Seeding the cloud: Financial bootstrapping in the computer software sector.

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This study investigates resourcing of computer software companies that have adopted cloud computing for the development and delivery of application software. Use of this innovative technology potentially impacts firm financing because the initial infrastructure investment requirement is much lower than for packaged software, lead time to market is shorter, and cloud computing supports instant scalability. We test these predictions by conducting in-depth interviews with founders of 18 independently owned nascent enterprises, of which three quarters have adopted cloud computing. We identify particular bootstrapping methods used by start-ups in the computer software sector. Cloud computing enables firms to develop and launch products with minimal resources, reducing barriers to entry, with consequent increased competition. The primary business bootstrapping technique is foregoing wages, supplemented by small amounts of grant funding. Customers are a source of knowledge and expertise for product development, which occurs in an iterative process. Product bootstrapping techniques have changed in response to technological innovation, although methods to acquire tangible assets are identical over time. Astutely applied, financial bootstrapping is a resource management strategy essential to the growth and survival of high technology firms.

Keywords: software industry; bootstrapping; cloud computing; social networks; private equity; business angels; disruptive innovation

Introduction

High technology based firms are an important source of employment creation, economic growth and technological innovation (Colombo et al. 2010; Freear, Sohl, and Wetzel 2002; North, Baldock, and Ullah 2013; Rasmussen and Sørheim 2012). Central to the development of a high technology small firm sector is a considerable level of start-up activity and new firm formation. A barrier to this expansion, however, is the ability of firm founders to acquire adequate finance for their nascent ventures (Basu and Parker 2001; North, Baldock, and Ekanem 2010). This is particularly evident for founders lacking a track record in entrepreneurship (Jones and Jayawarna 2010), adopting unproven or untested technologies (Westhead and Storey 1997). These firms are seldom financed from formal external sources (Mason and Harrison 1999), and may be restricted to the firm founder's personal resources (Blumberg and Letterie 2008), and those accessible from established networks (Jones and Jayawarna 2010). Firm founders, therefore, often make optimal use of minimal resources in starting and developing their businesses (Baker and Nelson 2005).

A burgeoning literature details methods and techniques used by owners in resourcing their new ventures (Malmström 2014). Although there is no commonly accepted definition of bootstrapping, authors have identified commonly used techniques (Freear, Sohl, and Wetzel 1995; Winborg and Landstrom 2001; Harrison, Mason, and Girling 2004), which are listed in appendix one. Subsequent studies empirically examine use of these techniques by small firms (e.g. Neeley and Van Auken 2010). This widely adopted approach does not account for changes in resourcing requirements over time due to changing industry structures, business models (Baden-Fuller and Haefliger 2013) and technological innovation (Christensen 1997). This is a notable omission in relation to the high technology sector, as new inventions, innovations and technologies

likely have implications for resource requirements and acquisition (Christensen 1997).

We examine these issues by investigating resource acquisition strategies of independently held start-ups[2] in the computer software sector. We have selected the latter to investigate the impact of technological change on bootstrapping behaviour of new ventures, as it is witnessing a transformational change through the introduction of cloud computing. Variously described as having the potential to become the fifth utility (Buyya et al. 2009), revolutionise the Information Technology (IT) sector (Mikkilineni and Sarathy 2009), and transform the means by which software is developed and delivered, cloud computing has emerged as a potentially revolutionary technology (Sharif 2010).

Adopting cloud computing for the development and delivery of software applications has significant implications for the business model of new firms, as this technology constitutes a 'pay by use' model rather than large upfront investment in infrastructure. Barriers to entry are relatively low, as start-ups are able to develop and deliver software applications with minimal financial resources. This has significant financing implications for new firms, which we investigate by posing the following research questions: (1) How do firm founders of start-ups in the computer software application sector resource their fledgling ventures? (2) What are the resourcing implications of adopting cloud computing?, and (3) Have resourcing techniques used by founders of new firms changed in response to disruptive technological change? The novelty of this research is that we investigate direct resourcing implications of the

[2] We adopt Butchart's (1987) broad definition of high technology firms, and all ventures in our sample fulfil the definition of start-ups provided by Burgel et al. (2000), as independently held firms younger than 10 years operating in a high technology sector.

introduction of technological innovation for new firms in the computer software sector. We contextualise our findings in relation to the literature by comparing bootstrapping techniques used by firms in our sample with those used by computer software firms studied by Freear, Sohl, and Wetzel (1995), and Harrison, Mason, and Girling (2004).

