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Research Article

Urban Policy Response to Radical Innovation in Sustainable Energy: The Case of University Spin-Offs and Local Triple Helix Interaction

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Abstract

This paper pictures several risk-taking strategies of young high-tech firms in bringing energy inventions to market and ways urban policy (municipalities) may provide supporting facilities and help accelerate the energy transition. Derived from a longitudinal study of 100 firms in northwest Europe, two findings contribute to practice. Firstly, a share of almost 40 percent of university spin-off firms fails in the market introduction; if the market introduction is reached, 30 percent is relatively late. This development calls for attention to acceleration and risk-taking concerns. However, risk-taking firm strategies, like targeting radical inventions and new markets, tend to hamper early market introduction. Secondly, urban policy supports filling risk-related needs, particularly in large metropolitan networks. Cities (municipalities) may act as launching customers and provide sites and organizations for practical experimentation (e.g., in living labs) alongside steering on cross-faculty application platforms at the university that also connect with city functions. Cities' initiatives, however, tend to be fragmented and miss priority. Partnering in Triple Helix networks with local universities and businesses may improve the situation, for example, by priority setting, better alignment, and integration. The urban policy also has a role in improving broader conditions, particularly the attraction of related R&D firms to the city/region and the attraction and retention of top-class researchers.

Keywords
Energy transition; university spin-offs; risk-taking; early market introduction; urban policy; Triple Helix networks

1. Introduction

In the post-pandemic time, the need for coordinated efforts to increase sustainable energy production and use has become tremendously pressing. Cities have taken a leading role in sustainable energy transition already in the recent past, derived from solid urgency due to cities' high energy consumption (ca. two-thirds of global energy demand), CO_2 emissions (about 75 percent), and population growth (estimated 70 percent by 2050 live in cities) [1]. To make more efficient use of the world's energy resources, meet global climate targets, and develop underlying technology inventions, however, it is essential that more cities take a leading role in the energy transition and that this role is strengthened. Given such a situation, it can be questioned to what extent urban policy (at the municipal level) can address the challenges of climate change [2-5]. The literature indicates *two* broad ways cities (municipalities) can contribute. *Firstly,* as actors enacting transition processes in urban functions like housing, transport, and public services on their territory, they also generate and produce sustainable energy. *Secondly*, as actors supporting research at universities, including higher educational institutes, and providing seedbeds and local sites for the creation, experimentation, testing, and demonstration, etc., of sustainable energy solutions. However, cities' potentials are also limited, namely due to 'system resistance,' including mainstream market dynamics of large incumbents fearing for vested interests, delay in regulatory reforms, and grown complexity in policy-making stemming from the increased participation of actors like citizens, large firms, local universities [6-8].

In the context of fastening energy transition, increasingly, attention is given to the market introduction of more radical technology solutions in cities, for example, created by small spin-off firms at universities [9-11] (note 1[1]). University spin-off firms can easily access new transitional technology, e.g., developed in founders' Master's or Ph.D. work. As independently established firms aimed at further developing university inventions [12, 13], they often receive basic local support at the university in the early years namely, through incubator services and accelerator programs. Part of them tends to remain vulnerable due to missing market knowledge and management skills, short in financial capital and legitimacy, making market introduction a long-term affair [14-17]. Another part, in contrast, is genuinely risk-taking and may quickly shift to local or specialized markets.

[1] This paper is a condensed version of an article in Energies named Municipalities' Policy on Innovation and Market Introduction in Sustainable Energy: A Focus on Local Young Technology Firms, co-authored by Marina van Geenhuizen and Razieh Nejabat (2021). New in the current paper is more detailed attention to time to market and stronger emphasis on Triple Helix networks and ecosystems.

Compared to large incumbents, such firms are better able to quickly and flexibly capitalize on inventions and sustainable practices. Further, using smart networking – like in (protected) niche experimentation and collaboration - they may fasten scaling up considerably and enable inventions to be used by larger market segments [18-20]. All-in-all, there are divergent ideas about the potential of university spin-off firms in transitional change and early market introduction of more radically new inventions.

