies and environmental commitment related to technological aspects are relevant factors that drive the radical nature of green products or services.

Patents reduce information asymmetries in entrepreneurial finance (Conti et al., 2013b) and can act as a signal for start-up financing. Lerner (2002) find that small, capital constrained firms have a higher propensity to patents than larger firms. One reason for this is the financial role of patents. The Berkeley Patent Survey (Graham et al., 2009) finds that one of the main reasons for start-up firms to obtain a patent is to secure financing. High technology start-ups with little or no track record commonly face the problem of financing costly development of new inventions, or the R&D required to reach commercialization (Rowlands, 2009). A patent can also be considered an asset that can be used as collateral for debt financing (Yang et al., 2023). Previous studies that have examined the role of patents on firm financing find a positive relationship between patents and venture capital financing (Conti et al., 2013b; Hsu and Ziedonis, 2013). Conti et al. (2013a; 2013b) when distinguishing between types of external investors, find that venture capitalists are endogenous to the process, but private investors are not and ultimately that firms with more patents attract venture capitalists and not private investors. As crowdfunding will have a mix of investors, we aim to examine the role of patents in crowdfunding for Cleantech firms.

Our study focuses on the 177 early-stage Cleantech firms that have raised funding through European equity crowdfunding platforms between 2014 and 2018. The aim of our study is to obtain a deeper understanding of the role of

patents of Cleantech firms in their funding along with assessing the potential impact of equity crowdfunding on innovation. We investigate by posing the following research questions: (1) Do Cleantech firms with patents attract more crowdfunding? and (2) Does crowdfunding have an impact on innovation for Cleantech firms? This study also draws on signaling theory. This study adds to the financing of start-up and early-stage firms' literature by taking a first-time look at the role of patents in attracting crowdfunding, while also investigating the post-campaign increases in innovation of Cleantech firms.

2. Background Literature

2.1. Patents and Signaling Theory

A patent is a type of intellectual property that gives its owner the legal right to exclude others from making, using, or selling an invention for a limited period of years, in exchange for publishing an enabling public disclosure of the invention (WIPO, 2024). IAS 38, Intangible Assets (IAS Plus, 2022), outlines the accounting requirements for intangible assets, which are non-monetary assets which are without physical substance and identifiable either being separable or arising from contractual or other legal rights. The recognition of patents is set aside clearly under IAS 38 where key criteria must be met before including the determinable value of a patent under the intangible asset heading. It is also important to note the role of the research and development definitions in the value of intangible assets. Research costs must be expenses to the profit and loss account whereas if certain criteria is met, development costs can be capitalized as intangible assets. As such, we see a clear link between the definition of a patent and the recognition of intangible assets as part of our study.

Patents, grants, and awards can be aligned to Spence's (1973) original conceptualization of signals of quality insofar as they act as certifications of novel and useful inventions, which can be viewed as a proxy for quality and provide investors with external quality assessments (Hsu and Ziedonis, 2008). Patent registration can be expensive, due to registration fees, legal advice etc., but a start-up's ownership of a registered patent at the time of offering shows that an entrepreneur has already incurred the costs. Moreover, patent ownership can protect against the risk of future market entrants, so it could be interpreted as a signal of a company's strength and quality. Therefore, our study ties into signaling theory as developed by Spence (1973). Signaling is a reaction to informational asymmetry in markets because company management has information that investors do not have. Asymmetries can be reduced if a party has more information than others. Signaling theory states that information on a company's financial health is not available to all parties in a market at the same

time. Specific to start-ups and early-stage ventures, potential investors try to evaluate the unobservable characteristics of start-ups by interpreting the signals of entrepreneurs (Connelly et al., 2011). Similarly, signaling theory has been used to explain which types of information lead investors to invest in start-ups (Cosh et al., 2009; Robb and Robinson, 2014). This helps to minimise the information gap between investors and stockholders (Miller and Del Carmen Triana, 2009). Ahlers et al. (2015) highlight that reliable signals are not typically available from start-ups, because they may not have a credit history yet. Specific to equity crowdfunding, Ahlers et al. (2015) provide the first study exploring the significance of signals in equity crowdfunding. They find strong empirical evidence that signaling plays an important role for investors, especially concerning potential risk factors, the share of equity offered, and board structure and size. Several studies have examined signaling in equity crowdfunding and highlight key signals that impact both firms and investors. These include the amounts raised (Vismara, 2016), human capital (Piva and Rossi-Lamastra, 2018), project updates (Block et al., 2018), campaign communications (Dorfleitner et al., 2018), team quality (Angerer et al., 2017), and marketing strategies (Davis et al., 2017).

Patents play an important role in the development of innovative firms by acting as a signal for quality (Hottenrott et al., 2016), thereby helping to obtain venture capital financing (Haeussler et al., 2012). Patents are also often used as collateral for debt financing (Conti et al., 2013b). Graham et al. (2009) and Knight (2013) suggest that early-stage ventures patent in order to protect their competitive advantages on technology from possible imitators.

2.2. Financing Early-Stage Cleantech Firms

Advancing technological innovation in the Cleantech sector has become a public policy priority worldwide, as reflected in the 2015 Paris Agreement (United Nations, 2015). It is further demonstrated as an urgent need in the most recent United Nations Intergovernmental Panel on Climate Change report (2021). Innovative SMEs have the potential to develop significant technologies to address future low-carbon economic requirements if they can successfully scale their business (Lerner, 2010; Owen et al., 2019). Financing Cleantech SME innovation should therefore be an essential cornerstone of policies to tackle climate change (Owen et al., 2020). Studies show that investment in sustainable startups can drive the transition to cleaner production (Bocken, 2015; De Lange, 2019). Consequently, this has increased the research focus on the involvement of different providers of entrepreneurial finance (De Lange, 2019). Despite Cleantech's importance for sustainability goals, investors have shown diminished interest in investing in Cleantech startups (De Lange, 2016, 2017, 2019; Cumming et al., 2017). This is due to the fact the financing gap is a greater

problem for the diverse forms of Cleantech ventures as they are capital intensive, have a high technology risk profile and uncertain exit opportunities for investors (Ghosh and Nanda, 2010; Rodriguez et al., 2020). The environmental-societal risk-reward balance is often viewed as unfavourable (Bocken, 2015; Owen et al., 2018), with investors not rewarded for the full environmental-societal value of their investment. The development of Cleantech is often characterized by long development times and high capital intensity (Gaddy et al., 2017; D'Orazio and Valente, 2019) and studies have likened Cleantech development as the *valley of death* (Bürer and Wüstenhagen, 2009; Balachandra et al., 2010). There is also an equity investment gap in knowledge-intensive early-stage firms (Wilson et al., 2018). According to the IEA (2021), half of the technologies required to achieve net-zero emissions have not been invited yet. Understanding the financing requirements for these technologies is essential (WEF, 2021). Yet there has been little attention to early-stage Cleantech innovations that develop potentially game-changing technologies that can contribute and assist in decarburization and climate mitigation (Polzin, 2017; Owen et al., 2018, 2019, 2020; Owen, 2021). Due to the above, early-stage Cleantech firms suffer from a *liability of newness* compared with other new ventures (Lehner and Nicholls, 2014; Lehner et al., 2018) and resourcing these firms can be quite challenging (Owen et al., 2018).

