New ventures based on open innovation – an empirical analysis of start-up firms in embedded Linux

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Abstract

An important and intriguing aspect of e-entrepreneurship is the formation of new ventures in the domain of open source software (OSS). Previous research on these ventures has primarily looked at the design of business models, yet has neglected other key questions relating to the management of these firms, despite clear indications that some existing insights on venture management cannot be applied to new ventures in OSS. The purpose of this paper is to explore how three key challenges of venture management – the liabilities of newness and smallness of start-ups and market entry barriers – affect new ventures in OSS. Based on empirical data from personal interviews and a large scale survey we find that many of the liabilities that are typically discussed in the entrepreneurship literature are much less of a challenge for new ventures in OSS. Our findings have interesting implications for the emerging theory on e-entrepreneurship, and for entrepreneurs considering to exploit business opportunities in OSS, and more generally business opportunities based on open innovations.

Keywords: Entrepreneurship, Innovation, Liabilities of newness and smallness, Open Source Innovations, Embedded Linux

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1 Introduction

For many years the field of entrepreneurship was defined almost exclusively in terms of the person of the entrepreneur and his or her actions. More recent publications, however, point out that the conceptual understanding of the field should not only be based on the presence of enterprising individuals, but also on the presence of lucrative business opportunities [1, 2]. It is not surprising that this shift in focus and with it the re-discovery of the importance of opportunities for explaining the phenomenon of entrepreneurship has occurred at a time when the internet creates an uncountable number of new business opportunities.

The term "e-entrepreneurship" has been coined to address the discovery and exploitation of business opportunities in the internet economy. One important and intriguing aspect of e-entrepreneurship is the formation of new ventures in the domain of open source software (OSS). OSS not only poses a threat to incumbent software vendors and challenges the prevalent paradigm of software development, but also opens up opportunities for new ventures.

Previous research on this aspect of OSS has focused mostly on the question of how firms can derive revenues from publicly available software code, i.e., they investigate which business models work best in this space [3, 4, 5, 6]. Others have also addressed the question what motivates commercial firms to participate in the open source development process [7, 8, 9]. However, while these questions are relevant to understand the goals and the strategic design of new ventures in open source software, other key questions relating to the management of these new firms have received little attention – despite clear indications that some existing insights on venture management cannot be applied to new ventures in OSS due to the characteristics of this space. Specifically, the change from tight to loose regimes of IP protection, from localized to distributed innovation processes and from resource-intensive software R&D to free availability of (continuously enhanced) software code have far-reaching implications for the management of start-up firms.

The purpose of this paper is to investigate how three key challenges of new venture management – the liabilities of newness and smallness of start-ups and further market entry barriers – play out in the space of open source software. These challenges need to be addressed by every entrepreneur wanting to achieve a successful market entry and to establish the venture project as a viable economic entity. Thus, liabilities of newness and smallness and market entry barriers have received much attention from scholars in entrepreneurship, and have an important place in the emerging theory of this field [10, 11]. Yet, apart from rather general insights coming from the entrepreneurship literature, no knowledge exists on these challenges in the context of OSS, and one can only speculate about their importance for the management of new ventures in OSS.

Our analysis of these challenges is based on empirical studies of firms involved in the development of "embedded Linux". This term denotes variants of the open source operating system that are adapted to "embedded systems" such as machine controls or VCRs. What makes this industry so interesting for an analysis of venturing in open source is, among other things, the fact that firms make extensively use of the open source innovation process, as will

be laid out below. As a result, the long established industry of embedded operating systems is undergoing a shift towards OSS, offering plenty of business opportunities for aspiring entrepreneurs and potentially changing the industry structure completely.

In our analysis, we combine 30 in-depth interviews with industry participants in the field of embedded Linux and a large-scale survey of 268 embedded Linux developers. Our results show that several liabilities of newness and smallness, which are typically considered to be of high importance for venture management by the literature, are mitigated by the characteristics of OSS. In turn, other challenges become relatively more important.

These insights have several implications, on the one hand for entrepreneurs pursuing a business opportunity in OSS, on the other hand for theory-building in the area of e-entrepreneurship. For entrepreneurs our results give a clearer understanding of the challenges that have to be overcome in order to capitalize on an emerging business opportunity in OSS and to establish a successful firm. For theory-building in the area of e-entrepreneurship our results imply that the liabilities of newness and smallness which are typically discussed in the general literature on entrepreneurship cannot be applied per se to ventures which make use of open innovation processes. Furthermore, the trend we observe foreshadows general developments in several other industries and thus gives researchers a preliminary understanding of firm formation based on open source innovation processes, and in a more general perspective the commercialization of open source innovations.

This paper proceeds with an introduction to the literature supporting this study. This review highlights the theoretical underpinnings of the liabilities of newness/smallness and of market entry barriers, discusses the value chain activities of e-ventures, and gives background information on OSS, especially embedded Linux and embedded operating systems. In section 3, the design of our empirical research study is explained. Research questions are formulated in section 4, while section 5 presents the results of our analysis. The paper ends with a discussion and conclusion.

2 Background

This paper addresses a topic that builds on several strands of literature. First, the literature on entrepreneurship is reviewed, as it offers general insights into the challenges new ventures face during their early development. In particular, the management of new firms is challenged by liabilities of newness and smallness as well as barriers to successful market entry. Second, the emerging literature on e-entrepreneurship illuminates the specifics of new ventures founded in the internet economy. Third, background information on OSS and in particular embedded devices is given.

2.1 Key challenges for venture management

On their way to viable organizational entities, new ventures are confronted with a multitude of challenges. As business mortality statistics suggest, discontinuance rates of start-ups can be as high as 70% in the first five years, depending on the specific industry in question [12, 13, 14]. However, research also makes the point that a professional management

of ventures can raise the odds for success considerably [15, 16, 17]. Thus, it is not surprising that numerous studies exist which address the challenges new ventures face during the early stages of their evolution and which analyze factors of new venture success [18, 19].

