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DOI
10.34190/ECIE.19.085

Publication date
2019

Document Version
Final published version

Published in
Proceedings of the 14th European Conference on Innovation and Entrepreneurship, ECIE 2019

Citation (APA)
Nejabat, R., & Van Geenhuizen, M. (2019). University spin-off firms and market introduction of sustainable energy inventions. In P. Liargovas, & A. Kakouris (Eds.), *Proceedings of the 14th European Conference on Innovation and Entrepreneurship, ECIE 2019* (Vol. 2, pp. 700-707). Academic Conferences. https://doi.org/10.34190/ECIE.19.085

University Spin-off Firms and Market Introduction of Sustainable Energy Inventions

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10.34190/ECIE.19.085

Abstract: Many university spin-off firms today are involved in sustainable energy technology. However, to what extent and how spin-offs reach market introduction of their inventions, is not well-understood. Spin-offs may differ in many ways, like entrepreneurial orientation and competences, and opportunities in their ecosystem. To contribute to a better understanding, this paper explores differences in market-introduction (time)and underlying factors. It draws on a carefully selected sample of almost 40 university spin-offs in Europe and it applies rough-set analysis to explore relationships. The results suggest a high probability of positive development if spin-offs grow up in a 'Innovation Leader' country (like Sweden and Denmark) and employ multiple networks. A second set of favourable factors include a practical mind-set in the founding team through education merely at MSc level and accessing of substantial investment capital. In contrast, hampering factors include being involved in solar energy technology as a 'follower', while employing one-sided/poor collaboration networks. Overall, the results suggest substantial differentiation among spin-offs, and concomitant practical (policy) implications.

Keywords: university spin-offs; sustainable energy; market introduction; entrepreneurial orientation; entrepreneurial ecosystems

1. Introduction

Attention for market introduction of young high-tech firms' inventions has substantially increased in recent years (e.g. Roper and Tapinos, 2016; OECD, 2018). The specific technology studied in this paper is that concerning sustainable energy and the specific firm segment considered is that of university spin-offs . The last are defined as independent ventures established by graduates or university staff, with the mission to bring novel university knowledge to market (Pirnay et al., 2003; Shane, 2004; Rasmussen et al., 2011). We focus on advanced sustainable energy technology because enhancing energy transition seems an increasingly accepted policy aim in fighting climate change (Geels, 2011), and we focus specifically on university spin-offs as they are seen as being stronger equipped with newest technology and better able to 'disrupt' fixed structures of so-called socio-technical systems than ordinary spin-off firms and large established firms (Rinaldi et al., 2018). In particular, young university spin-off firms are seen as powerful in contributing to change due to their flexibility, willingness to take risk, creativity, responsiveness and forward-looking attitude (e.g. Janssen and Moors, 2013).

In opposing views, however, the disruptive power of young spin-offs is questioned due to reluctance and opposing reactions in the system (market), making market introduction by such firms less realistic. In this vein, stronger emphasis is put on risk and missing resources and capabilities, for example, financial ones and reputation, summarized in 'liability of newness or smallness' (Stinchcombe, 1965; Freeman et al., 1983).

Accordingly, market introduction and scaling-up are seen as more complicated affairs, for example, in finding the best collaboration partners, like large firms and public actors (Karltorp, 2014). In general, university spin-off firms, in early years, are facing lack of skills concerning markets and marketing, and lack of investment capital (Vohora et al., 2004; Van Geenhuizen and Soetanto, 2009). 'Alarming' situations may arise when a final round of (pilot) testing is still needed prior to market introduction, while capital providers remain reluctant, a situation indicated as the 'valley of death' (Bocken, 2015).