In more detail, much depends on the strategic choices made by the firms**,** reflecting their entrepreneurial orientation, particularly *risk-taking* [21-24]. In this paper, the risk-taking choices include orientation on manufacturing (compared to services) and the newness (radical character) of the energy technology (product or process) and of the markets involved. We may assume that young spin-offs that take substantial risks are faced with strong barriers, from stiff conditions at the energy system level, like competition with traditional technology and regulation, often causing the need for extended R&D and financial investment. However, if engaged at a higher level of radicalness, firm choices may also include moderate diversification (e.g., with related services or related traditional products) as a *risk-mitigation* strategy, for example, aimed at raising cash in the face of the 'valley of death,' or more broadly, to enable self-investment, which are key points of analysis in the paper [25, 26]. In particular, the paper explores strategies concerning networks and communities in the local innovation ecosystem, including Triple Helix networks of universities, government, and business [18, 27, 28]. We may assume that participation in such networks providing additional resources and competencies *reduces risks* and may shorten the time to market.

Cities tend to be different in capacity to respond to the urgency of fastening transitional change, particularly to young firms' risk-taking; for example, larger (global) cities tend to be well-positioned due to the high density of human, economic, intellectual, and cultural capital. Such difference is emphasized in the concept of agglomeration economies connected to local economies' size and diversity and partially in the more recent approach of urban entrepreneurial ecosystems [29-32]. The last approach emphasizes institutional features and networks supporting (facilitating) young firms' entrepreneurial (risk-taking) strategies. Similarly, the advantages of collaboration between universities, government, and business, can be seen as stronger developed in larger cities. Nevertheless, specialized university cities in more remote regions may also play substantial roles, specifically if they are nearby places of abundant availability of renewable energy resources [33]. Further, being part of a specific country's knowledge economy and institutional system (National Innovation System, NIS) can make a difference between cities in responding to transition challenges, like through national energy research programs, subsidies and tax regimes, and a culture of strong entrepreneurial spirit [34-37].

Given the urgency for novel technical solutions, the study aims to picture risk-taking strategies in the market introduction and how urban policy (by municipalities) may provide supporting facilities to avoid or mitigate entrepreneurial risk-taking. The following research questions are addressed: a) To what extent have local university spin-off firms been able to reach the market with their inventions, which time was involved, and what have been the underlying risk-related strategy factors, including networking in the urban innovation ecosystem? b) With which policy initiatives and facilities have cities responded to the need for more risk-taking and early market introduction?

The study's contribution to literature can be described as follows. First, it is one of the first empirical studies on risk-taking among university spin-off firms engaged in sustainable energy and differences in time to market. With the need for transition acceleration in the background, the study reveals that more radical choices in sustainable energy innovation cause delays in the market introduction, calling for more support or facilitation. Secondly, the results on the roles of municipalities in providing such support are new according to the comprehensive view used, revealing several important urban involvements but also fragmentation and lack of priority. The last situations also hold for tentative results on the position of municipalities in Triple Helix ecosystems.

The structure of the remaining paper is as follows. In section 2, the firm-level database and methodology of analysis of market introduction are discussed. Section 3 consists of two empirical parts: time of market introduction and underlying influences, using Cox Hazard modeling and case-study analysis (3.1), and support (facilities) that cities provide (3.2). The paper closes in section 4 with a discussion, including limitations of the study and a perspective on future research directions.