We address the dearth in the literature identified by Grichnik et al. (2014) and Winborg (2009) by investigating heterogeneity in resourcing strategies in high-technology start-ups with a sample that is significantly younger than that of earlier studies (e.g. Malmström 2014). We extend the cross-country comparison of Harrison, Mason, and Girling (2004), and respond to Rasmussen and Sørheim's (2012) call to investigate how private equity financiers interact with government supports to finance early stage high-technology firms. Finally, we note differences in inherent value by asset type across sectors by comparing our results with previous studies.

Resourcing high-technology start-ups

Resourcing small independently held firms is typically viewed from a financing perspective (Mac an Bhaird and Lucey 2009; North, Baldock, and Ullah 2013), reflecting the corporate finance tradition (Riding, Orser, and Chamberlin 2012). Software firms may encounter significant difficulties in accessing external finance for a number of reasons. Firstly, start-up high technology firms have particularly acute information asymmetries, primarily because of newness and lack of a credit history. This is exacerbated by difficulty in valuing firm-specific intangible assets being developed in untested markets, the high obsolescence rates of these assets, and appraising future growth potential of these products and services (Clarysse, Heirman, and Degroof 2003). Financing options are further limited by a lack of collateralisable assets. Internal equity is the principal source of funding for technology based small

firms, primarily because of credit rationing (Revest and Sapio 2012, 184). Capital structures of new technology based firms are therefore very different from other SMEs (Coleman and Robb 2012).

Requirements of new firms are not confined to finance, however, but include assets, capabilities, supports and systems that can be difficult to acquire by new ventures. Access to tangible and intangible resources varies considerably in nascent firms, and the Resource Based View of the firm (Barney 1991, 2001) proposes that this heterogeneous distribution of resources is long lasting. Access to intangible assets is particularly important for high-technology firms, and Hitt et al. (2000, 13) recognise the strategic importance of human capital, as "…Intangible resources more likely to produce a competitive advantage because they are more often rare and socially complex…".

Firm owners are often restricted in their resourcing options, however, and resources are perceived as scarce, particularly for new firms (Jones and Jayawarna 2010). Firm owners respond to these challenges by adopting bootstrapping techniques, which are used by the vast majority of new ventures (Freear, Sohl, and Wetzel 1995; Harrison and Mason 1997). Financial bootstrapping came to prominence in the literature through Bhide's (1992, 110) contention that "…the biggest challenge is not raising money but having the wits and hustle to do without it…". Harrison, Mason, and Girling (2004) identify two principal aspects to bootstrapping: (1) acquiring resources through social relationships at minimal cost, and (2) minimising the amount of external capital required through traditional debt and equity contracts.

Firm owners bootstrap critical resources through a variety of methods, including business alliances (Freear, Sohl, and Wetzel 1995; Hung 2006), personal sources

(Ebben and Johnson 2006), and social networks (Baker, Miner, and Eesley 2003; Heuven and Groen 2012; Jonsson and Lindbergh 2013). The latter are particularly important for resourcing new ventures (Jones and Jayawarna 2010), although past entrepreneurial experience does not have a significant impact (Grichnik et al. 2014). Bootstrapping techniques are used in firms of all ages (Ebben and Johnson 2006), and are more intensely used by nascent entrepreneurs (Grichnik et al. 2014) and in new enterprises (Jones and Jayawarna 2010). It is therefore postulated that bootstrapping is used by necessity, although a number of studies suggest that, judiciously applied, bootstrapping is an effective resource management strategy (Vanacker et al. 2011).