To our knowledge, only a few studies have addressed the market introduction of sustainability products, processes etc. by university spin-off firms, and this conforms to an overall small attention to firm-specific factors and entrepreneurial ecosystems (Bjørnali and Ellingsen, 2014). To a certain extent, studies by Triguero et al. (2013) and De Jesus Pacheco et al. (2017) are an exception given the systematic analyses of 'drivers' (determinants) of sustainability innovation among small firms, including firm-specific factors. However, these studies do not provide in-depth insights into developments and time-to-market. Against this backdrop, the paper aims to identify developments (time) to market introduction of sustainability inventions, and firm-specific and entrepreneurial ecosystem factors that shape those developments. In more detail, we question how do positive and negative development paths look like, and what is the relation with entrepreneurial orientation and competences and with interaction in the entrepreneurial ecosystem, such as collaborative networking and gaining investment capital? The study draws on a carefully selected sample - in four Scandinavian countries and the Netherlands - which allows for identification of preliminary types of spin-offs . These types are 'distracted' from the sample using rough-set analysis. In section 2, theory on the entrepreneurial perspective and ecosystems is discussed. This is followed by methodology, including data collection and basics of rough-set analysis (section 3). In section 4, the results of the analysis are presented.

Section 5 provides reflection and conclusion.

2. Theory

In order to unravel factors affecting the pace of market introduction, we examine relevant theory and explore a framework including (1) spin-off firms' entrepreneurial orientation (EO) and (2) competences, and (3) interaction with the entrepreneurial ecosystem.

2.1 Entrepreneurial orientation

The intention to develop and bring sustainability inventions to market encompasses various critical risk-related decisions, which can be summarized in entrepreneurial orientation (EO). This concept refers to the organizational processes, motivation and decision-making activities that firms use to act entrepreneurially. In other words, entrepreneurial orientation reflects innovativeness, risk-taking, pro-activeness, and competitive aggressiveness in specific strategic choices (Lumpkin and Dess, 1996; Dai et al., 2014; Shan et al., 2016). In 'green innovation' a basic choice is to act as 'first mover' and attempting to create the market, or to act as 'follower', the last with less risks but also less opportunities. The sustainable energy systems in which the firms are involved, are faced with different risks, some are already accepted in the market, like wind and solar, while hydrogen and new biofuels are less wanted. Accordingly, we take the energy system in which firms are active as an indicator for different risk-taking in entrepreneurial orientation. Related is the firm decision to be involved in main improvements, like new types of solar cell using new materials and wind turbines that are gearless, versus less risky improvement in the practical application which we name 'way of value creation'.

Moreover, a main entrepreneurial decision, on the way, is whether maintaining focus on the new solution and facing a larger risk of failure, or spreading the risk by using the same (platform) technology for other products/services, or to move to services in the same market (Mohr et al., 2013). Diversification is important in reducing risks but it may also deter attention from the new solution, thereby causing delay in market introduction.

2.2 Competences

The competence-based view posits that owning competences to make better - more efficient and effective - use of resources, may increase competitiveness (e.g. Rasmussen et al., 2011). Such competences are connected to dynamic capabilities that enable firms to recognize and acquire those resources that are useful in responding to changes in the business environment and reformulate strategies accordingly (Teece, 2007; West and Noel, 2009). Earlier research has found that university spin-offs often lack competences from business/market education and market experience (Clarysse and Moray, 2004; Van Geenhuizen and Soetanto, 2009). However, some spin-offs may own experience from previous work; such aspects of founders are acknowledged as positively influencing the pace of commercialization and growth of young high-tech firms (Colombo and Grilli, 2010; Visintin and Pittino, 2014; Diánez-González and Camelo-Ordez, 2016). In addition, it seems that difference in technical depth of knowledge (more or less fundamental) and practical orientation and application knowledge in the founding team, are important (e.g. Roper and Tapinos, 2016).

2.3 Entrepreneurial ecosystems

The approach of entrepreneurial ecosystems integrates elements of geography of entrepreneurship (strategic management and innovation) and regional development (Stam and Spigel, 2016; Audretsch and Belitski, 2017).