2. Materials and Methods

2.1 Sample and Measurement

The study uses a sample of 106 spin-off firms in northwest Europe, Scandinavia, and The Netherlands [38]. The choice of Denmark, Finland, and Sweden are motivated by their favorable small firm and innovation conditions that enable researchers to observe market introduction and longer-term survival of spin-offs. At the same time, Norway and Netherlands are included as these have faced several less favorable conditions (some) in past years. The study is retrospective and ‘follows’ spin-offs within the time frame of 1999 to 2018. Further, the location of spin-offs’ founding includes large metropolitan areas like Copenhagen in Denmark, Stockholm region in Sweden, North Randstad (e.g., Amsterdam) and South Randstad (e.g., Rotterdam and Delft) in The Netherlands, and also medium-sized and smaller cities at a distance from such areas, like Trondheim (Norway) and Lappeenranta (Finland). The sample size was the outcome of a search using universities' lists of spin-off firms, national reports on sustainable energy research and application, and sector journals like Nordic Green. Some spin-offs that failed before the start of the data collection may have been overlooked, but simulation outcomes indicate no need for concern about representativeness [38].

Further, to collect firm data, like a year of market introduction and risk-taking strategies, a *multi-source* data collection method was used, encompassing semi-structured interviews and telephone inquiries of firm founders, supplemented with desk research. Data collection (in fact, the researchers ‘reconstruction’ of firms’ history, started in 2015 and lasted till the end of 2018. In addition to the larger sample, a set of in-depth case studies – university spin-off histories covering 1999 to 2020 - has been established more recently.

The characteristics of the 106 spin-off firms can be summarized as follows (see, Appendix 1 for variables (indicators), measurement, and scores. Regarding *strategic choice* (low risk-taking), services are a minority, represented by 25.5 percent of the sample; more incremental innovation is undertaken by 59 percent and established and emerging markets are targeted by 25.5 and 56 percent, respectively. Further, about half of the spin-offs undertake diversification as a risk-reducing strategy (52 percent). About networking in urban innovation ecosystems, 59 percent employ early networking with a large firm (organization), and 41 percent access substantial investment early in time (first four years). For recruiting essential staff, this is 23 percent. And finally, regarding ‘favorable’ urban innovation ecosystems (NIS influence), a small majority of the sample is in Sweden, Finland, and Denmark (53 percent) and in large metropolitan and adjacent areas (57 percent).

2.2 Modelling

The modelling will be guided by three assumptions on time-to-market, derived from above mentioned theoretical reflection on risk-taking and -mitigating strategies, related network use, and quality of urban innovation ecosystems. The assumptions on *early market introduction* include:

1. Strategic choice: the less risk-taking, the earlier the market introduction.
2. Resources through urban innovation ecosystem networks: the earlier the use/networking (recruiting staff), the earlier the market introduction.
3. Quality of urban innovation ecosystem: the better NIS quality and stronger the metropolitan character, the earlier the market introduction.

To explore market introduction as an 'event' in time, Cox proportional hazard analysis is used as a semi-parametric method that calculates probabilities of a certain event. The method assumes that the 'predictors' (independent variables) have a multiplicative effect on a basic hazard function. A specification of the model is given in Appendix 2. The method has often been used to analyze longitudinal censored data, which matches our database being censored at two sides [39-41]. The outcomes provide the hazard ratio (HR) for each 'predictor' (Table 1).

Table 1 Cox regression results on time to market (HR is hazard ratio).

Independent variables (indicators)	*Model 1* $HR(s.e.)$	*Model 2* $HR\ (s.e.)$	*Model 3* $HR(s.e.)$	*Model 4* $HR(s.e.)$
1.Strategic choice				
More incremental innovation	0.36(0.10)***			0.39 (0.12)***
Smaller newness in market	0.69(0.28)**			0.54 (0.11)***
Services vs. manufacturing	0.29(0.08)***			0.26 (0.07)***
Business diversification	1.07 (0.28)			1.32 (0.38)
2.Urban ecosystem networking				
Early joining marketing staff		0.60(0.19)		0.60(0.20)
Early first collaboration		0.46(0.15)**		0.50(0.17)*
Early first investment		0.60(0.19)		0.55(0.18)*
3. Urban ecosystem quality				
Stronger NIS (country-level)			1.42 (0.09)	1.44 (0.41)
Stronger metropolitan character			0.84 (0.36)	0.79 (0.08)**
No. of USOs	106	106	106	106
LR Chi-square	40.66	16.45	2.84	61.92
Log likelihood	-243.62	-255.55	-262.73	-232.38
P value	0.0000	0.0009	0.33	0.0000