Bootstrapping techniques are used more frequently by entrepreneurs with higher levels of managerial and business experience (Grichnik et al. 2014), and bootstrapping is consistent with widely implemented lean business model methodologies (Jones and Jayawarna 2010; Ries 2011). Bootstrapping techniques are therefore adopted by design rather than necessity, as increasing capital efficiency is the principal intention (Ries 2011), rather than compensating for lack of resources (Winborg 2009). A potential disadvantage to using bootstrapping techniques is that minimising resource inputs may negatively impact the expansion and development of high-growth firms, particularly in the technology sector (Beck and Demirguc-Kunt 2006; Chaganti, DeCarolis, and Deeds 1995; Harrison, Mason, and Girling 2004; Pierrakis and Mason 2008). On the contrary, Vanacker et al. (2011) find that firms with greater intensity in bootstrapping experience higher growth over time.

Bootstrapping techniques are "…the fundamental building block of a new [high-technology] venture…" (Harrison, Mason, and Girling 2004, 309) for a number of reasons. Firstly, firm founders do not expend valuable time and resources seeking external investment, which is inappropriate for start-ups (Bhide 1992), as they do not

have access to cash flow to make regular repayments on debt, and they may be too risky for equity investors. Secondly, reliance on bootstrapping techniques relieves firms of interference from external contractual obligations (Vanacker et al. 2011) and unrealistic expectations of external investors (Bhide 1992). Thirdly, implementation of bootstrapping techniques may be particularly valuable for new high-technology firms seeking early market validation and feedback of a beta product (Ries 2011). Finally, although new high technology firms are perceived as having '…[the] liability of smallness and newness…' (Jones and Jayawarna 2010, 127), these characteristics are a source of competitive advantage for firms seeking to commercialise disruptive technologies (Carayannopoulos 2009).

Resourcing implications for software firms adopting cloud computing

Cloud computing refers to applications delivered as services over the internet, and the hardware and systems software in datacentres that provide those services (Armbrust et al. 2009). Thus, cloud computing may be conceptualised as a combination of three layers of abstraction: software-as-a-service (SaaS), platform-as-a-service (PaaS), and infrastructure-as-a-service (IaaS) (Weinhardt et al, 2009, Vaquero et al, 2008). The first layer is the focus of our study, and refers to software products which are delivered by developers and cloud vendors to end-users via internet (West, 2010). Examples of these services include word processors (Vaquero et al, 2008), online business software (Briscoe and Marinos, 2009), customer relationship management and enterprise-resource management programs (Sultan, 2010).

A number of factors suggest that firms adopting cloud computing for the operation and delivery of software applications have significantly different resourcing requirements from other firms. Firstly, cloud computing represents a transition from a

capital intensive investment model in packaged software to an operational cost model. This means that firms can develop and distribute software through the cloud with minimal resources, although it also means that competition in the initial stages is intense because of the potential for many new entrants. Similarly, the nature of the software as a service model means less spiky and more predictable and recurring revenue streams. Migration from a packaged software and perpetual license model provides technical and infrastructural challenges, however, along with marketing, customer dynamics and selling proposition changes. It also creates infrastructure and communication challenges for customers, investors and the wider financial community in contending with discontinuity and change to a different revenue model (TripleTree 2006). Another related factor is that, as lead times to market are shorter, time required for development and delivery of software is less. As the time period for customer acquisition is theoretically shorter, firms can approach external finance providers at an earlier stage, thus the time for bridging the initial development period is shorter. A third potential implication for SMEs is that cloud computing provides the capability for instant scalability and internationalisation.

Adoption of cloud computing by enterprises varies considerably across the European Union, where almost 20% of enterprises use cloud computing for delivery of services (Eurostat 2014). Use by firms in Ireland is higher at 28%, but considerably lower than Finland where over half of all enterprises use cloud computing. Unsurprisingly, use of cloud computing is greater by firms in the ICT sector, with 60% of Irish ICT firms utilising web based products and services (ibid). As evidenced from table 1, this is significantly higher than the average for the European Union (44%), but lower than adoption rates in Finland (82%) and Norway (71%). The greatest barrier to

adopting cloud computing cited by survey respondents was insufficient knowledge and perceived security risks.