2.3. Crowdfunding

Several alternative sources of finance have emerged for environmentally sustainable startups (Mazzucato, 2013). Recent research indicates that there is increasing interest from investors who are valuing sustainability (Hawn et al., 2017; Durand et al., 2019). Owen et al. (2020) suggests that while crowdfunding is viewed as an important financing method within both developed and developing countries' innovation and finance ecosystems (Hörisch, 2015; Lam and Law, 2016), its potential is not sufficiently used in the context of environmentally oriented ventures. Crowdfunding has emerged as a new source of external equity finance that plays an increasingly important role in the financing of young entrepreneurial firms (Lee et al., 2015; Short et al., 2017). Scholz (2015) states that crowdfunding is becoming very relevant for small businesses with impacts on innovation. The crowdfunding market has increased dramatically over the last decade, second only to venture capital in number of deals completed in 2020. It is anticipated that this will continue to grow rapidly in the future with the global crowdfunding market expected to reach $40 billion by 2026 (Statista, 2020).

There have been limited studies undertaken on equity crowdfunding in Cleantech firms. A number of studies have investigated sustainable ventures and sustainable projects in relation to other forms of crowdfunding, such as reward-based (Bonzanini et al., 2016; Adhami et al., 2017). Using a reward-based

platform, Indiegogo, and specific to Cleantech firms, Cumming et al. (2017) find that Cleantech crowdfunding is negatively related to individualism and is more common when oil prices are rising. Bonzanini et al. (2016) examine the determinants of campaign success across renewable energy on 13 different platforms while Bento et al. (2019a) examined the extent to which specific project characteristics influence the ability to raise funds on a reward-crowdfunding platform, Kickstarter. In another study by Bento et al. (2019b) they find that technological risks contribute to decreases in the excess of returns of the projects and countries' technological capacity and cultural dimensions explain variances in returns. They also concluded that larger average investments are associated to projects with superior return/risk profiles. Examining differing types of crowdfunding across Europe, with a focus on 'green' platforms, Adhami et al. (2017) find significantly positive effects of green crowdfunding activity on two different indexes of environmental performance and well-being at the local level. Being a sustainability-orientated firm does not increase the chances of success or of engaging professional investors, although it attracts a higher number of restricted investors and could suggest doing so for the 'social good' (Vismara, 2018). Slimane and Rousseau (2020) assessed the success factors of crowdfunding campaigns for renewable energy projects in France. The need for a clear research and policy agenda to assist early-stage Cleantech financing has never been greater and one in which crowdfunding can play a vital role (Owen, 2021).

3. Hypothesis Development

3.1. Patents as a Signal for Finance

Early-stage ventures use patents as signals of quality to secure financing (Long, 2002; Mann and Sager, 2007). Studies have shown that having patents increases the likelihood, as well as the amount, of external equity (Hsu and Ziedonis, 2013; Zahringer et al., 2017). These results have led to the conclusion that patents are signals of quality. Specifically for early-stage ventures external equity financing has differing findings between different types of external equity, in particular angel investment and venture capital investment. Conti et al. (2013a) and Vo (2019) find that patents are not a signal of quality for angel financing. However, numerous studies have pointed to the fact that patents act as a signal of quality for venture capital financing (Haeussler et al., 2012; Vo, 2019; Hall, 2019).

In relation to crowdfunding there has been limited studies on the role of patents in crowdfunding campaigns. Studies show it is important to differentiate between different crowdfunding types, including donation, peer-to-peer lending-based, reward-based, and equity-based crowdfunding (Mazzucato and

Semieniuk, 2018; Vismara, 2016) because the crowds' motives to back a campaign are significantly different between these crowdfunding types (Cumming and Johan, 2013). Each type of crowdfunding has certain needs of the startup or project initiator (Mollick, 2014).

Examining equity-based crowdfunding, Ahlers et al. (2015) find that external certification (including patents and government grants) had little or no significant impact on success. Vismara (2016) shows that intellectual capital plays an important role for sophisticated investors that fund companies in the very early-stages on equity crowdfunding platforms, but the patent itself does not seem to be a significant predictor of a campaign's success. Scheaf et al. (2018) state that patents are relatively inflexible signals from equity-based platforms to reward-based crowdfunding platforms. Studies have also focused on reward-based crowdfunding and Cotropia (2018) finds that patented projects are not more likely to obtain funding compared to non-patented ones but that patent-pending projects are more successful in getting funded suggesting investors are attracted to the prospect of future patent success by investing early. Roma et al. (2017) find that patents are complementary when raising financing on reward-based crowdfunding platforms. However, Meoli et al. (2019), find that from a reward-based crowdfunding context there is a negative signaling role of patents on a campaign's success. They explain that this is due to the specificities of the reward-based crowdfunding model, the fact backers do not receive any equity in the company, the fact patents and high innovation may be difficult for backers to understand (Colombo et al., 2015) and it is very different from traditional sources of finance for early-stage ventures which ultimately suggests that patents could have a negative signaling value in the context of reward-based crowdfunding. We focus our study on equity crowdfunding (Ahlers et al., 2015; Signori and Vismara, 2018) since investor motivations are different between donation-based and reward-based to that of equity crowdfunding. We also know that equity-based crowdfunding platforms raise more than reward-based platforms (Vulkan et al., 2016).

Hypothesis 1. Cleantech firms with patents will attract more equity crowdfunding than Cleantech firms without patents.

3.2. Innovation and Crowdfunding

Innovation is viewed as a component of competitiveness and competitive advantage (Bruton et al., 2015; Hervé and Schwienbacher, 2018) but it can take place in several ways and can be difficult to measure due to its abstract nature. Innovation in firms has been one of the primary themes in economic research for many years. Beginning with Schumpeter's (1942) intuition on the role of the "innovative" entrepreneur, the field has considerably widened and now includes numerous different aspects. There are several studies that claim external

relationships and networks can foster innovation performance (Freel, 2000; Nieto and Santamaria, 2007; Rogers, 2004). Other studies state that patents offer consistency and objectiveness because examiners may validate new inventions on their utility, which is an important point to measure innovation (Boone et al., 2019). In contrast, Jin et al. (2019) discuss that while patents may be ideal to some industries, the new-product indicators might be more appropriate to others. The existing empirical literature lists a wide range of indicators used to measure innovation, including citing patents, granted patents, R&D investment, and new product launches, among others. Regardless of the choice, there are significant limitations and differences in aspects to be measured, thus it is important to properly identify its features for an appropriate use in empirical research and to incorporate several metrics (Taques et al., 2021).

Several studies (Janger et al., 2017; Michel and Bettels, 2001; OECD, 2015) have identified innovation indicators stating 'inputs' and 'outputs' of innovation. Examples of inputs include R&D expenditure, employees with higher education qualifications and expenses on ICT related activities. Intermediary outputs are considered in-between 'inputs' and 'outputs' and are classified as patent applications, patents granted and trademarks. Sales of innovative products, new product announcements and people engaged in knowledge-intensive activities are considered as examples of innovation outputs (Taques et al., 2021).