Based on the specific characteristics of start-ups vis-à-vis (larger) established firms, research on entrepreneurship typically sees liabilities of newness and smallness [20] and market entry barriers [21] as key challenges of new venture management (see table 1). The latter stem to some degree from the characteristics of newness and smallness of start-ups, yet have several aspects that are of a more general nature, which warrants a separate discussion.

Newness as a challenge for venture management

The scholarly discussion of liabilities of newness can be traced back to a seminal paper by *Stinchcombe* (1965) [10]. He posits that new organizational entities are confronted with substantial liabilities of newness that challenge new venture management, and that lead to higher failure rates of new firms compared to older ones. Empirical support for his argument comes mostly from research in organizational ecology [22].

Within a new firm (whose boundaries need to be defined by management), liabilities of newness arise mainly due to a lacking organizational structure and a lack of firm-specific roles, tasks and capabilities. The founding team has to devote scarce resources – in particular management time – to address these shortcomings. Furthermore, the introduction of a structure as well as the learning of new roles, tasks and capabilities often causes inefficiency, worry, and conflict among organizational members, additionally putting new firms in a disadvantageous position compared to established entities.

Similar arguments can be made regarding the interaction between a new firm and its environment, as start-ups lack exchange relationships with all kinds of external stakeholders such as customers, distributors, banks and governmental agencies. These relationships have to be created by new firms, yet without possessing the access, experience, reputation, and legitimacy of established firms [23, 24].

While many challenges are associated with the newness of an organization, new ventures also have benefits from this characteristic. First, they are able to plan "on the green field", i.e., they can form their business without path-dependencies on earlier business decisions. Second, new ventures have advantages over older competitors, who are subjected to the liability of aging (inertia) [25, 26]. Inertia stems from an increased level of standardization and routinization in firms and typically makes organizations reluctant to start processes of organizational transformation, even in the face of drastic external changes [27, 28]

Smallness as a challenge for venture management

Newly founded firms typically start as small organizations with few personnel and financial resources. Analogous to research on the liabilities of newness, studies show that being small is negatively correlated with survival rates of firms [29, 30]. The literature offers several reasons for this empirical observation.

A lack of financial resources limits the ability of small firms to withstand unfavorable business conditions, and makes them vulnerable to even minor inefficiencies [31]. Furthermore, while new ventures possess many degrees of freedom in their business planning, their options are generally restricted by very limited availability of resources. Thus, they might not be able to shift their organization to a more favorable strategic position. In addition, small firm size is typically associated with a very limited market presence and little market power [23], putting small firms into a disadvantageous position in negotiations.

The limited number of personnel makes it necessary that small firms employ people with the qualities of generalists rather than specialists, as the amount of labor to be processed does not warrant a high degree of specialization within the organization [32, 33]. Thus, it is likely that small firms encounter critical gaps in required skills [20], which in turn raises the odds for erroneous business decisions. The limited number of personnel also implies that small firms have difficulties in tackling larger business tasks. Furthermore, this limitation makes it difficult for small firms to offer its personnel external training, as they are needed in-house in their day-to-day activities. There is only little slack within a small firm that could be used for innovative or training purposes.

These liabilities arising from the small size of start-ups are countered by several advantages coming from this characteristic. The organizational structure of small firms can be overseen by all employees, giving them a clear understanding of their contribution to the business. As empirical studies show, employees in small firms are more satisfied with their work as employees in large organizations [34]. In addition, there are no lengthy reporting procedures in small firms, communication is more direct and red tape is encountered only rarely, enabling small firms to arrive at business decisions quickly [35].

Market entry barriers as a challenge for new venture management

Studies on barriers to market entry have a long tradition in research on industrial organization and were pioneered by *Bain* [36]. In general, the existence of entry barriers decreases the likelihood, scope and speed with which firms can enter a market and establish themselves as competitors to incumbents [37]. Thus, the existence of entry barriers leads to fewer entries into a market (i.e., fewer realizations of business ideas) and gives incumbent firms advantages such as higher market share and higher profitability [38, 39].

The influential work of *Porter* [21] discusses six major types of market entry barriers – cost advantages of incumbent firms, product differentiation of incumbent firms, capital requirements, switching costs of customers, access to distribution channels and government policy –, while *Karakaya and Stahl* [40] identify 19 different barriers to market entry based on a comprehensive review of the literature. In addition to those mentioned by Porter, the latter identify barriers such as heavy advertising by incumbents, extensive R&D efforts by incumbents, existing brand names or trademarks, incumbents' expected reaction to market entry and the possession of strategic raw materials.

For new ventures, barriers to market entry pose a major challenge as has been pointed out by influential authors such as *Penrose* (p. 228) [41]: "The ability of small firms to seize on profitable opportunities in which they can grow will be destroyed if barriers are erected

against their entry (…)". Furthermore, empirical research indicates that the presence of entry barriers tends to have a greater impact on new venture formations than on diversifying firms [42]. Yet, research also points out that in emerging markets, new ventures can try to erect entry barriers to shield themselves from later entrants and thus reap special benefits from first mover advantages. Still, latecomers' disadvantages and the actual abilities of new ventures to erect entry barriers have to be analyzed carefully. As *Narasimhan and Zhang* [43] observe, in many cases new firms race into a market to avoid the disadvantages of entering late, rather than to capture the advantages of being early. Meta-analysis of studies on entry timing decisions have produced mixed results regarding their performance implications[44]. As *Tellis and Golder* [45] stress, many studies that identify the first mover strategy as being the superior type of entry timing strategy suffer from methodological flaws, putting the findings into question. Table 1 gives an overview on the challenges discussed above.