Table 1. Use of cloud computing services by ICT firms in the European Union

Country	Buy cloud computing services	Office software	Database hosting	File storage	CRM software	Computing power to run the enterprise's own software	A high degree of cloud computing services (Combined)
European Union (28)	44	18	24	29	17	17	27
Denmark	66	31	35	46	35	32	51
Germany	26	:	:	:	:	:	:
Ireland	60	27	32	47	25	23	40
Spain	47	16	35	36	15	23	28
France	40	12	25	29	11	9	19
Italy	54	19	24	27	14	12	25
Netherlands	54	22	38	39	29	12	38
Austria	35	12	12	22	6	11	16
Finland	82	37	28	48	45	18	59
Sweden	65	25	25	43	29	30	49
United Kingdom	60	27	37	43	29	32	44
Norway	71	36	41	50	40	36	59

Source: Eurostat (2014).

The software sector in Ireland

There has been extensive growth in the IT sector in Ireland over the past three decades, to the extent that Ireland is one of the largest exporters of computer software in the world (Giblin 2011, Barry and Bergin 2013). Although a large proportion of exports are produced by multinationals, the computer software sector is predominantly comprised of indigenous firms (Andreosso-O'Callaghan, Lenihan, and Reidy 2014). The Irish software sector comprises 1,056 technology companies, over 90% of which are SMEs, directly employing 103,000 people (ISA 2014). Half of these employees work in the indigenous software sector, which includes 806 firms, over 99% of which are SMEs (by revenue), with revenues of €1.8 billion, over 50% of which are generated from exports (ISA 2014). In the past 3 years, indigenous software firms have grown by 39%, and foreign firms and multinationals report a growth rate of 23% (Lero 2014).

The emergence of a large indigenous software sector is attributed to a number of factors, primary of which is an intense policy of seeking inward FDI (Andreosso-O'Callaghan, Lenihan, and Reidy, 2014). These multinational firms created a demand for software, facilitated access to networks and connections, and provided managerial experience for emerging prospective entrepreneurs in the sector. The national development agency, Enterprise Ireland also plays a role in supporting fledgling firms by assisting capability development, and providing seed and venture capital (Barry 2008). Public support is one element of a supportive ecosystem for start-up software firms, which also includes accelerator programmes, incubator centres, and over 15 venture capital firms and other private investment organisations specialising in the sector (ISA 2014). Venture capital investments in the 'computer related' sector comprise 80% of total investment, compared with 37% and 6% for the US and Europe respectively (Barry and Topa 2008). Resultant fast growth in the sector has generated a number of challenges, however, particularly availability of sufficient skilled technical employees (ISA 2014). Demand for skilled employees in specific roles, such as programming, software development and cloud computing is much higher than supply (FIT 2014), with consequent upward pressure on entry salary levels. Availability of finance at some points in the 'funding escalator' (Gregson, Mann, and Harrison 2013) is also evident, as access to second-stage venture capital funding is a significant challenge for indigenous firms (Lero 2014).

The profile of the sector is not dissimilar to that studied by Harrison, Mason, and Girling (2004), with which this study is compared. Although much smaller, the software sector in Northern Ireland was predominantly owned by Northern Ireland interests, and over 70% of the firms had less than 25 employees (Harrison, Mason and Girling 2004). Similarly, a small number of large multinationals accounted for a large proportion of

exports from the sector. Dominance of a small number of large firms was also observed in Freear, Sohl, and Wetzel (1995), although there are differences in other aspects of the external environment, including level of state supports and availability of private equity investment.

Data and methodology

Firms in our sample were selected from the Irish Centre for Cloud Computing (IC4), the national research centre comprising universities and 30 industry members, of which 23 are independently held Irish owned SMEs. Our sample consists of 18 of the latter, and whilst not representative of the national population of cloud computing start-ups, these firms have profiles ideally suited to our explorative study. Data was collected in a series of in-depth interviews conducted with firm founders at their place of business (14) or the researchers' university (4) during July and August 2011. The average length of each interview was an hour, with the shortest lasting 33 minutes and the longest lasting an hour and 39 minutes. All interviews were recorded, transcribed and coded following Campbell et al. (2013). Face-to-face in-depth interviews are particularly appropriate when seeking specific information regarding firm financing and use of personal funds and other personal assets, which firm owners are reluctant to reveal when using remote research methods (Harrison, Mason, and Girling 2004). Additionally, as firm financing is interconnected with firm owners' income (Avery, Bostic, and Samolyk 1998), they are reluctant to convey sensitive financial data. Interviews are effective in this regard, because although firm owners may be reluctant to provide exact financing figures, they are usually forthcoming with approximate amounts.