Studies have shown that early-stage Cleantech firms show more technological novelties than those of other technology-related firms and that supply-drive technological innovations are particularly important in Cleantech (Horbach, 2008). Dangelico (2017) states that new technologies and environmental commitment related to technological aspects are relevant factors that drive the radical innovative nature of green products or services. Jensen et al. (2020) find that Cleantech start-ups have higher technological capabilities compared with other start-ups and provide evidence that Cleantech start-ups develop more market novelties than any other control peer group used in their study.

Innovation and future growth opportunities are essential to Cleantech firms in their ability to scale and reach commercialization (Mazzucato and Semieniuk, 2018; Lehner and Nicholls, 2014; Lehner et al., 2018). Doran and Ryan (2016) confirm that firms exploiting market and technological opportunities for the supply of environmentally responsible features are associated with high innovation capabilities. Sáez-Martínez et al. (2016) study eco-innovation in startups and find that both combinations of technological trajectories and R&D strategies are important drivers of eco-innovation in young firms. Jensen et al. (2020) find that startups in Cleantech have, on average, higher technological capabilities compared with all other startups, but they also show that Cleantech startups are more likely to combine existing technologies in novel ways suggesting that Cleantech firms are more innovative. Our study aims to confirm

this and also investigates whether crowdfunding has a positive impact on innovation and growth opportunities.

Understanding equity crowdfunding post-campaign outcomes is gaining increased attention (Eldridge et al., 2021). There is scant amount of research on post-campaign performance and most of the literature on the impact of crowdfunding on innovation and growth stems around the role of backers in their ability to provide feedback which in turn could lead to idea generation and innovation. There can be several non-financial benefits to early-stage ventures utilizing crowdfunding, with the contribution towards incremental innovation viewed as the greatest benefit, as it promotes growth (Paschen, 2017; Stanko and Henard, 2016). Firms that suffer from liabilities of newness and smallness would benefit from customer participation (Chang and Taylor, 2016) and therefore, crowdfunding should increase the level of innovation within an early-stage venture, due to idea generation and external feedback from backers (Hervé and Schwienbacher, 2018). Successful equity crowdfunding campaigns can create market awareness and visibility (Schwienbacher and Larralde, 2012), which is often essential for young and small firms that need to attract additional resources to support their development (Vanacker and Forbes, 2016). Paschen (2017) finds that crowdfunding supports growth by reducing the cost of financing and the provision of knowledge from external backers. Cumming et al. (2019) warns that the degree of growth may be impacted by the model of crowdfunding that is used insofar as that backers are more vested in equity crowdfunding models due to an investment stake and are more likely to contribute ideas and provide feedback which can assist in innovation and growth. Their finding also suggests that crowdfunding reduces the requirement for long-term debt, which has a negative correlation with firm growth thus increasing the level of reserves in a firm, which allows for financing expansion. Studies have suggested that equity crowdfunding can provide costless transfer of knowledge from customers to founders (Vismara, 2018) and that equity crowdfunding can act as a catalyst for growth through the influencing mechanism of the wisdom-of-the-crowd effect (Polzin, 2017; Eldridge et al., 2021). Walthoff-Borm et al. (2018) finds that from the year of the campaign and in post-campaign years, equity crowdfunding firms generally exhibit significantly more (3.4 times) patent applications than non-equity crowdfunding firms which suggests firms who seek equity crowdfunding are in fact more innovative in the first place. There has also been a recent study suggesting contradictory findings on the impact of crowdfunding on innovation and growth. Eldridge et al. (2021), sampling 230 UK firms using BVD Orbis Europe database, find that there is a negative relationship between crowdfunding and innovation. However, they do find that equity crowdfunding acts a catalyst for growth confirming findings of previous studies (Estrin et al., 2018), and that there is an impact of the wisdom-of-the-crowd effect (Polzin, 2017; Hervé and Schwienbacher, 2018).

Hypothesis 2. The amount of equity crowdfunding has a positive impact on innovation for Cleantech firms.

4. Methodology

4.1. Data

Our study investigates the role of patents in the equity crowdfunding of Cleantech firms across Europe and investigates the impact of equity crowdfunding on innovation. We compile a unique database of 177 Cleantech firms that have successfully raised equity on crowdfunding platforms, for the first time, including all firms that have raised equity crowdfunding from 2014 to 2018. Our data comes from several sources. We first use the websites of European-based equity crowdfunding platforms (see Table 1) to identify and collect data on the firms that have successfully applied for and raised equity crowdfunding during the 2014–2018 period (inclusive). We undertook detailed verification checks on the validity of each of the equity crowdfunding platforms used in this study by cross-referencing them with the Crunchbase database ensuring completeness of all Cleantech firms that raised equity crowdfunding on European platforms. The selection of country was dictated by the validity of the equity crowdfunding platforms cross-referenced using the Crunchbase database. Using the information on the platform websites and cross-referencing with Crunchbase, we collated campaign-specific data including the amount raised, the number of investors, and the equity given to investors. We undertook detailed examination of the qualitative information used in each campaign pitch to obtain information on the purpose of funding allowing us to classify the primary use of funding in each campaign. In addition to the campaign-specific information, we then used multiple sources to collate data on each firm.

We use the Orbis Europe database, Bureau Van Dijk (BVD) which contains high-quality accounting data on privately held and publicly traded European firms (Faccio et al., 2011; Walthoff-Borm et al., 2018; Eldridge et al., 2021). It also contains basic information on the patent and royalty portfolio of each firm. We then cross-reference their patent portfolio by using PATSTAT and Espacenet to see their exact status of patents granted or patents pending before and after the crowdfunding campaign. Finally, we examined each firm on the Crunchbase database to assess whether firms have raised equity financing before and/or after the crowdfunding campaign (Hornuf and Schwienbacher, 2018; Signori and Vismara, 2018).

Table 1. Crowdfunding Platforms and Countries

Crowdfunding Platform	**Country**
Spreds	Belgium
FundWise	Estonia
Funderbeam	Estonia
Invesdor	Finland
SoWeFund	France
WiSeed	France
Companisto	Germany
Seedmatch	Germany
Spark Crowdfunding	Ireland
BacktoWork	Italy
MamaCrowd	Italy
OnePlanetCrowd	Netherlands
Symbid	Netherlands
The Angel Crowd	Spain
FundedByMe	Sweden
Crowdcube	United Kingdom
Seedrs	United Kingdom
Syndicate Room	United Kingdom
Crowd for Angels	United Kingdom

4.2. Variables

Definitions of variables used to test our various models are provided in Table 2. We conduct three main tests using appropriate dependent variables. First, we examine determinants of equity crowdfunding using 'amount raised' as the dependent variable. The amount of equity crowdfunding raised is a quantitative measure, being the amount that a firm raised on an equity crowdfunding platform. Second, we examine the determinants of innovation. In previous studies, Eldridge et al. (2021) define innovation using the net income growth rate while Walthoff-Borm et al. (2018) define innovation as the share of intangible fixed assets (including capitalized R&D expenses and the value of patents, trademarks, and brands) in total assets. They also include number of patent applications as an indicator of innovation. Our definition of innovation takes a similar approach, focusing on the accounting definition under IAS 38. We define innovation as increases in intangible assets at t+1, t+2 and t+3 to assess the post-campaign impact of crowdfunding on innovation over several years. We also examine the changes in intangible assets on yearly basis comparing the intangible asset value at the base year with the total amount at the end of year 1, 2 and 3 post-crowdfunding to ensure completeness and accuracy of our testing. Like Walthoff-

Borm et al. (2018) we also include patents as another proxy of innovation, using patents pending post-crowdfunding as a proxy for innovation. These are patents that have been applied for after the crowdfunding campaign date, and we believe both proxies are a good measure of innovation in Cleantech firms. As stated, we use two separate dependent variables in our testing. We use the monetary value of intangible assets in the post-equity crowdfunding period, at three intervals, t+1, t+2 and t+3, to reflect up to three years post-equity crowdfunding. We also assess the determinants of innovation by assessing the year-on-year changes in intangible asset monetary values to reflect the increases in the post-equity crowdfunding period.