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

This ratio reads in a simplified way as follows. If a hazard ratio is close to 1, the 'predictor' does not affect the event of early time to market. As each 'predictor' coding is based on the logic of 'the better the situation, the lower the score', a hazard ratio substantially less than 1 means that market introduction is according to the assumed direction. Conversely, if substantially greater than 1, the market introduction contradicts the assumed direction.

3. Results on Market Introduction and Urban Policy

3.1 Time of Market Introduction and Underlying Influences

More than half of the sampled firms (61 percent) have reached market introduction, measured as 'reported first sales,' while 39 percent failed. On average, the market introduction was at the age of 4.4 years, with some variation (Appendix 1). If the age of five is taken as a borderline between early and later/no introduction, early introduction is observed among 35 percent of the firms.

In our exploration of influences on early market introduction using the Cox Hazard ratio (Table 1), we consider several partial models, namely, Strategic Choice (Model 1), Urban Ecosystem networking (Model 2), Urban Ecosystem quality (Model 3), and Full model (Model 4). About partial models, the strongest single partial model is Strategic Choice (Model 1 at log-likelihood of -243.62), including three significant indicators out of four. The results suggest that early market introduction is connected to small risk-taking, particularly services, and in turn, the late market introduction is connected to strong risk-taking. Business diversification does not provide a clear pattern, as assumed. Further, Networking for resources/capabilities in the Urban innovation ecosystem is the next strongest partial model (Model 2), including early collaboration with a large firm as significant. This is followed by substantial early investment (in the full model). The full model reads as follows: relatively early networking increases the chance of early market introduction, and conversely, relatively late networking increases the chance of late or no market introduction.

About Urban ecosystem quality, surprisingly, the strength of the national innovation system (NIS) and the metropolitan character of the spin-offs' location is not significant in the single model (Model 3). However, the full model (Model 4) suggests combining urban ecosystem quality with the other partial models provides relatively strong results (log-likelihood of -232.38). Accordingly, for urban ecosystem networking, importance is suggested for early networking (with large firms and investment consortia), aside from the importance of an overall stronger metropolitan character. The list reads as follows: the stronger the metropolitan character, the larger the chance for early market introduction; in turn, the weaker the metropolitan character, the larger the chance for late market introduction (See note 3[2] for a more detailed interpretation of hazard ratios). Remarkably, the national innovation system (NIS) quality does not show significant results (large standard error) and points to a different direction compared with the assumptions. This situation may follow from spin-offs' reaction to support from national research programs and subsidies, facilitating them to shift to or remain with highly innovative research themes, and concomitantly more radical strategic choices and late market introduction.

To illustrate different time-to-market (MI) and follow-up developments, we use two extreme case studies (A and B) (Table 2). Case Study A (relatively late MI) deals with strong risk-taking and

[2] The hazard ratio compares the hazard of occurring the event (time of market introduction) in one group related to its reference group. The reference group here is the 'worst' situation derived from our assumptions, e.g. risk strategies that cause delay, no (or late) risk mitigation through external networking. Accordingly, by focusing on strategic choice, the results in the full model indicate that with a probability of 74 per cent time to market introduction is longer among manufacturing-oriented firms compared to services firms. The same holds for innovation type: with a probability of 61 per cent, time to market is longer among radical innovation compared to incremental innovation. Similarly, spin-off firms entering new/emerging markets, need more time to market by a chance of 46 per cent. The other way around in (risk-mitigating) networking in urban ecosystems, late collaboration and late access to investments come at a probability of 50 and 55 per cent respectively with a longer time to market introduction, and for a lack of metropolitan character and longer time to market introduction this probability is 21 per cent.