The approach is not entirely new, as attention has been given to knowledge spillovers, seedbed conditions, talent, and opportunities for competition and collaboration, etc. in many studies before (e.g. Porter 1998; Iammarino and McCann, 2006; Cooke, 2007). What is new is emphasis on the interaction of different types of factors and focal attention on entrepreneurial start-ups and risk-taking behavior (Acs et al., 2017; De Jesus

Pacheco et al., 2017). We include network collaboration as an indicator of interaction, e.g. through alliances and accessing investment capital (Lavie, 2006; Walter et al., 2006; Milanov and Fernhaber, 2014). Building and maintaining networks is, however, not an easy task. At young age, networks include relations with friends and family, but sooner or later, networks have to shift to 'arms' lengths ones', in which rules of business apply, like with established energy providers, battery industry, turbine manufacturers, policymakers, etc. (Hite and Hesterly, 2001). Particular young firms may act somewhat 'aggressive' or 'pro-active' by collaborating with a diversified set of partners, eventually in consortia, enabling niche development and experimentation, while others are reluctant (Lopolito et al., 2011). We distinguish between multiple relationships - and concomitant rich and influential networks - as opposed to single or one-sided relationships. Further, gaining substantial amounts of investment capital is highly relevant, as it is the most often missing resources (Van Geenhuizen and Soetanto, 2009), after the first (informal) investments, specifically for firms in hardware, equipment, and new materials. We also include the national innovation system (NIS) as it provides broader conditions for market-introduction, like entrepreneurial culture and national incentives (subsidies) (e.g. Lundvall, 2007).