In relation to our independent variables, when examining potential determinants of the amount of equity crowdfunding, we include the variables firm age since incorporation, the number of investors on a given campaign, and whether firms have raised equity funding or debt funding prior to their equity crowdfunding campaign. We also include variables concerning whether firms have patents pending, patents granted, or no patents at the date of the equity crowdfunding campaign. When examining the determinants of innovation, we include firm age, the number of investors and whether the firm has obtained funding (both equity and debt) prior to their equity crowdfunding campaign. We also assess the role of equity crowdfunding on innovation by including an independent variable on the amount raised during the equity crowdfunding campaign. We then assess the role of patents pre-and-post equity crowdfunding along with funding (both equity and debt) post the equity crowdfunding campaign.

Our control variables include the following: Country of crowdfunding platforms (Table 1); Sector, using the sectoral classification of the MIT energy initiative (Gaddy et al., 2017), which includes Energy Efficiency, Recycling and Waste Management, Renewable Energy, and Transportation; Use of funds, including Expansion, IT Development, Research & Development, Sales & Marketing, and Working Capital; Type of equity funding raised pre-and-post equity crowdfunding, including Angel, Convertible, Grant, Venture Capital, and Crowdfunding.

Table 2. Definitions of Variables used in statistical models

Patent Granted – Whether a firm has been granted a patent or not (binary 1:0)
Patent Pending – Whether a firm has a patent pending or not (binary 1:0)
Patent Granted Pre-Crowdfunding – Whether a firm has been granted a patent or not before the crowdfunding campaign (binary 1:0)
Patent Granted Post-Crowdfunding – Whether a firm has been granted a patent or not after the crowdfunding campaign (binary 1:0)
Patent Pending Pre-Crowdfunding – Whether a firm has a patent pending or not before the crowdfunding campaign (binary 1:0)
Patent Pending Post-Crowdfunding – Whether a firm has a patent pending or not after the crowdfunding campaign (binary 1:0)
Number of Patents Granted Pre-Crowdfunding – The number of patents granted before a crowdfunding campaign.
Number of Patents Granted Post-Crowdfunding – The number of patents granted after a crowdfunding campaign.
Number of Patents Pending Pre-Crowdfunding – The number of patents pending before a crowdfunding campaign.
Number of Patents Pending Post-Crowdfunding – The number of patents pending after a crowdfunding campaign.
Firm Age at Crowdfunding – Age of the firm from incorporation date to raising crowdfunding.
Investors – Number of Investors who contributed to crowdfunding campaign.
Amount Raised – Monetary amount (€) raised as part of crowdfunding campaign..
Equity Funding Pre-Crowdfunding – Monetary amount (€) of equity raised before crowdfunding campaign.
Debt Funding Pre-Crowdfunding – Monetary amount (€) of debt raised before crowdfunding campaign.
Equity Funding Post-Crowdfunding – Monetary amount (€) of equity raised after crowdfunding campaign.
Debt Funding Post-Crowdfunding – Monetary amount (€) of debt raised after crowdfunding campaign.
Raised Equity Funding Pre-Crowdfunding – Whether a firm has raised equity funding or not before the crowdfunding campaign (binary 1:0)
Raised Debt Funding Pre-Crowdfunding – Whether a firm has raised debt funding or not before the crowdfunding campaign (binary 1:0)
Raised Equity Funding Post-Crowdfunding – Whether a firm has raised equity funding or not after the crowdfunding campaign (binary 1:0)
Raised Debt Funding Post-Crowdfunding – Whether a firm has raised debt funding or not after the crowdfunding campaign (binary 1:0)
Intangibles – The monetary value of intangible assets (€)
Change in Intangibles – The monetary value of changes in intangible assets (€)
Shareholder Funds – The monetary value of the shareholder funds (€)
Change in Shareholder Funds – The monetary value of the change in shareholder funds (€)
Note: for Intangibles, Change in Intangibles, Shareholder Funds and Change in Shareholder Funds, variables include timing differences T-1 (prior to crowdfunding campaign), T+1, T+2 and T+3 (years 1, 2 and 3 post-crowdfunding campaign)
Use of Funds: Expansion, IT Development, Research & Development, Sales & Marketing, and Working Capital
Sector Classification: *Energy Efficiency, Recycling/Waste Management, Renewable Energy, and Transportation.*
Type of Equity Funding – *Angel, Convertible, Grant, Venture Capital, and Crowdfunding.*

Table 3. Summary descriptive statistics of variables

Variable	N	Mean	Median	SD	Min	Max
Age (Years)	177	5.05	4.00	3.80	0.00	26.00
Investors (N)	177	776	368	2,280	16	22,712
Amount Raised (€)	177	828,918	450,000	1,392,670	50,000	11,200,000
Intangibles (€) (T-1)	177	270,327	0.00	1,725,775	0.00	21,464,000
Intangibles (€) (T+1)	177	373,920	0.00	2,221,695	0.00	24,946,000
Intangibles (€) (T+2)	177	613,422	8,000	2,881,004	0.00	27,184,000
Intangibles (€) (T+3)	177	773,238	25,078	3,232,076	0.00	25,178,000
Shareholder Funds (€) (T-1)	177	610,344	117,000	1,526,243	-1,813,000	12,009,000
Shareholder Funds (€) (T+1)	177	832,881	214,000	2,158,487	-1,765,000	20,484,000
Shareholder Funds (€) (T+2)	177	729,431	152,500	2,617,505	-5,045,118	15,385,325
Shareholder Funds (€) (T+3)	177	872,119	154,500	2,631,347	-6,987,392	14,100,000

4.3. Tests

Our testing regime consists of ordinary linear regressions. First, we examine the determinants of equity crowdfunding using the amount raised as the dependent variable, and coefficients for these tests are presented in Table 6. We test our base model, before running extended models to include country, purpose of the funds, type of equity funding raised pre-crowdfunding and sectoral control variables. Second, we examine the determinants of innovation for Cleantech firms. We include intangible assets post-crowdfunding as a dependent variable, and coefficients for these tests are presented in Table 7a. We include intangible assets computed at t+1, t+2 and t+3, before running extended modules to include country, purpose, type of equity funding raised pre-crowdfunding and sectoral control variables. We also included changes in intangible assets (year on year) and the coefficients for these tests are presented in Table 7b. We then assess patents pending post-crowdfunding, and coefficients for these tests are presented in Table 8. Although a number of variables are closely related, correlation tests do not suggest a high degree of first-order collinearity among the independent variables.