Bootstrapping studies to date have predominantly used questionnaire surveys (e.g. Harrison, Mason, and Girling 2004; Winborg and Landström 2001). Our

explorative study requires a less structured research method to gain a full list of bootstrapping techniques used, and understand firm founders' motivations and strategies. Obvious questions regarding sources and amounts of resources were supplemented by queries about contextual issues such as previous business experience, area of expertise, prior relationships with employees and contractors to the firm, future growth intentions, investment preferences, and prospects and challenges for the increased use of technological innovation. Information was also sought about the firm owner's background in raising finance, including previous experience with financiers, networks and contacts with private equity providers, and how this influenced the financing decision. Firm owners were questioned about their preference for managerial independence and control, their strategic direction and expected exit path, and how these factors influenced the search for resources. This information is important to fully understand why firm founders use particular bootstrapping methods (Winborg 2009), as these strategic decisions have implications for firm growth. Interviews are particularly effective in this regard, as they facilitate a deeper discussion regarding the role of experience and preference in seeking resources, the structure and dynamics of social networks, challenges faced in securing specific resources, perception of value in a resource, and intentions regarding expansion and likely growth trajectory.

Table 2. Profile of software development firms

Firm	Firm age (years)	Number of Employees (FTE)	Founding entity	Background of firm founder	Principal Product Bootstrap Method
a.	3.5	10	Team	Electronic engineer.	Employs programmers in India.
b.	3	4.5	Team	Technology; Senior Management.	Co-founder is principal developer.
c.	1.7	7	Lone founder	Design; Engineer	Employs programmer in Poland.
d.	2	4.5	Lone founder	Software developer	Employs developer part-time
e.	4	3	Lone founder	Software developer	Commercialised consultancy project.
f.	4	7	Team	Sales and marketing	Developers part-funded by university.
g.	3	5	Lone founder	Business analyst and project manager.	Employs developers in Lithuania
h.	2.5	3	Team	Real estate manager	Acquaintance programmes during evenings/ weekends
i.	2	10	Team	Sales and marketing	Initial technology developed by Microsoft
j.	6	4	Team	Project manager; Sales; Business development	Commercialised consultancy project.
k.	3	21	Team	Sales; Business development	Developed evenings/ weekends whilst in employment
l.	10	9	Team	Web design	Commercialised consultancy project.
m.	2	4	Lone founder	Founder of IT and media companies.	Founder 'borrows' developers from his other firm
n.	1.5	3	Team	Computer engineering	Use open source software.
o.	1	3	Lone founder	Information Technology; Sales; Management	Employs developers on contract.
p.	5	4	Team	Programmer	Developed personally; hired programmers on contract.
q.	1.5	3	Team	Project manager; Business development	Employed small development team on contract.
r.	7	8	Lone founder	Sales	Employed developers on contract.

Findings

Profile of sample firms

Detailed profiles of firms in our sample are provided in tables 2 and 3. All firms are less than 10 years old, and classified as start-ups (Burgel et al. 2000), with an average age of

3.5 years and a median age of 3. All firms have developed a software product, which is being trialled by a number of customers, with one exception. We adapt the accepted industry term beta for products at this stage of development, which entails "…pre-release software deployed to real-world users…" (Xue et al., 2011, 1) before general mass market release. Income from customers is minimal in most cases, however. A wide breadth of software products reflects firm founders' previous employment and entrepreneurial experience, which are classified as technical or general business background. The latter comprise half the sample, and have experience in sales, business development or general management. The other half of the sample have strong technical skills, primarily as developers, programmers and in one case, design. Firm size varies, with an average of 6.3 and a median of 4.5 employees. Firms are owned by founders, with the largest two having a wider ownership structure. There are variations in the breadth of skills in teams directly employed by each enterprise, and differences in firm capacity, both in terms of product and business development. Almost two fifths of the firms were established by lone founders. The remainder were set up by teams of two, and two enterprises had three founders. Size of the founding team does not appear to influence the pace of development of the application software, although larger teams with diverse skills have separate roles in finance and sales. Lack of programming skills in founders is not an impediment to developing an application software enterprise, and all firms employ external developers.