Please insert table 1 about here

2.2 Value chain activities of e-ventures

The advent of the internet has led to a massive wave of newly founded companies which base their business on electronic information and communication networks. The emerging literature on e-entrepreneurship has identified several specifics of these new firms which assist in defining the domain [46]. One key characteristic of e-ventures is the conception of their value creation activities. While *Rayport and Sviokla* [47] point out that electronic information and communication networks allow virtual value creation activities linked to the physical value chain as depicted by *Porter* [48], *Weiber and Kollmann* [49] go beyond this conceptualization by stressing that autonomous virtual value creation activities exist in e-ventures. These activities are of a different nature than physical value chain activities, as they are based primarily on processes of information collection, systemization, selection, combination and distribution.

Against this background, various configurations of virtual and physical value chain activities are possible, with the extremes being completely virtual or completely physical value chains of firms. Clearly, the latter firms cannot be subsumed under the heading "e-ventures". Yet, it is less clear how to categorize the firms in between these extremes. *Kollmann* [46, p. 10] suggests that a categorization of such firms can be obtained by analyzing which activities form the core of the value generation process. E.g., while autoscout24.de is an e-marketplace bundling information on used cars and giving transparency on market offerings to customers, seat.com is just a virtual distribution channel in addition to the physical value chain of the Seat automotive company. Thus, the former firm is an e-venture, while the latter is not. While this classification according to the core of the value generation process is very helpful, one can think of cases where it is less clear how to classify a firm [see, e.g., 50]. Yet, this is a problem encountered with most definitions in the social sciences.

This paper focuses on new ventures in OSS, specifically in embedded Linux, as will be explained in the following paragraph. These firms base the core activities of their business on virtual value chain activities from software input, its development to its marketing, and as such can be categorized as e-ventures. Furthermore, they represent a particularly interesting object for research studies in the field of e-entrepreneurship, as they rely to a large degree on "e-R&D" from a network of OSS developers, and thus put special emphasis on a virtual value chain activity that to date has not received much attention from researchers in this field.

2.3 OSS and embedded Linux

The phenomenon of OSS has captured the imagination of numerous entrepreneurs. In the late nineties, the IPOs of OSS-based ventures VA Linux (now VA Software) and Red Hat have raised enormous amounts of capital, and experienced even greater stock price surges subsequently [51, 52]. While the exuberance of open source ventures went away with the internet bubble, OSS seems poised to stay, and with it the opportunities it offers to entrepreneurs.

By definition, OSS is software under a license which conforms to the "Open Source Definition" [53]. Among other things, this definition requires that each recipient of a program's executable (binary) code is entitled to obtain also the source code, and is allowed to modify it and to diffuse modified or unmodified versions. The most widely used open source license, the GPL ("General Public License"), adds an additional requirement. This license, which governs the use of Linux among others, stipulates that modifications ("derived works") of OSS under the GPL be again licensed under the GPL. This so-called "viral" or "reciprocal" characteristic has strong implications for business models that could potentially be built on OSS. A second feature of high relevance for entrepreneurs is that charging per-unit royalties for OSS is excluded. However, OSS can be sold against a one-time payment, which opens up opportunities for firms specializing in commissioned development based on existing OSS. Other business models make use of OSS by bundling single components into complete systems (e.g., Red Hat and SuSE) or by selling complements to it such as hardware, training, or manuals [3, 4, 5, 6].

What has startled programmers and academics alike is the surprising success of OSS projects such as Linux, Apache, Sendmail, or Jabber. These publicly and freely available software packages have reached wide diffusion as well as a quality comparable or even superior to that of commercial substitutes despite the fact that they were, at least in earlier phases of their history, not supported by any commercial company. Rather, they grew out of geographically dispersed communities of developers collaborating over the internet. The process these communities use to develop OSS – the so-called "open source process" – contradicts most textbook-knowledge on software engineering, but proved very successful [54]. Its power derives from the openness and public availability of the code, which allows any interested programmer to use, inspect, and improve the code. Furthermore, comments, error corrections ("bug fixes"), and additional code can be sent to the maintainer of the OSS project at very low cost.

Apart from technical aspects of the open source process, also the issue of developers' motivation has received considerable attention [e.g., 55, 56, 5758, 59]. Programmers working on public open source projects contribute their programming effort without receiving direct monetary compensation – seemingly a contradiction to the concept of a utility-maximizing individual. Different sources of motivation have been identified, among them need for new functionality in the software, development support by others, reputation among peers, fun of programming, learning, signaling to the job market, the wish to give back to the OSS community, and an aversion to proprietary software in general.

Despite the fact that contributions to OSS projects are not directly monetarily rewarded, the popular picture of OSS programmers as altruistic hobbyists misses the point. A survey found that 30 percent of respondents were paid by their employer for their work on OSS, and these paid programmers spent on average twice as much time per week on OSS development than volunteers [55]. Hence, in terms of hours worked, contributions by paid programmers – i.e., from firms – account for about half of all contributions in this survey. Obviously, the share of contributions to an OSS project that originate from commercial firms depends strongly on the nature of the OSS project. OSS software packages that are only of interest to firms or that require hardware typically not available to hobby developers will receive very few if any contributions from hobbyists [6].

A particularly interesting and important instance of such OSS is "embedded Linux". This term denotes variants of the Linux operating system that are tailored to embedded devices, i.e., devices possessing computing capability that (unlike a PC) are built for a specific purpose [60]. Examples are mobile phones, VCRs, machine controls and aircraft. Embedded devices are becoming more and more ubiquitous, and Linux has become one of the top choices as an operating system for them [61, 62, 63]. Since embedded devices are extremely heterogeneous, the operating system needs to be adapted to the specific device. For instance, specific requirements may exist regarding real-time capability, low memory needs, stability, unusual CPUs, boards, or periphery. Hence, device manufacturers intending to use Linux in their devices have a high need for customized versions of the open source operating system.

This rise of Linux in embedded systems opened up opportunities for entrepreneurs. A large number of start-ups are providing software and services related to embedded Linux, among them firms such as LynuxWorks, MontaVista, and TimeSys in the US, and Denx, Mind and Sysgo in Europe [64]. Due to the need for adaptations, most companies in this field adopted a service business model, providing customized development to device manufacturers. These firms epitomize "e-transformation" by using the internet and the open source process it enables across their value chain: for inputs, for development, as well as for marketing. They are the focus of this paper.