5. Empirical Results and Discussion

5.1. Descriptive Statistics

In Tables 3-5, we present summary statistics for the firms in our sample. Data on patents granted pre-crowdfunding reveals that these are accounted for by a small

number of firms (33% of our sample), which on average have 13.5 patents granted per firm (=800/59; see Table 4). On reviewing a sample of patents pending pre-crowdfunding, it appears that there is very little difference in innovative or novel steps from a previous (granted) patent application. Firms have submitted amended versions, or have not yet commenced developing the idea commercially, but are using the application as a signal of quality for other purposes such as external funding. In terms of patents pending pre-crowdfunding, we find 35% of firms have patents pending at the date of crowdfunding. When we examine the impact of crowdfunding on the number of patents post campaign, we find that only a small number of firms have new patents granted post-crowdfunding (11%). This may be due to the fact that on average the lead time for a fully granted patent can be between 18 – 24 months and might not fully reflect the impact of crowdfunding on their patents granted. A truer reflection is patents pending post-crowdfunding. We find a larger sample have new patent applications pending post-crowdfunding (27%). 38% of firms have patents fully granted with 49% having at least one patent pending. This provides us with a good opportunity to examine the impact of patents on crowdfunding and innovation. In terms of sector distribution, firms in the Energy Efficiency sector (36%) have the most patents granted, followed by Renewable Energy (25%).

Table 3 shows that the average amount raised during the crowdfunding campaign was €828,918[2]; the average number of investors was 776. When we assess the impact of patents on the amount raised, we see clear differences between firms with patents granted, patents pending and firms with no patents granted or pending. Table 5 shows that firms with patents granted pre-crowdfunding on average raised €1,050,450 in the campaign with firms with patents pending on average raising €905,200. We find that firms with no patents granted or pending raising less at an average of €726,365. We did however find that the number of investors represent the opposite pattern with the number of investors being smaller for firms with patents granted (675 investors), then those with patents pending (707 investors) and firms with no patents attracting the most investors at 851 investors. This ties into studies showing unsophisticated crowdfunding investors not wanting to invest in firms which seem to be technically complex (by having patents), thus making the campaign more difficult for potential backers to understand (Colombo et al., 2015; Meoli et al., 2019).

In terms of funding pre- and post-crowdfunding, we find that 68 firms raised equity funding pre-crowdfunding (38%) with an average investment of €1,167,000 and 75 firms raised debt funding pre-crowdfunding (42%) averaging €872,287. In post-crowdfunding, we find that 35 firms raised equity (20%) with an average investment at €2,584,000 and 89 firms raised debt funding (50%), averaging €735,845 per firm, which indicates that debt funding remained stable before and after crowdfunding. Specific to patents, we analyze the role of patents

2. We use the EUR/GBP exchange rate as of the date of the campaign end and convert the volumes from GBP to EUR for United Kingdom based platforms.

granted, patents pending or no patents on the type and amount of funding obtained pre- and post-crowdfunding (see Table 5). There is a significant difference between the funding amounts of firms with patents and those with no patents. In line with Conti et al. (2013b), we find firms with patents granted have more debt (€524,439) suggesting that firms could potentially use patents as debt collateral (Yang et al., 2023) leading to increased debt compared to firms with patents pending (€376,800) and firms with no patents (€315,778) pre-crowdfunding (see Table 5). In relation to debt funding post-crowdfunding, we find some similar findings, including a signal effect that equity crowdfunding in fact increases debt funding post campaign. Firms that have patents granted post-crowdfunding raised on average €638,755 in comparison to those with patents pending (€502,833) and firms with no patents (€257,889). This clearly demonstrates that having a successful crowdfunding campaign along with having a patent can lead to an increase in debt funding. From an equity funding perspective, we see a clear increase in the funding post-crowdfunding. Pre-crowdfunding, firms with patents on average raised €489,522 in external equity funding which is not a standout compared to firms with patents pending (€389,125) and firms with no patents, who in fact raised more equity at an average of €455,601. The major difference is the increase post-crowdfunding, we find that on average firms who have patents granted after a successful crowdfunding campaign raise €943,093 compared to that of firms with patents pending (€845,253) and firms with no patents (€243,901). This evidently shows that having a patent granted or pending followed by a successful crowdfunding campaign can lead to increased equity investment post campaign. This could be attributed as a signal to the market but perhaps provides comfort to external equity providers that there is an appetite for this product or service and has reached the commercialization and proof of concept stage.

Table 4. Summary data on patents

Patents			
	Number of Patents	**Number of Firms**	**% of Firms**
Patents Granted Pre-Crowdfunding	800	59	33%
Patents Pending Pre-Crowdfunding	754	62	35%
Patents Granted Post-Crowdfunding	59	20	11%
Patents Pending Post-Crowdfunding	306	48	27%
Overall Total (to date)			
Patents Granted	859	68	38%
Patents Pending	980	87	49%

Sector (%)	Patents Granted		
Energy Efficiency	36%		
Renewable Energy	25%		
Transportation	20%		
Recycling / Waste Management	19%		

Table 5. Funding by patents pre- and post-crowdfunding

Funding			
	Patents Granted	Patents Pending	No Patents
Amount Raised in Crowdfunding (€)	1,050,450	905,200	726,365
Number of Investors (N)	675	707	851
Debt Funding Pre-Crowdfunding (% of firms)	52%	31%	43%
Debt Funding Pre-Crowdfunding (€)	524,439	376,800	315,778
Debt Funding Post-Crowdfunding (% of firms)	56%	51%	49%
Debt Funding Post-Crowdfunding (€)	638,755	502,833	257,889
Equity Funding Pre-Crowdfunding (% of firms)	48%	47%	31%
Equity Funding Pre-Crowdfunding (€)	489,522	389,125	455,601
Equity Funding Post-Crowdfunding (% of firms)	29%	31%	10%
Equity Funding Post-Crowdfunding (€)	943,093	845,253	243,901

5.2. Crowdfunding and Patents

In Table 6, we assess the potential determinants of equity crowdfunding by selecting amount raised as our dependent variable. Coefficients for our base model are presented in column 1 with the extended model in column 2. We have an additional model incorporating intangible assets and shareholders' funds which is presented in column 3 with an extended model in column 4. Hypothesis 1 proposes that firms with patents will attract more equity crowdfunding. In the first two columns of Table 6 we provide evidence that patents have a significant impact on the amount raised. We find evidence showing that firms with no patents (pending or granted) pre-crowdfunding raise significantly less funding. We have similar results in our second base model where we include intangibles (t-1) and shareholders' funds (t-1). We once again find significance in patents granted and patents pending to those firms with no patents pre-crowdfunding. One of the key determinants of raising equity crowdfunding is whether a firm has a patent or not, suggesting that investors are willing to invest more money in firms who have a unique or novel invention providing confidence to the investors and the promise of future success. We suggest that our finding provides support for signaling

theory, i.e., patents act as a strong signal or collateral to investors and help ameliorate potential information asymmetries. A lot of innovation and R&D can be considered 'invisible' to investors, but patents are tangible, 'examinable' assets, and in some cases can be valued. Therefore, patents reduce that very considerable information asymmetry that exists with early-stage firms, particularly for firms in an emerging sector like Cleantech where R&D is at a very early stage, and the potential for certain components of the technology is unproven. As we find that firms with patents raise greater amounts of crowdfunding, we propose that this is an indication that patents somewhat reduce information asymmetries.