In the following sections we discuss bootstrapping methods used by firm founders to resource their new enterprises. We follow the approach adopted by Harrison, Mason, and Girling (2004) in identifying a binary classification based on business and product development bootstrapping techniques. This is particularly useful as it delineates resource acquisition behaviours by principal activities of the firm, and is

appropriate for a sectoral approach.

Table 3. Resource requirements of software development firms

Firm	Stage of Development	Principal Business Bootstrap Method	Funding requirement and preferred source
a.	Beta*; high growth	No salary; Personal savings; Grant funding	€300,000 required from business angel, equally matched with funding from development agency.
b.	Beta; high growth.	Consultancy; Grant funding.	€100,000 required from business angel, equally matched with funding from development agency.
c.	Beta; high growth.	Consultancy; No/low salary.	€100,000
d.	Beta; 2 large customers	No salary; Consultancy; Pension redeemed early; sold investments.	€100,000 (but not seeking finance at present).
e.	Beta; 1 large customer.	Consultancy.	n.a.
f.	Growth; 10 customers.	Consultancy; cross-funded from other businesses	€300,000 seed funding, equally matched with funding from development agency.
g.	Growth; 3 large corporate customers.	Low salaries; give staff equity share in lieu of salary.	€100,000 required from business angels, equally matched with funding from development agency.
h.	Beta. No customers.	No salary; Consultancy; Give developer equity in lieu of salary.	€100,000 required from business angels for developer, plus €15,000 feasibility grant.
i.	High growth.	Personal savings; Grant funding.	€2 million required from Venture Capitalists.
j.	Beta; growth; 36 (low fee paying) customers.	Low wages; personal guarantees for loans.	€1 million required from business angels.
k.	Growth; 3 large customers.	Personal savings; Personal guarantees on loans; prizes	n.a.
l.	Beta; high growth.	Loans from friends and family; Retained earnings	€2 million required. Seeking €500,000 from corporate finance house.
m.	Beta; Trialled with 4 customers.	No salary; Personal funds; guarantees on bank loans	€150,000 required from business angel
n.	Beta; Trialled with 20 customers.	Working from home	n.a.
o.	Beta. Growth.	No salary; consultancy; Grant funding.	€125,000 required from business angel, equally matched with funding from development agency.
p.	Beta; high growth.	Personal savings; low salary	€2 million required from business angels.
q.	Beta; Growth; 6 customers.	Low wages; personal savings.	n.a.
r.	Established; 3 large customers.	Low wages; personal savings.	n.a.

*We define Beta as "…pre-release software deployed to real-world users …" (Xue et al., 2011, 1).

Product development bootstrapping methods

The most important resource for development and delivery of computer software is

access to programmers, developers, engineers and employees with requisite programming skills. Access to these resources varies according to firm founders' skills, past experience and social networks, thus consistent with the Resource Based View (Barney 1991) there are significant differences in the resources available to each firm. Firms employed a developer or small teams of programmers to supplement their programming capacity and develop the software product. Firm founders use a number of bootstrapping techniques to acquire programming skills, including: (a) Employing developers on a part-time or a contract basis (all firms); (b) The firm founder was the principal developer of the software product (four firms), of which three were consultancy projects; (c) Acquiring licences for software, or using open software (three firms); (d) 'Borrowing' developers from another venture (two firms); (e) An acquaintance developed product on an infrequent basis (one firm) (f) Paying developers with equity in lieu of wages (two firms). Firm founders with inadequate in-house product development skills accessed developers and programmers through social networks, or through networks developed from previous employment or enterprise.