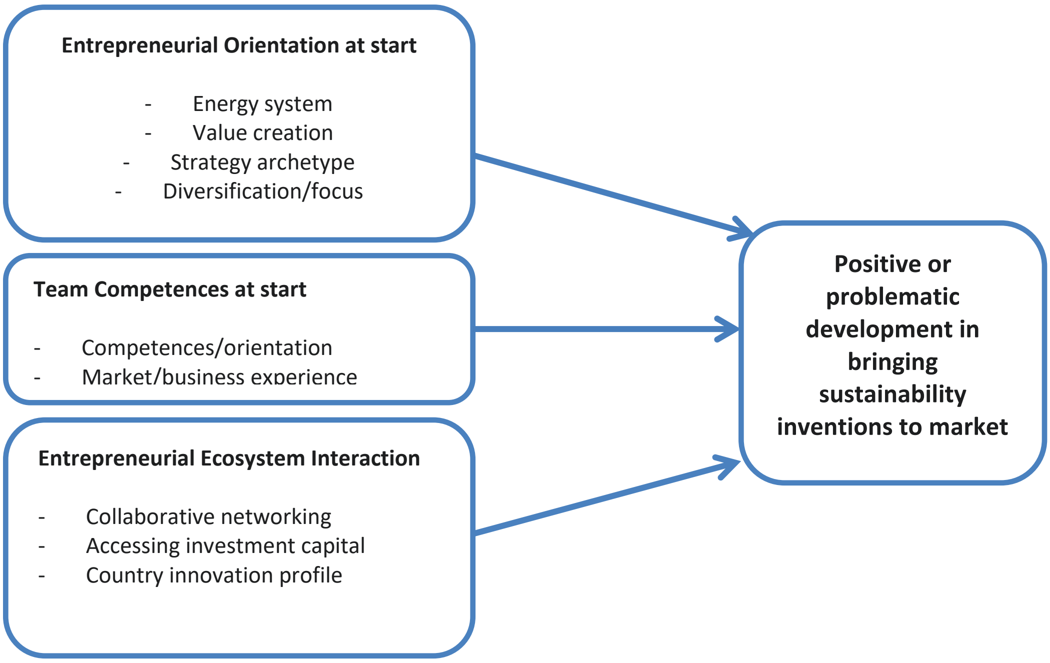

Figure 1: Research framework

3. Methodology

3.1 Data

We composed a selected sample of 37 university spin-off firms active in development and commercialization of sustainable energy solutions. The selection aimed at the creation of sufficient variation (contrasting theoretical positions) in the database concerning the above nine factors. The data were drawn from multiple sources, namely, in-depth interviews, the firms' website presentation and internet coverage, e.g. through branch journals, like Nordic Green. All results were cross-validated and checked by the two researchers (in 2015). In case of doubt, additional data were collected through telephone or email. The data list includes the founding team (education and experience), important events and years (firm establishment, pilot projects, introduction to market), networks and network partners, gaining of investment capital, and a set of data on the energy system, value creation, strategy archetype and diversification. We emphasize that a small sample composed through 'theoretical' sampling does not allow statistical generalization of results. Instead, it enables 'generalization' on the basis of theoretical positions of the firms (Eisenhardt and Graebner, 2007), like a 'typical' combination of country profile and multiple collaboration networks indicating a positive development.

3.2 Measurement

The sustainable energy systems include solar, wind and other systems or application in which the spin-off is involved, thereby also including new/improved car fuel systems and new fuels (Table 1). We measured value creation through the type of inventions, namely, those that belong to the core of the technology, like gaining higher efficiency in energy conversion or gas upgrading (more fundamental), versus those extending existing application of the solutions, like solar cells curved in the shape of roof tiles. Further, strategy archetype could be assessed by identifying 'first movers' if the solution was completely new and radical without a well-developed market, versus 'follower' or 'customer-intimate'. Substantial diversification was measured through engaging with an additional (related) product and market or engaging with mainly services, thereby reducing risks of the main invention; otherwise the firm was labelled 'focus'. Business/market experience was measured as pre-start experience of one of the founders versus no experience, while competence level was measured as one/more PhDs versus merely Master. Further, we measured collaborative networks as stable relations focussing on resources and we used the classes: none or few (like merely academic research collaboration) versus many and diverse (like investment, testing, customers, suppliers, policymakers etc.).

Table 1: Indicators and descriptive results

Indicators	**Categories (% share of sample)**
Entrepreneurial orientation	
Energy system	Solar: 35.1%; Wind: 18.9%; Otherwise (biofuels, fuel cells, combination, etc.): 27.0%; Automotive: 18.9%
Value creation	Core of energy technology: 67.6%; Additional application: 32.4%
Strategy archetype	First mover: 35.1%; Otherwise: 64.9%
Diversification/focus	Diversification: 27.0%; Focus: 73.0%
Founders' competences	
Business/market experience	Yes: 56.7%; No experience: 43.3%
Competence	PhD: 70.3%; practical (MSc): 29.7%
Interaction in entrepreneurial ecosystem	
Collaborative networks	Multiple: 54.1%; Otherwise (no/one-sided): 45.9%
Accessing substantial investment capital	No: 54.0%; Yes: 46.0%
Countries' innovation profile	Innovation Leaders: 43.2%; Norway (Innovation Follower): 18.9% Netherlands (Innovation Follower; no stable policy): 37.8%
Dependent variable	
Development in bringing inventions to market	Positive: 59.5%; Problematic: 40.5%

Accessing substantial investment capital was measured as small amount/nothing versus amounts exceeding 1 million Euro. And finally, national innovation systems are measured using the countries' profile in the Innovation Union Scoreboard (2015): 'innovation leaders' (Denmark, Sweden, Finland) versus 'innovation followers' (Netherlands and Norway), the last with a somewhat weaker entrepreneurial culture (risk-taking).

We also emphasize consistency of policy over time, as the Netherlands had developed a favourable national policy (wind) energy but dropped this policy later on, while Norway has favoured use of e.g. hydropower over a long time.

The dependent variable – bringing inventions to market as a 'positive development' versus a 'problematic development' - was measured as follows. The label 'positive development' is assigned to those cases facing a short time (within about five years) to market introduction since firm start, or a short time to successful pilot testing and favourable follow-up among still young firms, while the label 'problematic development' is assigned to firms experiencing a relatively long development/testing time without market introduction (within about five years), young firms facing a pilot testing that appears problematic in the first years, and firms that were closed. The borderline of five years after firm start was taken after robustness checks. All above indicators, including the dependent variable, are measured and coded at categorical level.