It is important to differentiate between intangible asset values and patents granted. While patents granted are included in the intangible asset values, it can be quite difficult to measure and value patents. Under the IAS38 criteria, patents can be difficult to value unless there is an existence of an active market, and as such the patent value may only be included as the cost of the patent application itself and all the R&D expenditure to develop the patent cannot be capitalized. Therefore, it is interesting to note that intangible assets is also statistically significant for the amount of crowdfunding raised. As only 33% of firms have a patent granted pre-crowdfunding (see Table 4), it is apparent that it is likely other capitalized development costs under intangible assets are a major influence of crowdfunding investors seeking to invest in Cleantech firms.

Positive shareholders' funds, that includes retained earnings, are also statistically significant, which shows that Cleantech firms with a track record and positive retained earnings, showcasing steady performance, raise more funding. It is interesting to note that previous studies state that investors may not be rewarded for the full environmental-societal value and the risk-reward balance is viewed as unfavorable to investors (Bocken, 2015) and one of the key determinants of raising equity crowdfunding is that of having positive shareholder's funds. While recent studies have suggested equity investors are targeting more investments in green firms (Mrkajic et al., 2019), the findings of Table 6 suggest that at the same time they are still seeking firms with positive performances and the ability to develop intellectual property.

We find that firms that have previously raised equity pre-crowdfunding raise greater amounts on crowdfunding platforms. There are several reasons for this. Previous studies have found that firms embark on crowdfunding as they have difficulties obtaining traditional methods of financing (Walthoff-Borm et al., 2018). Due to the nature of early-stage Cleantech, they may struggle to raise traditional sources of finance and have no option but to resource to equity finance due to lack of collateral assets at their disposal. They may use equity crowdfunding to further gain legitimacy from investors to reach proof of concept and achieve commercialization. Equity investors are more willing to invest in firms that have already had previous success raising equity financing and as such are willing to invest greater amounts into an equity crowdfunding campaign. This

is another possible signal to equity crowdfunding investors that previous investors (Angels or Venture Capitalists) have invested, thus providing comfort over the business listed on a crowdfunding campaign.

Interestingly, we do not find a statistically significant result for firms that have previously raised debt financing. One would expect that firms that have previously raised debt finance to continue this financing pattern, build upon their relationship with debt providers and raise additional debt (Coakley et al., 2018). It is clear from our results that there are distinctions in the sources of finance for firms that embark on crowdfunding. Firms that raise equity pre-crowdfunding will raise significantly greater amounts on crowdfunding campaigns than firms that obtained debt financing pre-campaign. This raises the question on the reasons why Cleantech firms embark on crowdfunding and whether it is due to financial constraints, lack of collateral for debt financing or to use the capital to develop their R&D. Throughout our testing we find no statistical significance between any specific country, use of funds, type of equity funding, or sector, and the amount raised.

Table 6. Determinants of the raised amount of Equity Crowdfunding

Dependent Variable	**Amount Raised**			
	Base Model 1	Ext Model 1	Base Model 2	Ext Model 2
Firm Age	0.04134** (0.02084)	0.00613 (0.05044)	0.03247 (0.02175)	0.01723 (0.14846)
Investors	0.00223*** (0.00031)	0.00134*** (0.00045)	0.00079*** (0.00012)	0.00071** (0.00032)
Raised Equity Funding Pre-CF	0.38145*** (0.15829)	0.29412** (0.15444)	0.25206 (0.17473)	0.32781 (0.25218)
Raised Debt Funding Pre-CF	-0.14793 (0.15777)	-0.13827 (0.13923)	-0.11476 (0.16805)	- 0.16566 (0.15447)
Patents Granted Pre-CF	0.42801*** (0.15791)	0.32783** (0.15655)	0.30606* (0.17354)	0.28061** (0.11220)
Pending Patents Pre-CF	0.37273** (0.17423)	0.29812** (0.14212)	0.35403** (0.16150)	0.21962** (0.09324)
No Patents Pre-CF	-0.41532*** (0.15866)	-0.37421** (0.17714)	-0.42186*** (0.17086)	-0.37125*** (0.10897)
Intangibles (T-1)			0.09891* (0.05917)	0.00687 (0.04095)
Shareholders' Funds (T-1)			0.14409*** (0.05729)	0.13991*** (0.05714)
Constant	1.28565*** (0.18659)	1.18744* (0.71006)	1.05890* (0.66849)	1.30992*** (0.28418)
Country		Yes		Yes
Sector		Yes		Yes
Use of Funds		Yes		Yes

Type of Equity Funding		Yes		Yes
# Obs.	177	177	177	177
Adj. R2	0.4866	0.3735	0.4771	0.5191
F	14.40	4.64	18.88	2.74

Table 6 reports the regression results of the determinants of the raised amount of equity crowdfunding. The regression model above includes the full model extending the base model with country, sector, use of funds and type of equity funding fixed effects. All variables are defined in Table 2. Standard errors are in parentheses. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.

5.3. Innovation

We analyze the potential determinants of innovation by selecting intangible assets and patents pending post-crowdfunding as our dependent variables. In Tables 7A and 7B we report regression coefficients for intangible asset values post-crowdfunding. We use leading variables (t+1, t+2 and t+3) in our testing. We also include the year-on-year changes in intangible assets value to ensure completeness over our testing. Through both models we find similar results. Hypothesis 2 proposes that the amount of equity crowdfunding will have a positive impact on innovation for Cleantech firms. We find that the amount raised on equity crowdfunding campaigns has an immediate direct impact on intangible assets values, but it also has a statistical significance over a three-year period. This indicates that crowdfunding has a positive impact on innovation and intangible assets. Descriptive statistics on intangible asset values indicate that in the year immediately after crowdfunding, average intangible asset value rises from €270,327 to €373,902 but the following year (t+2) the average value increases to €613,422 (see Table 3). One can assume that firms with more finance can invest in intangibles, R&D and further develop their technologies. IAS38, Intangible Assets, is the accountancy standard that sets the criteria for recognizing an intangible asset. It is commonly known that IAS38 is considered conservative in its criteria to recognise development costs (Tan, 2020) and a very restrictive accountancy standard (Ahmed and Falk, 2006). This is very relevant for our study as the criteria for capitalization is so rigorous that firms seeking to capitalize their intangible assets will have to ensure that; a) the technical feasibility of completing the intangible asset (so that it will be available for use or sale), b) they have the ability to use or sell the asset, c) there is the existence of a market or, if to be used internally, the useful life of the asset, d) they have the availability of adequate technical, financial and other resources to complete the project, and e) that the cost of the asset can be measured reliably (IAS Plus, 2022). Comfort can be gained by the fact that firms must reach the above criteria in order to capitalize their intangible assets and any increases will show an increase in innovation, intellectual property and the development cost component of R&D expenditure.