Firm founders relate that the external environment presents a significant challenge in accessing developers and programmers with the requisite skills at an affordable salary. They cite the relatively large presence of multinational high-technology firms in Ireland as a considerable impediment in this regard, as programmers are in short supply, and those that are available are in high demand, thereby inflating wages. One firm founder noted that "…The problem with the Industrial Development Authority attracting all the multinational firms is that it makes recruitment very difficult for the rest of us…". Firm owners surmounted this problem by sourcing developers resident abroad, who were identified through domestically based acquaintances. They are based in a variety of countries including Poland, Lithuania, and

India. Firm founders noted that whilst this bootstrapping method ensures access to developers at reduced cost, remote management of resources was problematic. Geographic proximity of the developer is most important in this regard, as ease of management is related to distance from developers. In one case, a firm founder used an employment agency to source a developer. This proved to be a long, expensive process, the result of which did not fulfil the resource requirement.

The second resource required to develop and deliver software applications is access to hardware or infrastructure through which the software application is developed and delivered. All firms have adopted cloud computing to develop and deliver their software applications, with four exceptions. These firms are termed 'cloud natives', as they initiated development and delivery of software through the cloud. Firm founders appreciate the benefits of no initial capital investment, and the potential for scalability and 'instant' internationalisation through the cloud. Firms not delivering their applications through the cloud include two firms that have purchased servers, and are unwilling to abandon their investment. Another firm is resident in a university incubation unit, and does not pay for central processing unit (CPU) time on servers. The fourth firm founder has only one (large) customer, and is reluctant to continue paying the monthly cloud subscription until he gains further traction.

One of the most important resources for all firm founders in product development is information and feedback from customers. Software development is not a linear process, nor is it a process whereby a final product is developed 'at the first attempt'. Rather, it is an iterative process whereby the product is honed, altered and improved on the basis of feedback from trial by customers. In this stepwise process, the most important product development resource is customer feedback, recommendations and experience imparted. This information is essential for the development of software

applications for general deployment (as opposed to software developed to a definite specification). Interviewees do not pay directly for this information, and it is elicited through offering free trial periods and reduced fees to customers. The principal value of customers, therefore, is not generated from income but from recommendations on how to improve the software product. This strategy is central to the lean start-up methodology practiced by all firms, as they seek to develop a viable product and gain traction in the market. Through testing a minimum viable product (Ries 2011) in the marketplace early in the process, firm founders relate that they can progress development of the product quicker and more effectively than attempting to perfect the software without customer feedback. It is also important in building a reputation, which facilitates sourcing investment and attaining more customers. Additionally, it may aid scalability as additional customers may be acquired through vertical integration. Customer feedback is the most effective product development resource at the nascent stages, and is particularly important for founders seeking to design and develop new software applications without specification or perfect information about client needs.

Business development bootstrapping methods

All firm founders were unanimous on the strategic approach to expanding firm competencies and expertise, by managing the growth process in a measured, balanced manner. They view financing as important, although it is not the first order concern. Rather, astute management is of critical importance at this stage, as firm owners are wary of "…expanding too rapidly and being unable to offer support and adequate resourcing…". Similar to Freear, Sohl, and Wetzel (1995), the principal business bootstrap method used is foregoing income, and over 80% founders reported taking no or very low wages. Another strategy to reduce the wage bill was compensating developers with equity in lieu of cash, a tactic used by two founders.

All but two firm founders accessed grant funding[3], which was essential for the sustainability and survival of the firm in the first 12 months. The most commonly sourced grants provided by the government agency Enterprise Ireland consist of the Commercialisation of Research and Development (CORD) grant (maximum value of €30,000 over 12 months), a feasibility grant of €25,000, and innovation vouchers valued at €5,000 each. Firm owners stress the additional value of the latter in accessing academic researchers, with resultant knowledge transfer. Firm founders supplemented these relatively small amounts of grant funding with consultancy income, and cross-subsidise the new venture with income from other businesses. These sources are important for survival of the business, although pursuit of this income distracts from development of the product and delays time to market. All firm owners invested personal savings in their start-up ventures, ranging from €3,000 to €500,000. Five founders received substantial sums from friends and family. Other business bootstrapping techniques used by firm founders include early redemption of pension plans, cashing-in share options, and providing personal guarantees for business loans.