3.3 Rough-Set Analysis

Rough-set analysis is increasingly recognized as a useful classificatory method, including elements of causal relations (e.g. Pawlak, 1991; Polkowski and Skowron, 1998), for example, in performance of firms, evaluation of university incubation projects, transport systems, etc. (e.g. Dimitras et al., 1999; Nijkamp et al., 2002).

Different from regression models, it enables analysis of merely categorical data and of small samples, while no assumption is made about a normal distribution of the data. Further, analysis is possible of data that are slightly imprecise, e.g. due to missing information.

The basic procedure in rough-set analysis works through information (attribute) reduction, i.e. finding a smaller set of conditions with the same or close classificatory power as the original set. Further, the analysis composes decision rules in various rounds. A decision rule is presented in an 'IF condition(s) THEN decision' format. The procedure in our study leads to 11 of such rules, of which we show the seven strongest (Table 2).

We used the following quality checks of the procedure. First, the determination of independent variables (condition attributes) that are in the 'core', indicating the strongest classification power: energy system, collaborative networks and countries innovation profile. The quality of classification of attributes in the 'core' is 0.84, which is below the maximum of 1.0 but still acceptable, whereas the quality of classification of all condition attributes is 1.0. Secondly, K-fold cross-validation (Chen, 2009) in which the results indicate a sufficient level of accuracy (almost 70 per cent in total) for the obtained rules.

4. Results

In determining the importance of the decision rules, we use strength and coverage. The strength of a rule indicates the share of all spin-off firms displaying the same combination of condition attributes (in rules) as well as the same outcome on the dependent variable. The coverage is the absolute number of spin-offs involved. The higher these outcomes, the better the rules describe parts of the sample. The results of the final estimation are in Table 2, including rules on positive and problematic development (Nejabat et al., 2018). The strongest rules on positive development cover the following:

- Rule 1 indicates that the combination of operating in an innovation leader country (Denmark, Finland or Sweden) and employing multiple networks makes a positive development towards the market likely, at a strength of 50 per cent. This rule suggests important support from local cluster collaboration, from national networks in investment programs and from interaction with domestic multinationals (multiple networks).
- At weaker strength (31.8 per cent), Rule 2 indicates that the combination of a practical orientation (indicated by merely Master level) and gaining of substantial investment capital, makes a positive development likely. The rule suggests successful performance by adopting a smart 'follower' role and the use of investment capital for accessing additional market segments abroad.
- Again, somewhat weaker (strength 27.3 per cent), Rule 3 indicates that the combination of wind energy technology and being a 'follower' makes a positive development likely. The rule suggests benefits from providing wind-farm services and taking smaller risks, e.g. in an integrated approach.
- Likewise Rule 4 (strength 22.7 per cent) indicates that the combination of new car fuel technology and employing multiple networks makes a positive development likely. The rule puts emphasis on benefits from multiple networks in a situation of potential resistance to adoption from established technology.

Table 2: Rough-Set Rules on bringing invention to market

	Rules (Firms' Attributes) a)b)	**Dependent Variable**	**Cove-rage**	**Strength %**
1	Country (Innovation leader) & Multiple networks	Positive	11	50.0
2	Competence (MSc) & Gaining investment capital	Positive	7	31.8
3	Energy system (Wind) & Strategy archetype (Follower)	Positive	6	27.3
4	Energy system (Automotive) & Multiple network	Positive	5	22.7
5	Energy system (Solar) & Single network & Strategy archetype (Follower)	Problematic	7	46.7
6	Country (Norway) & Focus & Competence (PhD)	Problematic	4	26.7
7	Energy system (Otherwise) & Country (Netherlands) & Value creation (Core)	Problematic	3	20.0

1. Rules with coverage of one/two firms or strength of less than 20 per cent are not shown.
2. Some rules may slightly overlap.