3 Research questions

As the preceding section has shown, liabilities of newness and smallness as well as the presence of market entry barriers are widely considered as key challenges for the management of new firms.

Our paper focuses on new firms at the intersection of internet and OSS. These phenomena are among the most important trends in IT, generating a large number of business opportunities in the e-economy. Yet, not much knowledge exists on how these trends affect the challenges ventures in this field encounter during the early stages of their development. In particular, the change from tight to loose regimes of IP protection, from localized to distributed innovation processes and from resource-intensive software R&D to free availability of (continuously enhanced) software code have far-reaching implications for the management of these ventures, and in a broader perspective for the exploitation of business opportunities in OSS.

The purpose of this paper is to investigate how the challenges of new venture management discussed above play out in the space of OSS. In order to achieve this goal, we aim at answering the following three research questions:

1) In what way does the open source process provide opportunities for the formation of e-ventures? How can the commercial exploitation of electronic information and communication networks extend to all activities of the value chain, including virtual product development ("e-R&D")?

2) How does the open source process change the rules for new ventures that build on OSS instead of proprietary software? In particular, in what way does it affect liabilities of newness and smallness and barriers to market entry?

3) The internet and OSS are instances of more general trends, namely, networking on the one hand and open and distributed innovation on the other hand. To what extent can the findings derived from the empirical study of the embedded operating industry be generalized to venturing in other industries?

4 Research Design and data

This research is based on a combination of a qualitative, interview-based study and a large-scale survey of embedded Linux developers. The interviews provided a detailed understanding of the characteristics of the embedded Linux industry and allowed to identify the relevant questions to be asked in the quantitative study. The two studies are described in the following.

4.1 Qualitative study – interviews

During the period from May 2002 to June 2003, a total of 30 in-depth interviews were conducted. The focus of the interviews was on the open source development process, in particular on the question if and how this process can work in a field that is dominated by commercial firms, not hobbyists. Linked to this, the business opportunities arising from this process were investigated. In addition, some information on technical aspects and on the use of embedded Linux was collected. Of the interviewees, 13 worked for software firms specializing on embedded Linux, six for hardware manufacturers using embedded Linux in

their devices. Another seven were industry experts, while four had indirectly to do with embedded Linux, mostly as sellers of competing proprietary products. Table 2 presents an overview. Most of the interviews (26) were conducted over the phone, two were face-to-face interviews, and two were conducted via e-mail. Of the 28 oral interviews, 18 were electronically recorded; in 10 cases handwritten notes were taken. The average length of the interviews was 53 minutes. The interviews were semi-structured and followed a guideline that was adapted over time to take findings of the earlier interviews into account [65, p. 30]. In order to increase comparability of the responses and to exclude the effect of time trends, those interviewees deemed knowledgeable about the embedded Linux development process (24 of 30) were provided with a web-based questionnaire in July 2003. Of those 24, 20 returned the questionnaire.

Please insert table 2 about here

The interviews were transcribed and analyzed using the software "AnSWR" to perform a qualitative content analysis [65, 66]. During the process of open coding, a hierarchical category scheme was developed consisting of 137 categories in total, of which nine are on the first, 57 on the second, 66 on the third, and five on the fourth level. In total, 657 relevant text segments have been identified and assigned to one or more categories. More details are given by *Henkel* [67].

4.2 Large-scale survey

To complement the findings of the qualitative study and to gain further insights into the development of embedded Linux and the conduct of start-ups in this environment, a web-based survey among developers of embedded Linux was conducted. The questionnaire was online from November 2003 to March 2004, and was advertised on several web portals and mailing lists dedicated to embedded Linux. Based on the interviews it was possible to choose those portals and lists that are the most relevant information sources for embedded Linux developers. The questionnaire contained 115 questions (mostly Likert scale questions and some open questions), and yielded a total of 268 valid responses. A comprehensive statistical description of the data is given by *Henkel and Tins* [68].

The basic population of the survey consists of all developers of embedded Linux that read the web portals or mailing lists where the survey was advertised. While the survey was in principle open to anyone, participation of respondents beyond this basic population seems very unlikely since the survey would have been hard to find for those people. In addition, filling it out in a way that made it look like a "sensible" response would have been difficult. While thus responses from outside the basic population can be safely excluded, it is not known what share of the basic population responded (i.e., the response rate) since data on the size of the basic population (subscribers of the mailing lists, visitors of the portals) was not fully available. A related problem is that participants in the survey were self-selected. However, these problems are hard to avoid in a survey such as this one, and occur, in

somewhat milder form, even when a given, known number of potential participants are individually addressed and only a fraction of them respond.

Some descriptive statistics of the respondents are given in table 3. They are nearly exclusively male, with an average age of 35 years (median: 34 years). Geographically, they are dispersed over 39 countries, with North America (42.4%) and Europe (39.5%) being the most important regions. Asked for what type of organization they were working, with five possible alternative answers, 60 respondents (22.4%) chose "Software company specializing on embedded Linux", 114 (42.5%) "Device manufacturer", and 23 (8.6%) "Manufacturer of components like chips and boards". The remaining 71 respondents (26.5%) described themselves as "Hobby developers" (41, 15.3%) or as working for "University or other non-profit research organization" (30, 11.2%). Hence, only a minority of respondents (15.3%) conform to the cliché of the open source developer as a hobbyists. Furthermore, in terms of hours per week, the hobby developers in the sample work on average only one third of what developers working for commercial firms do. The notion that hobbyists play a negligible role in embedded Linux development is thus confirmed.