additional barriers over time, like time pressure on MI and unexpected regulatory issues. Accordingly, this spin-off – involved in the manufacturing of high-efficiency membranes for gasification of waste in new markets like transport fuels - suffered from a lack of business focus (first years), followed by market introduction under pressure (still some quality issues) and hindering regulatory matters (gasification process). In addition, while early investment by a regional consortium was beneficial, repeated substantial investment later caused debt accumulation and bankruptcy. In contrast, Case Study B, active in high-accuracy solar panel testing equipment and climate chambers for existing/emerging markets, like universities' and solar manufacturers' research labs, was successful in early MI. The spin-off firm started to reduce risk-taking in various ways. It developed alternative strategies: limited diversification (related services), a small amount of additional external investment, acquisition of a small firm to access foreign markets, benefiting from incubation facilities, and rich (university) research networks.

Table 2 Selected 'extreme' university spinoffs and time to market introduction.

New product/ Technology	Year of firm start and location	Risk-taking or risk-mitigation	Results a)
A. Membranes (gasification of waste) Market: e.g. new fuels (transport)	2008 Norway Trøndelag	*Continued risk-taking* -Lack of business focus (first years) -Market introduction under pressure -Testing at sites partly at large distance -Regulatory issues delaying upscaling -Early and large investments, causing serious debt accumulation	Late MI (at age 6/7) Bankrupt at age 7/8
B. Solar panel testing equipment Market: university labs, labs of solar panel producers	2011 Netherlands Randstad	*Risk-mitigation* -Diversification with related services -Benefits from incubation facilities and rich (university) networks in early experimentation -Early investment (limited amounts) -Small firm acquisition to access markets abroad	Early MI (at age 3) Upscaling

a) MI is Market Introduction.
Source: note 4[3].

Considering the extreme positions, Case Study A (non-metropolitan area) could not benefit from supportive urban policy embedded in local networks and communities and eventually from warning against tight local investment consortia and regulatory constraints. Such an urban policy was not available at the time. However, today, these are still weakly developed, e.g., large firms (as a launching customer) and a sufficient variety of testing sites are missing in this location far from the metropolitan area. In contrast, Case Study B (metropolitan area) could benefit from extended incubation facilities, university networks (testing), and advanced labor markets.

[3] A set of 40 university spinoff company histories has been created by the first author by 2018, also including spin-offs in medical life-sciences and medical technology. Currently the set is being further extended with energy spin-offs.

3.2 Spin-Off Risk-Related Strategy and Urban Policy

Using a mix of desk research and personal interviews concerning spin-off firms' needs, and literature and interviews about cities' involvement (e.g. [42-47]) (note 2[4]), we explore several types of risk-related strategies among USOs. These strategies refer to the following needs: large amounts of investment, early experimentation and testing, and collaboration with a large partner. A fourth concerns general vulnerability among young firms from a city support perspective, including Triple Helix interaction. Special attention is given to conditions in Triple Helix development. Note that mentioning cities' initiatives in the text below does not mean that all cities in the study have engaged in supportive initiatives. However, some of them have shown in (the recent) past that particular initiatives can function well.