An interesting finding in relation to intangible asset values post-crowdfunding is the financing patterns. We find that increases in intangible assets are driven by debt financing. We find that for intangible assets post-crowdfunding, that debt financing pre-crowdfunding had an impact in that each euro of increase in debt is associated with a 1.38 euro increase in intangible asset values (see first column of Table 7A). This suggests that for innovation in Cleantech firms in our sample, that debt financing increased the value of intangible assets. We could argue that patents are used as collateral for debt financing (Conti et al., 2013b). A surprising finding is that equity funding pre-crowdfunding is negatively related to intangible assets values. This could provide us with some insight into why firms have sought crowdfunding in the first place. It seems that firms with strong intangible assets will in fact use debt financing. This finding is slightly contrary to the commonly held view that firms with greater intangibles are financed by equity. It is apparent that Cleantech firms with greater development of intangible assets will seek debt financing. This brings to question to role of intangible assets, the potential role of the differing types of intangible assets, such as capitalized development expenditure, intellectual property or patents granted and the ability to use these intangible assets as collateral for debt financing.

In relation to equity funding, there is no statistically significant impact of equity funding post-crowdfunding on intangible assets. The raised amount of crowdfunding has a positive impact on innovation and intangible assets, and debt funding pre-crowdfunding also has a positive impact on innovation and intangible assets (see Table 7A). It is apparent that crowdfunding has a positive impact on increases in intangible assets (see Table 7B) suggesting firms with greater finance can develop their intangible assets. We confirm this with the finding that firms with greater intangible assets were also utilizing debt financing before and after the crowdfunding campaign.

Table 7A. Determinants of innovation (intangibles)

Dependent Variable	**Intangibles**		
	Intangibles T+1	Intangibles T+2	Intangibles T+3
Firm Age	-0.84915** (0.34592)	-0.93790** (0.38037)	-0.96393*** (0.37677)
Investors	-0.180264* (0.09765)	-0.21865** (0.10737)	-0.22597** (0.10636)
Amount Raised	0.35881** (0.16552)	0.43283** (0.18200)	0.43890** (0.18028)
Equity Funding Pre-CF	-0.24515** (0.11808)	-0.31466*** (0.12984)	-0.35342*** (0.12861)
Debt Funding Pre-CF	1.38071*** (0.16909)	1.51663*** (0.18593)	1.37284*** (0.18417)

Number of Granted Patents Pre-CF	-0.98921*** (0.10985)	-0.13823 (0.12079)	-0.10220 (0.11964)
Number of Pending Patents Pre-CF	0.41955** (0.20430)	0.51451** (0.22465)	0.43486** (0.22252)
Equity Funding Post-CF	0.01981 (0.07880)	0.03232 (0.08664)	0.05359 (0.08582)
Debt Funding Post-CF	0.23235** (0.10583)	0.34133*** (0.11637)	0.63182*** (0.11527)
Constant	-0.48631** (0.20347)	0.50990** (0.22374)	0.43882** (0.22162)
Country	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Use of Funds	Yes	Yes	Yes
Type of Equity Funding	Yes	Yes	Yes
# Obs.	177	177	177
Adj. R2	0.5486	0.5690	0.6204
F	20.45	22.12	27.15
Table 7A reports the results of intangible assets/innovation regression models using leading variables t+1, t+2 and t+3. The regression model above includes the full model extending the base model with country, sector, use of funds and type of equity funding fixed effects. All variables are defined in Table 2. Standard errors are in parentheses. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.			

Table 7B. Determinants of innovation (change in intangibles)

Dependent Variable	**Change in Intangibles**		
	Intangibles T+1	Intangibles T+2	Intangibles T+3
Firm Age	-0.12296 (0.86043)	-0.21171* (0.12557)	-0.23774 (0.15820)
Investors	-0.64879*** (0.24895)	-1.03272*** (0.35448)	-.1.10594*** (0.44661)
Amount Raised	0.12664*** (0.04117)	0.20066*** (0.06008)	0.20673*** (0.07570)
Equity Funding Pre-CF	-0.12642*** (0.02937)	-0.19593*** (0.04286)	-0.23469*** (0.05400)
Debt Funding Pre-CF	0.17207*** (0.04206)	0.30802*** (0.06138)	0.16421*** (0.07733)
Number of Granted Patents Pre-CF	-0.144524 (2.73236)	-0.53769 (3.98759)	-0.17737 (5.02398)
Number of Pending Patents Pre-CF	0.36685 (0.50818)	0.13164 (0.74164)	0.51992 (0.93440)
Equity Funding Post-CF	0.01016 (0.01960)	0.02267 (0.02860)	0.04395 (0.03603)
Debt Funding Post-CF	0.31594*** (0.02632)	0.42492*** (0.03841)	0.71541*** (0.04840)

Constant	-0.25882 (0.50612)	-0.15919 (0.73863)	0.22862 (0.93060)
Country	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Use of Funds	Yes	Yes	Yes
Type of Equity Funding	Yes	Yes	Yes
# Obs.	177	177	177
Adj. R2	0.7113	0.7124	0.7431
F	40.42	40.63	47.28

Table 7B reports the results of changes in intangible assets/innovation regression models using leading variables t+1, t+2 and t+3. The regression model above includes the full model extending the base model with country, sector, use of funds and type of equity funding fixed effects. All variables are defined in Table 2. Standard errors are in parentheses. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.

The second proxy for innovation we use is patents pending post-crowdfunding. As stated previously, these patents were applied for after the crowdfunding campaign and can be used as a metric to measure innovation (Boone et al., 2019; Taques et al., 2021). Our findings support Hypothesis 2, as the raised amount of equity crowdfunding has a positive impact on the number of patents pending post-crowdfunding. We find that financing patterns are significant in the determinants of patents pending post-crowdfunding. We find that the amount of equity raised pre-crowdfunding is significant, highlighting that firms are using equity funding to develop patent applications. However, as our tests in Tables 7A and 7B suggest, debt financing has an important role to play in the development of intangible assets. It becomes clear that there are differing financing patterns for intangible assets, including those with patents granted to that of patents pending. It appears that firms who have been in a position to capitalize their intangible assets under IAS38 are more likely to be financed by way of debt. Firms who have patents pending post the crowdfunding campaign are more likely to be financed by equity. Therefore, capitalized intangible assets, including patents granted can be potentially used as debt collateral (Conti et al., 2013b). Firm age is also significant, in that older firms have more patents pending post-crowdfunding (see Table 8). This is unsurprising, as older firms have more experience and know-how in relation to the patent application, something that can be time consuming.

Table 8. Determinants of innovation (patents pending post-crowdfunding)

Dependent Variable	**Number of Patents Pending Post-Crowdfunding**	
	Base Model 1	Ext Model 1
Firm Age	0.13672*** (0.04197)	0.13719*** (0.03982)
Investors	0.00022 (0.00018)	0.00021 (0.00018)
Amount Raised	0.14521*** (0.04197)	0.15821*** (0.03917)
Equity Funding Pre-CF	0.05018** (0.02078)	0.05189** (0.01983)
Debt Funding Pre-CF	0.04175 (0.02705)	0.04851 (0.03940)
Equity Funding Post-CF	0.02415 (0.02391)	0.03192 (0.04480)
Debt Funding Post-CF	0.26505*** (0.02748)	0.27158*** (0.02681)
Constant	-0.27037 (0.57603)	-0.22984 (0.47191)
Country		Yes
Sector		Yes
Use of Funds		Yes
Type of Equity Funding		Yes
# Obs.	177	177
Adj. R2	0.3541	0.4307
F	14.23	7.35

Table 8 reports the results of determinants of the number of patents pending post-crowdfunding. The regression model above includes the full model extending the base model with country, sector, use of funds and type of equity funding fixed effects. All variables are defined in Table 2. Standard errors are in parentheses. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.