Please insert table 3 about here

The above characteristics hardly differ between respondents in general and those working for software firms specialized on embedded Linux. When considering characteristics of the employing firms, however, it is necessary to distinguish between the five categories present in our sample. Since our analysis focuses on embedded Linux software firms, table 4 shows statistical characteristics of this sub-group of the sample. These firms (N = 60) are quite young, with the median founding year being 1997 (average: 1993). They are also relatively small, with the median firm belonging to the size category 11-50 employees. Their experience in developing embedded Linux is necessarily restricted to a maximum of ten years, since the technology became available only in the mid-nineties. Accordingly, the earliest firm to start embedded Linux development did so in 1995, while the most recent entrant into this industry entered in 2003. Mean and median entry year are 2000. This statistical data show that embedded Linux firms constitute a rather young and entrepreneurial segment of the embedded operating system market, and are hence well suited for an analysis of venturing in this industry.

Please insert table 4 about here

5 Results

The arrival of Linux in the arena of embedded operating systems was found to have strong effects on this industry, with entrepreneurs being in the driver's seat in the ongoing

transformation. The fact that Linux is an open source operating system, the source code of which is publicly and freely available to anyone, lowers barriers to entry. In addition, it favors a shift of the embedded operating system industry towards a service business model, with start-up software firms selling customization services based on existing OSS to manufacturers of embedded devices. These firms mostly make active use of the open source development process. That is, they use the internet not only for obtaining their inputs (by downloading existing OSS) and for marketing, but also for their product development. This e-enabled informal collaboration mitigates restrictions these firms would normally face from resource scarcity. Thus, it is one of several factors mitigating liabilities of smallness. Finally, the internet-based open source process provides an effective and low-cost way of marketing a new firm's technological capabilities to the – in this field technically savvy – decision makers. This constitutes one of several ways in which the open source process helps to overcome liabilities of newness.

These aspects – liabilities of newness, liabilities of smallness, and market entry barriers – will be discussed in the following subsections, starting on the marketing side of the firm's internal value chain. For each aspect, qualitative as well as quantitative empirical evidence will be provided.

5.1 Liabilities of newness

As laid out in section 2, start-ups face a number of challenges specific to their newness. As to marketing, new ventures typically suffer from being unknown entities in the marketplace, from a lack of exchange relationships with customers and from not possessing a track record/reputation, which translates into a lack of trust in the abilities and offerings of new firms (cf. table 1). Yet, all of these aspects are essential for scoring much needed customer wins, and for bringing new ventures in a more favorable resource-dependence position once the first sales of the product are made [69, 70].

In the case of new ventures in OSS, active participation in the open source process helps to mitigate these liabilities, as it makes these firms publicly known and allows them to quickly build a visible track record of achievements. For example, competent programmers employed by an embedded Linux software firm might submit code they have developed to a public OSS project, might take part in discussions about new developments on a related mailing list, or might answer questions from other programmers on this mailing list. Such activities are valuable marketing activities since potential buyers of the firm's service offerings will often search in suitable open source projects for capable software firms. This marketing channel – which also can be interpreted as a by-product of the OSS process – not only provides much needed visibility for new firms, but at the same time allows potential customers to assess the abilities of the respective firm by inspecting the (open) source code that this firm has contributed. Furthermore, acceptance of submitted code into the "official" standard version of the project is considered a proof of quality, giving new firms the chance to build up a favorable track record and reputation. (Interestingly, this way of marketing the venture – by contributing to public OSS projects – feeds back into the precondition of this venture's foundation, namely, the existence of freely available OSS code.)

Hence, the very characteristics of the open source process give founders the possibility to easily reduce some key liabilities of newness that typically are associated with new ventures, and ceteris paribus make the exploitation of business opportunities less challenging than in other fields. Quotes from the interviews described in section 4.1 (translated by the authors where necessary) illustrate these considerations:

"I once published an article in a relatively high ranking publication […] addressing higher management […]. That was relatively expensive and yielded exactly zero responses. My job is not only to read mailing lists every day, but to respond also to really stupid beginner's questions […]. These are the things by which I have massively acquired new projects." (Embedded Linux software firm, EU)

"There are those [potential buyers of development services] that search for a competent partner […], who would, e.g., go through the mailing list to see who replied to questions and which replies seemed helpful and competent." (Embedded Linux software firm, EU)

"I'm hearing more and more companies backing up assertions of their software's quality by bragging that Linus Torvalds [maintainer of the Linux kernel] or another project maintainer accepted their code." (Industry expert, US)

"This is also a bit of marketing to say, look, we ported it to the new Infineon XYZ [processor], here is the source code […]"(Embedded Linux software firm, EU)

"When firms do that [publish their code], and this is certainly also a motivation for us, then it is to demonstrate competence. We repeatedly found that this code was considered a reference, that we were approached specifically because of that. This is certainly a marketing tool in this instance […] (Embedded Linux software firm, EU)

"The advantage for [our company], I call that the market exposure advantage. For the customer, it's lowering support cost. For us, it's market exposure advantage. […] we get recognition as specialists in that field […] Brand recognition, it's marketing. (Embedded Linux software firm, EU)

"The people that understand what that innovation is, they use it and will know that it came from MontaVista or from Red Hat or whatever and it's like a feather in their hat. It gives them credit and in the future if somebody chooses to use that and they need support for that particular option, they know that they're going to end up going to that company to get it." (Industry expert, US)

Findings from the large-scale survey of developers offer a quantitative view on this issue. One of the survey questions was, "What are the reasons for your company to reveal code?" Eleven potential reasons were offered, and participants were asked to indicate their level of agreement on a five-point scale from "agree strongly" to "disagree strongly". Two of these potential reasons – "because revealing good code improves our company's technical reputation" and "because visibility on the mailing list is good marketing" – are directly related to the topic of this paragraph. Table 5 shows correlations between the level of agreement to these statements and the size and age of the company (for software firms only). The significance levels clearly show that the importance of both visibility on mailing lists and the chance to build a reputation of technical capability are significantly negatively correlated to the age of the company. That is, the younger the firm, the more important are these low-cost marketing activities as reasons to contribute to the open source process. Hence, the statistical

analysis confirms what the quotes above illustrated, namely, that the marketing aspect of contributing to the open source development process helps to mitigate liabilities of newness related to the young firms' being unknown entities and lacking a reputation.