3.2.1 Large Amounts of Investment

Engaging in radical inventions (particularly in manufacturing) and new markets requires access to large financial resources to enable extended laboratory R&D and pilot testing periods. As pointed out above, early access to investment capital tends to be beneficial; however, most likely without accessing large amounts of (venture) capital investment several rounds later. Cities (or municipalities) have seldom been *directly* involved in providing venture capital (or similar investment). Instead, in countries like The Netherlands, the Provinces exploit Regional Development Corporations (RDCs), which may act as venture capital providers to innovative local businesses [42]. Important stakeholders in RDCs are large local organizations like universities, academic hospitals, and larger municipalities, the last with opportunities to *indirectly* influence investment in innovative start-ups. Some RDCs exploit a specific sustainable energy fund. Investment sums organized by RDCs in The Netherlands are often relatively small, e.g., 3 million, for example, for a spin-off in flying kite technology, compared to the ones in Scandinavian countries [43, 44]. In these countries, serious accumulation of (venture) capital debt has taken place in several cases (e.g., exceeding 20 million euros). It seems that municipalities have not or only weakly been involved here. However, they may see a potential future task of watching and warning on local ties in investment consortia that become (too) tight. Such task may be practiced by cities (municipalities) in organizing meetings as *'qualified matchmaking'* with financial investors, eventually inviting business angels and organizers of crowdfunding, but also evaluation of such meetings. Finally, we mention that cities (municipalities) in northwest Europe have already, for many years, acted as co-investor and co-organizer (with universities) of *accommodation* (incubators and accelerators) to provide a 'quality place,' including rich networking and training opportunities.

3.2.2 Early Experimentation and Testing

The strategic choice of new products and customer markets often requires practical places for co-creation, first testing, and application, like in on-campus field labs, 'sheltered' places (niches), real-life living labs, citizen co-operatives, etc., all enabling learning and fine-tuning of inventions

[4] Semi-open interviews were held by the first author with Professor dr. James Evans in Manchester (UK) (April 2017), concerning experimentation in cities and the university; and with Jaron Weishut (MSc) in Delft (NL) (November 2018), concerning field lab testing, roles of university, municipality and large firms and university spin-offs, followed by an update and expert meeting September 30 2022.

with customer demand, regulations (standards) and business models. Such experimentation can be illustrated with spin-off firms engaged in (fixed) charging systems for electric vehicles and solar energy equipment in public places, like in using lighting poles (flexible solar cells) [45, 46]. What cities can do – within the confines of their activities - is assigning specific urban sites and co-organize part of the experimentation, for example, in public green parks, public transport facilities, and business parks. Through such experimentation, spin-offs can 'confirm' their advanced position (legitimacy) in participation with the city and international firms (like in electrical systems, car manufacturing, and battery manufacturing), thereby mitigating risks and enhancing early market introduction. A recent example is in the municipality of Lund (Sweden), providing access to city road sections to implement a dynamic charging system of electric vehicles (while driving). In this case, experimentation and demonstration are taken up by a spin-off firm, the university, and various firms and organizations in transport [47].

3.2.3 Collaboration with a Large Partner

Early collaboration with a large firm or other organization tends to be advantageous based on our model results, most probably by providing additional resources, e.g., specialized knowledge about customer needs, eventually through acting as a launching customer, existing sales channels, etc. However, for young spin-off firms, finding a trustworthy partner is difficult as it requires the credibility of the young firm itself and fair agreements, e.g., in dealing with intellectual ownership. What cities have done is act as launching customers by themselves. The range of inventions and the financial involvement are limited due to regulation. Still, they include a broad diversity, like street attributes (e.g., local traffic observation), energy efficiency in municipality buildings, and municipal parks producing solar and wind energy. Further, a relatively new initiative is *'Start-up-in-residence,'* as initiated in San Francisco [48], which provides spin-off firms with opportunities to match their product/service with local urban needs in a more tight relationship.

3.2.4 General Vulnerability and Supporting Networks and Communities

Our results indicate a high probability of early market introduction in metropolitan cities (Table 1). Most importantly, support from professional start-up networks and communities tends to be well-developed today in such cities at high density and variation (richness). Accordingly, young technology firms may benefit from e.g., business idea testing, incubator/accelerator programs, personal coaching, access to lab space and maker space, and access to investors. Stockholm exemplifies a large city with well-established networks and communities of this kind, through STING [49]. Owned by a public-private foundation of business actors, academia, and the public sector (City of Stockholm, Stockholm County Council, etc.), it enables a certain steering by cities on the type of support and application areas of new technology in the city. As a partner in networks like STING, cities may advice about technology that matches the city and start-ups 'technology readiness'. Such support may also include a critical attitude towards tight investment consortia to keep them open, flexible, and creative.