Adapted from Nejabat et al. (2018).

Whether a problematic development occurs, is somewhat less clear, as appears from a lower strength of the rules and the combination of often three factors (Rule 5 to Rule 7):

- Regarding Rule 5, the combination of solar energy technology, poor collaboration networks and being a follower, makes a problematic development likely (strength 47.5 per cent). It suggests that even a follower, taking less risks, requires strong collaboration in bringing solar energy solutions to market; this situation may refer to competition from Chinese solar cell producers active in European markets at much lower customer price (Goodrich et al., 2013).
- Rule 6 is less strong (at 26.7 per cent) and indicates that spin-offs in Norway, with a strong focus and high technical skills (PhD) are likely to develop in a problematic way. This rule suggests problems of more basic research (core) that needs a long way to be transformed into a practical application. Such spin-offs may face the 'valley of death' or they may have gained substantial investment capital, however, at a (too) short pay-back period.
- And finally, Rule 7 (strength 20 per cent) indicates that spin-offs in the Netherlands in energy technology like fuel cells and alternative biomass (algae), while involved in more basic research (core), are likely to develop in a problematic way. The rule suggests that such spin-offs are engaged with pilot plants and testing on a real-life scale for a long time, and this may call for substantial investment while facing the 'valley of death'.

A deeper look into case studies of individual spin-offs indicates existence of quite some differences in time-to-market taken from start of the firm. Time-to-market ranges from one year for a service firm to more than five years for a firm developing advanced equipment. In addition, upscaling tends not to be a self-understanding step alongside or after first market-introduction.

5. Conclusion

The aim was to explore development (time) to market of sustainable energy inventions among university spin-off firms. Using a small selected sample and rough set analysis, it appeared that the combination of being active in an 'innovation leader' country and employing multiple networks provides the largest chance for a positive (quick) development to market. The last condition leads to advice to local governments and universities to facilitate connecting local spin-offs to (domestic) multinationals and other stakeholders for multiple collaboration. The second important combination associated with a positive development in market introduction, is practical competence (indicated by MSc) and accessing substantial investment capital. This combination would lead to advice for incubator management to enhance formation of founding teams that are balanced, namely, with practical input (MSc) aside from advanced technical input (PhDs), and to governments to support the supply of investment (venture) capital against relatively soft conditions, e.g. concerning pay-back schedules. In contrast, a large chance for a problematic development is connected to activity in solar energy solutions as a 'follower' and employing a single/one sided network. This combination reveals negative influence of emerging competition (from cheap solar panels from China).

Overall, the contribution of the paper is both theoretical and practical. Theoretically, support was found for two approaches to firms' market introduction, namely, entrepreneurial orientation (different amounts of risk-taking), in line with Lumpkin and Dess (1996) and Dai et al. (2014), and interaction with entrepreneurial ecosystems, e.g. through collaboration, in line with Milanov and Fernhaber (2014), Hayter (2016) and Audretsch and Belitsky (2017). However, one of our rules reveals negative influence of emerging competition (from cheap solar panels from China).The same holds for constraining influence from regulation, indicating that our preliminary framework needs to be extended. It also appeared that business/market experience among founders – as proposed in our framework - failed to be part of any strong rule, which calls for deeper investigation.

Our findings are preliminary and call for rigorous statistical testing. Accordingly, we have built a larger, random sample (n=105) which allows such approach in next steps of the study. A point of attention is precision in measurement. Time of market introduction has been part of assigning the label 'positive' versus 'problematic development', and five years was used as a borderline. However, market introduction tends to become more a short development rather than one single event in a year, particularly when 'launching customers' and co-creation with customers play an important role. Also, we measured number of years prior to market introduction from starting year of the firm, while number of years from starting the development process of the invention to a marketable product (often still at university) would better qualify, however, it is more difficult to measure.

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