Please insert table 5 about here

The lack of exchange relationships of new ventures is challenging not only in the context of customers, but also regarding suppliers – especially in oligopolistic cases where only few suppliers exist. We find that also this liability is alleviated by the open source process: In principle, an independent software firm could offer a service of customizing existing software also for proprietary embedded operating systems, and such firms indeed exist. However, an exchange relationship with the vendor of the proprietary operating system would have to be established, which can involve considerable transaction cost due to negotiating, contracting, and monitoring [71]. These transaction cost are absent for firms basing their service offerings on OSS.

> *"[…] by taking advantage of what is common [available as OSS] you can accomplish your special proprietary things, your goals much faster." (Embedded Linux software firm, US)*

> *"[…] worked on licensing Real Player. That was the slowest part of their process! They had to go out and negotiate a whole separate license […] Whether or not you choose free software [OSS] for a project depends largely on how much transaction cost you are willing to put up with. The more free software, the faster the development process." (Industry expert, US)*

5.2 Liabilities of smallness

In recent years, the requirements on embedded operating system have become more and more demanding [72], with advanced networking features and graphical user interfaces gaining importance. A firm offering a proprietary embedded operating system has to stay on top of these developments – even if many of these features do not anymore provide a differentiation in the marketplace, but are rather considered by buyers as a "must have". A small firm entering this industry would have to replicate the R&D effort of incumbents to join the game in the first place, and then would have to work continually to stay abreast of further technical developments. In addition, it needs to have the capacity to do error correction ("bug fixing") and testing of its developments to make sure it does not ship flawed code to its customers. In short, all of these activities require extensive access to human and financial resources, which small firms lack, putting them in a very disadvantageous competitive position vis-à-vis larger companies.

These liabilities of smallness are much less relevant for software firms dedicated to embedded Linux. They build their market offering on a suitable version of standard Linux, typically on one of the most recent releases. That is, they obtain a fully-fledged, stable operating system featuring the most recent technologies – for free. They can thus focus on

those features that their customers demand, instead of expanding effort just to stay up-to-date with respect to "must have" developments.

Apart from providing valuable software for free, open source projects also offer informal development collaboration, helping participants to improve the code they contribute and to develop it further even when internal resources would not be sufficient for this. This requires, of course, that the respective firm is willing to share its code: obviously, it will in some cases be preferable to keep important code secret in order to protect competitive advantage [9]. However, in many cases firms indeed make their developments public and benefit from doing so, as the following quotes illustrate:

"This is precisely the advantage of the 'GPL way' that, when I make the code public, I can resort to support from the mailing lists and can discuss these problems with other developers facing similar problems. I can not do all this when I keep the code secret." (Embedded Linux software company, EU)

"[…] it doesn't cost me any more to make those mailing lists available. I get benefits from providing those because I get patches back, and it facilitates my business." (Embedded Linux software company, USA)

"There is of course the classical reason that, when we work on RTAI [Real-time Application Interface] we gladly make it public to have it validated externally. What other developers say is definitely relevant since nobody anymore sees through the Linux kernel completely. (Embedded Linux software company, EU)

"MontaVista tries aggressively to get their developments checked in into the next official version [of the Linux kernel].That software is […] a Linux pre-patch kernel that gets tried out all over the world by many different users and developers [… they get] testing for free." (Industry expert, USA)

"I know that our version of Linux is going to be extensively tested with both MySQL and with Oracle. That would be something far beyond our ability […] it would be an enormous financial burden for a company like QNX [vendor of proprietary embedded operating system]. But I get it for nothing, or for my participation in Linux." (Embedded Linux software company, USA)

Reasons to make code public: "I always got back much more than I gave. Furthermore, we are a very small company. I just can not do myself everything I need. So I have to rely on the work of others." (Embedded Linux software company, EU)

Reasons to make code public: "One reason is certainly that some things just can not be done […] with the available resources. Assuming I have a certain team size at my disposal and have a certain task, and that task is suitable for an open source project, and I can assume that more people worldwide are interested in it, then it makes very much sense to bundle resources." (Embedded Linux software company, EU)

As for liabilities of newness (section 5.1), also for liabilities of smallness our quantitative data confirm the findings from the interviews. One of the survey questions asked, "Please consider those embedded Linux developments by your firm that are potentially useful for others. That is, they are not too specific to your firm […]. What share of this code is freely revealed?" For software firms, the average share of revealed code was 57.5%. Hence, the firms in our sample do consciously keep some of their developments secret, but reveal the majority of it. Relating the share of revealed code to characteristics of the company, we find that the size of the company has a significant negative influence (5% level). However, simple

correlations do not reveal this relationship due to influences of further variables such as characteristics of the individual programmer and experience of the company with embedded Linux. Taking these influences into account in a multivariate regression (which would be beyond the scope of this paper), company size has a significant negative effect which proves robust across different specifications and various estimation methods – OLS, Tobit, and ordered Probit [9].

Apart from liabilities of smallness relating to R&D and operations, new ventures typically suffer from their smallness also in their marketing activities. Here, the literature on entrepreneurship suggests that new ventures should select marketing activities which are low-cost, but produce a strong impact in the marketplace [17]. By using mailing lists as marketing tools, as has been shown in our discussion in the previous section, new ventures in the field of embedded Linux have found a marketing channel which fulfills these requirements well. This is also illustrated by the quotations given above. Furthermore, as table 5 shows, highly significant correlations between the level of agreement to these statements and the size of the company exist. Both visibility on mailing lists and the chance to build a reputation of technical capability are significantly negatively correlated to the size of the company, i.e., the smaller the firm, the more important are these low-cost marketing activities as reasons to contribute to the open source process.