In more detail, municipalities can also influence transitional change by being active in so-called *Triple Helix Ecosystems*. These systems are understood as conceptualizing three core actors in creating economic (social) benefits from university knowledge, i.e., university, government, and business. More recently, several additional actors, particularly citizens active in urban experimentation have been recognized as important contributors [50]. Note that the term 'eco' is added to 'Triple Helix systems' to emphasize interactive processes of innovation and entrepreneurship that take place in communities of interdependent actors and in a (social) context that enhance (or restrict) innovation and entrepreneurship [50-56]. It needs to be mentioned that although the number of empirical studies on boundary-spanning and interaction within Triple Helix Ecosystems has enormously increased to date (e.g. [19, 52, 57]), a focus on municipalities and sustainable energy firms in such ecosystems has remained scarce in empirical research [58]. Regarding the chains of energy generation, storage, transmission to use/consumption (energy saving), alongside management (AI) and policy-making, we mention two *background* conditions influencing risk-taking and early market introduction.

3.2.5 Background Conditions in Triple Helix Interaction

First is the bridging of barriers and partial integration between university, government, and business in which one takes over and integrates part of the activity of the other to enrich its activity and that of other(s). In detail, cross-border endeavors can be supported by appointing part-time staff at university (professors) who also work at large firms or in municipality organizations. Another (more recent) support is an installment of multidisciplinary application platforms of sustainable energy at the university, aimed at better information creation and exchange, research linkages, legitimacy, investment, etc., serving both cross-faculty networks within university and universities' external networks. Cross-faculty networks focused on sustainable energy, include, e.g., chemical engineering, mechanical engineering, electrical engineering, aerodynamics, industrial design, artificial intelligence, management, business and customer behavior, law and regulation, and policy analysis. University spin-off firms may benefit from such cross-faculty and wider networks in their attempts to deal with risks, e.g., in identifying new customer needs, new regulations, and overall feasibility as a business, e.g., at on-campus testing sites. The overall picture in a country like Germany (derived from more than 700 medium-sized and large municipalities) suggests that integrating government and private firms is a driving factor in creating innovation conditions. At the same time universities concentrate on creating structural knowledge and knowledge transfer, being less directly involved [58]. This situation means that the university's more recently planned multidisciplinary application platforms would have a challenging task in increasing Triple Helix networking and integration with municipalities and the (local) business sector. However, a warning is in place here. The rise of competition between local stakeholders involved needs to be avoided in boundary-spanning and integration, which may happen if their tasks and activity become similar.

Second is attracting and nurturing major parts of R&D chains at a larger scale in the region, potentially serving to complete the profile of R&D at universities and local firms. Science & Technology Parks may be helpful in such attempts by providing sites for *upscaling* production to reach wider market acceptance. University spin-off firms can benefit as part of such an endeavor, but remarkably, they may also act as mediators or connectors between parts of the chains by themselves [19]. A related condition is a better attraction of global talent as top-class researchers and retaining them in the region. Such efforts are mainly successful by increasing the local supply of high-quality housing and living conditions (habitat) [31, 33, 54]. All-in-all, a good combination of cross-faculty and cross-university Triple Helix initiatives with local/regional presence of R&D chains and top-class researchers in trust-based steering by university and municipality [55-62] may help to unleash entrepreneurial potentials at the university and faster market introduction [59-61]. Such development is more pressing due to the current need to reduce dependence in the European Union on Russian fossil fuels [63].