To summarise, the raised amount of equity crowdfunding has a positive impact on both increases in intangible assets and the number of patents pending post-crowdfunding. Our findings thus support Hypothesis 2. From a financing perspective, there is a difference between funding types of firms with greater intangibles and firms that have patents pending in the post-crowdfunding period. We find that firms with greater levels of intangibles in the post-crowdfunding period are being financed by debt. We can assume that these firms have capitalized their development costs and perhaps have patents granted and therefore are more advanced and have the capacity to take on debt financing or are using these capitalized assets and patents granted as collateral for debt financing.

Across all our models in testing for country, purpose, equity funding type and sectoral control variables, we find no statistical significance between any specific country, use of funds, type of equity funding, sector and intangible assets or patents pending post-crowdfunding.

6. Conclusion

In this paper, we provide new evidence on the determinants of financing, in particular the determinants of equity crowdfunding, for Cleantech firms while highlighting the role of patents. We find that firms with patents attract more crowdfunding as compared to firms without patents. We also find that the amount of finance raised in crowdfunding campaigns has a positive impact on intangible asset values and also has a positive impact on the number of patents pending post-crowdfunding. This indicates that raising greater amounts of finance through equity crowdfunding has a positive impact on innovation and innovative activity. We find that debt financing post-crowdfunding also leads to higher intangible asset values. Equity financing pre-crowdfunding does not have such an impact on intangible asset values, which is consistent with patents and capitalized intangible assets being used as collateral for debt financing. However, we find that equity funding does have an impact on patents pending post-crowdfunding suggesting that firms with access to greater amounts of equity apply for and develop patent applications, which is a costly activity. Our findings suggest that equity investors are willing to invest in patents that are pending, thus are more willing to take a risk on the promise of success.

The theoretical framework underpinning this study is signaling theory. We provide new evidence to support signaling theory by identifying pre-campaign patents granted or pending as a positive signal for crowdfunding campaign success. Our study supports and builds upon previous studies that have concluded that having patents increases the likelihood, as well as the amount, of external equity and therefore, acts as a signal of quality (Hsu and Ziedonis, 2013; Mann and Sager, 2007; Zahringer et al., 2017). Specific to equity crowdfunding, this study builds upon previous studies on equity crowdfunding and signals used in determining the amounts raised (Ahlers et al., 2015; Vismara, 2016) and more recent studies that seek to assess the impact of crowdfunding on innovation (Walthoff-Borm et al., 2018; Eldridge et al., 2021). There have been suggestions that while crowdfunding is viewed as an important financing method within both developed and developing countries' innovation and finance ecosystems (Hörisch, 2015; Lam and Law, 2016), its potential is not sufficiently used in the context of green or eco-entrepreneurship. We believe our study contributes to the literature in several ways. Firstly, we provide evidence for the role of patents in reducing information asymmetries. Secondly, we provide equity crowdfunding investors with the knowledge that firms with patents granted or patents pending

will raise more during the campaign. Thirdly, funding post-crowdfunding and levels of innovation post-crowdfunding can assist policymakers to evaluate whether equity crowdfunding is an efficient and worthwhile form of financing for Cleantech firms. The above contributions offer insights for eco-entrepreneurs seeking equity financing and highlight the role equity crowdfunding can play for these types of firms. This insight deepens our understanding of the dynamics between finance and eco-entrepreneurship but also assesses the role of external equity funding in promoting innovation in green firms. Our study paves the way for future research in eco-entrepreneurship and financing of these firms. Specifically, future studies could delve into the nuanced mechanisms through which equity crowdfunding fosters innovation. Investigating the long-term sustainability and growth trajectories of Cleantech firms' post-equity crowdfunding could offer valuable insights into the lasting impact of this type of funding for eco-entrepreneurs.

For Cleantech firms seeking equity crowdfunding it is important to highlight and market their current commercialization status clearly and if patents have been granted or are pending, to disclose this in the pitch itself. Specific to investors, based on their risk-taking profile, firms that have a stable financial position and have reached commercialization, i.e. have a patent (granted or pending), have potential to succeed. In terms of policy implications for government, and to put greater emphasis on the immediate climate crisis by supporting innovative Cleantech firms, they could increase crowdfunding co-financing programs along with public-private principally venture capital co-financing (Owen et al., 2019) arrangements for Cleantech firms. It should be noted that the most innovative firms with more patents granted or pending are in the energy efficiency and renewable energy sectors and perhaps more emphasis and supports should be provided to these types of firms. One method which could be reviewed is the R&D tax credit to supplement this tax credit for early-stage Cleantech firms. An example being Ireland, regarded as a European leader in R&D tax credits providing 25% of R&D expenditure in addition to the 12.5% corporation tax deduction at the standard rate. The U.K. also has favourable tax treatment specific to SMEs with the SME R&D Relief, which is a deduction of an extra 130% of the qualifying costs from yearly profit; however, early-stage firms will most likely not make a profit in their early years. They also have a patent box initiative which allows companies to apply a lower corporation tax of 10%. Perhaps these examples could be increased much further specifically to Cleantech firms who are in their early-stage of development. While the U.K. has advanced tax incentives for investors, along with suggestions of *Green Tax Breaks* (Rankin, 2020), other countries around Europe could follow to improve investment efficiency, interest from prospective investors, and individual investor incentives, and additional supports to firms will surely stimulate further investment in this space. COP27 has shown that huge policy implementations and funding are required, and it will

be vital for innovative SMEs to secure some of this funding to ease the patent capital gap burden that exists for Cleantech firms.

Our study also has limitations. Firstly, we examine firms that obtained crowdfunding from 2014 to 2018 with some of those firms yet to be able to raise financing post-crowdfunding. We examine the year before and up to three years after the campaign. A dataset with a longer timeframe and a re-examination of those firms in the future would be beneficial to examine financial patterns and decision making over a longer period and to assess whether many of these firms have had any major changes, such as acquisitions or liquidation. Secondly, we gathered this dataset on patents in late-2021 and undertaking a re-examination of these firms would be beneficial especially to assess whether they have more patents granted or patents pending after this date. Third, we examine European firms that raised equity crowdfunding on European platforms only. There was a possibility they may have raised equity crowdfunding in other markets, in particular, the U.S. Further studies may aim to add to this by using a dataset with a longer time span, investigate firms who also raised outside of European platforms, and compare Cleantech firms with that of other firms in different industries.

The crowdfunding market has increased dramatically over the last decade, second only to venture capital in the number of deals completed in 2020. The global market is expected to reach $40 billion by 2026 (Statista, 2020). Investment in Cleantech has soared in recent years, reaching a peak at $301.7bn globally in 2020 and it is anticipated to continue to grow (Statista, 2021). As such, we believe that it is inevitable that crowdfunding will become a stable source of finance for innovative Cleantech SMEs in the future and we find that it is a valuable source of finance with positive impacts on innovation.

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