5.3 Market entry barriers

As has already been pointed out in the previous section, entering the embedded operating system industry as a vendor of a new proprietary system would require considerable capital just for matching the present development level of incumbent systems. This barrier to entry is strongly reduced for firms basing their market entry on embedded Linux. Also the barrier erected by extensive continuing R&D efforts of incumbents is much easier to surmount since embedded Linux firms benefit from ongoing development both of the standard Linux kernel and of modules specific to embedded Linux. They can thus more quickly focus on what differentiates them in the marketplace. The following quotes support these arguments:

> *"[In] the embedded market there is an enormous amount of engineering effort done to re-invent the wheel over and over again, and all these companies write their own operating systems or modify it. The standard proprietary systems that are out there are very labor-intensive […] Being able to use embedded Linux jumps them over wheel re-invention […], they are able to actually work on whatever it is they are doing." (Embedded Linux software company, US)*

> *"It's hard to write device drivers. It's hard to write good application programs. The more you can take advantage of ones that already exist, the more quickly you can get to focusing on what differentiates your product or your service from everyone else's product and their service." (Embedded Linux software company, US)*

The open source process also impacts another entry barrier, namely, switching costs of customers. First, switching to embedded Linux is – ceteris paribus, i.e., given identical technical performance etc. – easier for a device manufacturer than switching to a new proprietary operating system. To see why, consider that device manufacturers usually not just

buy an operating system as a black box, but have to program their application software in a way that it interacts seamlessly with the operating system. This is often simplified considerably when access to the source of the operating system is given and when this code can be modified if necessary. The latter is always the case for embedded Linux, but typically not for proprietary operating systems (although recently they have moved to a higher degree of openness [73]). When in addition the device manufacturer employs programmers with some knowledge on Linux – which, given its popularity, is not unlikely – switching to embedded Linux is far easier than switching to some less-known proprietary operating system. Provided, of course, that the device manufacturer feels secure that it can resort to reliable outside support if necessary – which leads us back to the point that the use of Linux in embedded systems creates opportunities for new ventures.

Secondly, customers should be more willing to switch to embedded Linux than to some proprietary competitor – again ceteris paribus – since the lock-in created is lower. That is, the switching cost *created* by the move to the new operating system is reduced by the fact that Linux is OSS. While it is true that the lock-in to *Linux* is comparable to that to some proprietary system, the lock-in to a particular vendor is much lower. Hence, the risk of opportunistic behavior by the software vendor after lock-in has been created is reduced, which makes the device manufacturer more willing to switch in the first place.

6 Discussion and conclusion

The empirical analysis presented in this paper has shown that key challenges for new ventures discussed by the entrepreneurship literature are less relevant for new firms in the field of embedded Linux. Several liabilities of newness and smallness as well as a number of entry barriers were found to be mitigated by the open source development process. Among other things, active participation in this open innovation process gives firms visibility towards potential customers, helps to build a technical reputation, and allows them to overcome capacity limitations by recruiting outside development support.

The above is not to say, though, that no entry barriers into the embedded Linux industry exist. One challenge that remains – or rather, becomes even more relevant than for proprietary software start-ups – is to find a sufficient number of expert programmers that know their way through the huge quantities of embedded Linux code that are publicly available.

Our findings have interesting implications for the development of the embedded operating system industry. Reduced entry barriers in embedded Linux, in particular reduced sunk cost required for entry, lower the lower bound for industry concentration [74]. This fact, which gains importance to the degree that Linux gains market share in the embedded arena, counteracts the trend towards consolidation driven by increasing technical sophistication of embedded operating systems. The most likely scenario is hence one of a relatively fragmented market in which firms compete by the quality of their services (excluding vendors of tools etc.). These firms are unlikely to attain profit levels similar to those of large proprietary software vendors, which is the obvious downside of services businesses and reduced barriers to entry. However, many have demonstrated the viability of healthy and profitable businesses.

Apart from these more general considerations on industry evolution, our findings have important implications for entrepreneurs considering exploiting business opportunities in OSS and researchers in e-entrepreneurship.

For entrepreneurs our results give a clearer understanding of the challenges that have to be overcome in order to capitalize on an emerging business opportunity in OSS and to establish a successful new venture. Overall, the findings suggest that aspiring entrepreneurs will encounter favorable conditions for exploiting their business opportunities. However, as the above discussion of industry evolution has shown, the competitive landscape is likely to change in the coming years, challenging entrepreneurs to continuously adapt their businesses.

In addition, the preceding discussion implies that entrepreneurs need to possess or at least have to acquire in-depth industry knowledge when they want to succeed with their venture projects. Though our findings show that the challenges associated with establishing a new venture in embedded Linux are in large parts mitigated due to the specifics of this domain, entrepreneurs still have to recognize that relatively easy ways exist in this area to address the challenges they are facing. In order to be able to act accordingly, industry knowledge is indispensable, which is also an aspect that is continuously found to be among the most important success factors for new ventures and ranked highly in evaluations of venture teams by venture capitalists [75].

Furthermore, applying a more general perspective, the preceding analysis can be helpful for entrepreneurs intending to exploit business opportunities derived from any kind of open source innovation. First, these opportunities exist in any field of software where open source solutions to build upon are freely available (which are actually most fields of software) and where users have a high need for customization. The latter was found to be the case even in the seemingly homogeneous field of web server software [76].

Second, opportunities arising from open and distributed innovation processes are not restricted to IT industries. In principle they can occur in any industry, as the internet supports such innovation processes in many fields. For instance, von Hippel [77] reports that internet-based user communities have been established in countless areas, and gives an example of kite surfers who develop and then freely reveal new design specifications for kites online. This has induced some kite manufacturers to cease their own R&D efforts and to build their kite designs on freely revealed design specifications, thereby making use of the much higher innovative potential of the user community. In this way, entrepreneurs in various industries could build businesses on freely revealed innovations from online communities, benefiting from mitigated liabilities of newness and smallness as well as lower market entry barriers. Hence, understanding how to best use the trend towards open and distributed innovation processes to the advantage of new ventures is essential. This paper has presented some preliminary insights.