4. Discussion and Conclusion

The need for acceleration of energy transition calls for the quick market introduction of radically new energy inventions. Focusing on university spin-off firms, it was observed that risk-taking choices (product, market) tend to hamper early market introduction. It was also found that several important urban policy initiatives may mitigate negative impacts from risk-taking and potentially accelerate transitional change, but these initiatives are faced with *fragmentation* and *modest integration* and miss priority. Initiatives that work well include acting as a qualified matchmaker, providing specific sites and coordination of experimentation (e.g., first field testing, urban living labs), acting as launching customers, eventually in co-creation, stimulating local supportive networks and communities, and enhancing cross-border initiatives between organizations. A need for better integration holds not only for urban policy initiatives but also for local Triple Helix networks and university spin-offs. In general, actual support provided requires close monitoring, as evidence on effectiveness tends to be mixed on whether it works [64].

Policy recommendations derived from this study and directed to university spin-off firms, local universities, and municipalities, can be summarized as follows. Our recommendation towards *university spin-off firms* focuses on risk-taking and include**:** waiting with firm establishment until main technology steps (hurdles) have been taken, adopt limited diversification (services) to enable (partial) self-investment, and seek early collaboration with large firms in the same value chain. For *local universities* (valorization centers, entrepreneurship centers, incubators), we would recommend including improving integration (and connection) of spin-off firms***:*** better integrate them through relationships with value chains, alternative modes of commercialization, and multidisciplinary knowledge creation and diffusion platforms. Further, training needs to focus better on identifying risks (technology, markets, regulation, investment) and dealing with potential impacts. Making a plea for alternative schedules of reimbursement of venture capital or help creating a 'softer' type of venture capital in a consortium context (in some places already reality) can also be recommended. Towards municipalities: as time and investment tend to be critical factors in more radical innovation, we recommend municipalities to further intensify providing time-reducing and cost-reducing facilities like experimentation places and living labs and launching customer activity, aside from collaboration with local citizen groups as important users of innovation. Further, to connect well-performing (rich) local/regional professional start-up networks and communities with the multi-disciplinary platforms at the university covering different faculties and main external university networks in sustainable energy. Such policy lines deserve to be sufficiently integrated and to receive priority. They also require monitoring of expected impacts.

The study has some limitations that provide points of departure for a research agenda. Firstly, with a focus on university spin-off firms (and other young high-tech start-ups), *strategic choices,* particularly risk-taking ones and *mitigation* of impacts from risks, call for *deeper* investigation than could be provided in the current study, like on self-investment and preventing the accumulation of debt, monitoring and anticipation on competition and hindrance from regulatory (standardization) issues. In addition, investigation of benefits from cross-faculty and cross-university (Triple Helix) networks is needed, while building such networks calls for monitoring and evaluation. On the side of urban policy, our preliminary results call for a more systematic investigation of urban support and facilities (using a large sample of cities) and to assess how these are working and can be improved and extended. This may also include an investigation of how benefits in large metropolitan cities can be made available in smaller cities in rural areas. Secondly, the study has a narrow scope through university spin-offs as a market introduction and commercialization channel. More channels, such as licensing of patents to large firms and university-industry contract research (projects) could be taken as new subjects of study, similarly with a focus on risk-taking and risk-mitigation in the speeding-up market introduction and an integrative view.

Further, about the generalizability of the results, we must admit that regarding *universities and Triple Helix*, entrepreneurial attitudes and business orientation are typical for many northwest European and US universities but not for universities in other parts of the world. Hampering conditions to business orientation may include fear for business failure e.g. among university staff (legal liability) and a concomitant preference for merely licensing patents to large firms. Ways to improve such background conditions while matching cultural values are barely known, but research has recently taken off, and policy initiatives have been established. We deal with a differentiated field and the need for balanced policy decisions in which risk-taking entrepreneurship and innovation can blossom. Accordingly, we are facing a wealth of future research lines.

Author Contributions

The first author has elaborated the research question and the context of the research aside from the policy context of cities. The second author has performed the quantitative modelling and interpretation of results from an entrepreneurship point of view. Both authors are responsible for the design and collection of the sample.

Competing Interests

The authors have declared that no competing interests exist.

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