For researchers in e-entrepreneurship our results show that not only very specific topics, but also basic building blocks of entrepreneurship theory such as the liabilities of newness and smallness of new firms need to be explored in the context of e-entrepreneurship, since electronic information and communication networks have profound effects on new venture management. As this study was able to point out, the challenges typically associated with new

venture management play out quite differently for new ventures in the field of embedded Linux.

Furthermore, while most studies in e-entrepreneurship to date study various virtual value chain activities, research on the specific aspect of "e-R&D" has not garnered much attention. As our study was able to show, participation in virtual, informal R&D networks can have several beneficial effects.

For researchers focusing on OSS or user innovation [78], studying new ventures can highlight ways of commercializing open and distributed innovations. Relatedly, only few studies address the question of how user innovations grow into new venture projects and successful young firms [79]. Plenty of research opportunities exist when looking at the topic of opportunity recognition and exploitation from the angle of the literature on user innovations. These studies would tie in nicely with research on e-entrepreneurship, as many firm formations in this area have been based on innovations by users, as, e.g., the origin of online auction house eBay illustrates.

As a fairly young area of interest, the field of e-entrepreneurship offers numerous research opportunities. With more and more researchers addressing questions in e-entrepreneurship, the field will gradually overcome its own liabilities of newness and smallness.

Appendix

Table 1 *Key challenges for new venture management [adapted from Gruber [17]]*

	Challenges for new venture management	Literature
Newness of the firm	• unknown organizational entity • lack of trust in the abilities and offerings • reliance on social interactions among strangers • lack of exchange relationships • lack of internal structures, processes/routines • lack of experience • lack of historical data for planning purposes	Stinchcombe (1965) Hannan/Freeman (1984) Robertson/Gatignon (1986) Schoonhoven/Eisenhardt/Lyman (1990)
Smallness of the firm	• very limited financial resources • few human resources • lack of critical skills • limited market presence • limited market power, disadvantage in negotiations	Aldrich/Auster (1986) Mugler (1995) Pleitner (1995) McGrath (1996)
Market entry barriers	• key entry barriers are: o capital requirements o access to distribution channels o switching costs of customers o R&D efforts by incumbents	Bain (1956) Gilbert (1989) Karakaya/Stahl (1989) Porter (1980)

Table 2 *Overview on the interviewees*

Firms contributing to embedded Linux		Device manufacturers	Other embedded software firms	Industry experts
USA	**Europe**			
Code Poet FSMLabs Independent dev. Lineo LynuxWorks MontaVista TimeSys	Denx emlix Mind Pengutronix reLinux Sysgo	Convergence Innominate Maintainer, RTAI Siemens CT Siemens ICN SSV Embedded Syst.	Microsoft QNX SleepyCat Wind River	Author “Embedded Linux” Code Weavers Intevation Free Software Foundation LinuxDevices LinuxJournal Maintainer of Debian Linux
Σ 7	Σ 6	Σ 6	Σ 4	Σ 7

Table 3 *Descriptive statistics of the respondents*

Age	16-25: 15.6% 26-35: 44.1% 36-45: 24.0% 46-55: 14.8% 56-older: 1.5%			
Gender	male: 259 female: 5 missing: 4			
Regions	North America: 42.4 % Europe: 39.5 % Asia: 9.9 % Australia: 4.6 % South America: 3.4 % Africa: 0.4 % missing: 1.9 %			
Occupation	professional programmer: 61.9% IT-manager: 7.5% student: 7.8% engineer: 7.8% full-time faculty: 5.6% other: 7.5% missing: 1.9%			
Experience as software developer				
Years developing…	*any kind of software*	*OSS*	*sw for embedded systems*	*embedded Linux*
Mean	14.2	4.9	7.1	2.5
Median	14.0	4.0	5.0	2.0
Std. dev.	8.3	3.7	6.5	1.7
Minimum	1.0	0.2	0.1	0.1
Maximum	35.0	20.0	30.0	10.0
Missing	13	49	16	35
N	255	219	252	233
Type of organization participants work for				
Software company specializing on embedded Linux	22.4%	*Commercial, total:*		
Device manufacturer	42.5%	73.5%		
Manufacturer of components like chips and boards	8.6%			
Working as a hobbyist	15.3%	*Non-profit, total:*		
University or other non-profit research organization	11.2%	26.5%		

Table 4 *Descriptive statistics of the embedded Linux software firms in our sample*

Year when company was founded
Mean: 1993 Medium: 1997 Oldest: 1914 Youngest: 2003 Std. Dev.: 16,02
Size of company
Just me: 3 (5,1%) 2-10: 20 (33,9%) 11-50: 15 (25,4%) 51-200: 10 (17,0%) more than 200: 11 (18,6%) missing: 1
Year when company started developing embedded Linux
Mean: 2000 Medium: 2000 Oldest: 1995 Youngest: 2003 Std. Dev.: 1,83

Table 5 *Correlations between size and age of company and level of agreement to "Visibility" and "Reputation" as reasons to reveal code (Spearman's rank correlation coefficient, rho; for software firms specializing on embedded Linux, N = 60)*

	Size of company	**Age of company**	**Reason: Visibility**	**Reason: Reputation**
Size of company	1.0000 N = 59			
Age of company	0.5311 (0.0000) N = 56	1.0000 N = 56		
Reason: Visibility	-0.2566 (0.0663) N = 52	-0.3507 (0.0169) N = 46	1.0000 N = 52	
Reason: Reputation	-0.3991 (0.0034) N = 52	-0.2630 (0.0774) N = 46	0.4411 (0.0012) N = 51	1.0000 N = 52

Note: Size of company is given on a five-level scale (see table 4). Age of company is given in quartiles of the age distribution of software firms (x = 1 for firms founded 2000 or later, x = 2 for 1998 to 1999, x = 3 for 1994 to 1997, and x = 4 for firms founded 1993 or earlier). Agreement to reasons is given on a scale from -2 ("strongly disagree") to 2 ("strongly agree"). Numbers in braces denote significance levels of correlation.

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