As firms progressed from the initial product development stages, they raised various amounts of external equity to finance growth. 50% of firm founders raised finance from angel investors, which they source from social networks. Firms that source private equity have prior experience in raising seed capital and/or negotiating with venture capitalists, business angels, and state agencies. This has both positive and negative effects. Firstly, those with prior experience know *how* to approach equity

[3] Harrison, Mason, and Girling (2004) list 'research grants', and Winborg and Landstrom (2001) list subsidies from "County Administrative Board, County Labour Board, Swedish National Board for Industrial and Technical Development, and foundation Innovationscentrum" as sources of bootstrap finance. Some may consider grant funding a formal source of finance, although given the irregular availability and uncertainty of success in obtaining grants, we follow the aforementioned authors and include it as a bootstrap technique.

providers, which is equally as important as knowing *who* to approach. These applications are usually made on acceptable terms and generally result in the firm owner obtaining the funding required. The major issue for interviewees arose when private equity funding was matched with finance from the state agency, Enterprise Ireland. This tended to elongate the funding cycle, and sometimes resulted in a decrease in the investment originally proposed by the business angel. Despite the prolonged financing cycle, all recipients were satisfied with the matched funding model. Three firm founders also bootstrapped bank loans by using personal assets and guarantees as collateral for bank loans. This constitutes considerable risk, including provision of the family home as security, although the majority of interviewees do not apply for bank loans as they find the administrative and collateral requirements onerous. Firm founders also practice cost reduction in bootstrapping office accommodation and workspace. Three quarters of firm founders rent office space at below market rates, typically in incubators located in universities. One firm founder works from home, whilst another two are paying commercial rates.

Financial bootstrapping as development strategy

Internal and external equity are the principal sources of funding used by firm founders in our sample. Only two interviewees had bank loans for small amounts, and thus the capital structures of our sample firms consists predominantly of equity funding, consistent with previous studies (Hogan and Hutson 2011, Revest and Sapiio 2012, Coleman and Robb 2012). The majority of our sample has an aversion to seeking bank debt as they view the process too protracted, involving a large amount of administration, and a lengthy approval process. A small number are discouraged by negative experiences in the past. Reluctance to use debt is for practical purposes, rather than a strategic control aversion issue. As seen from the future funding requirements in table 3,

firm founders' preference for external equity means they are willing to relinquish equity. Firm founders are seeking much larger amounts of finance than previously used, and are conscious of the increased requirements for the sales and marketing stage of development.

Bootstrapping is the central element of a business model used by firm founders at startup, as resources are committed to the iterative process of product development. Exempt from the demands of investors and banks, bootstrapping enables startups to progress to a stage of development where hope to attract significant amounts of investment. Firm founders stated that they used bootstrapping methods by choice rather than by necessity. Interviewees stress the importance of developing their business in a careful systematic manner. They emphasise that the capacity of each aspect of the business must be developed and funded incrementally, specifically that development, services, sales and marketing should be grown and expanded in tandem. Citing prominent firm failures, firm owners state that it is important not to expand the sales and marketing function too early, as the business may not have the capacity to meet demand. Similarly, interviewees state that it is important not to invest large amounts of equity in developing software products, and that it is necessary to roll-out the product before it is fully developed. It is important to trial the software, and to improve the offering before it is launched on the wider market. This process frequently results in a crucial 'pivot' of the software or the business, which may prove critical to the survival of the firm (Marmer, Herrmann, and Berman 2011). An early launch is important to gain a foothold in the market and establish traction, especially because it is difficult to secure Intellectual Property (IP) rights for these software products.

Although business models vary considerably, most interviewees have a strong desire to 'grow organically'. They emphasise a strategy for growth to be driven by

revenue, rather than 'cost led'. Firm owners are wary of incurring large up-front development costs, and they generally do not seek large amounts of funding in the nascent stages. This is primarily an issue of timing, as in most cases businesses are not sufficiently developed to receive equity finance. More importantly, firm owners recognise the need to acquire a number of customers before approaching prospective funders or government agencies for support. Thus, the strategic motive of the financing decision is not driven by a desire to retain control or maintain managerial independence. Rather, it is directed by a pragmatic business approach that is informed by past experience. Significantly, past experience with funders is a determining factor in the source of finance employed.

Comparison of bootstrapping methods in Irish software firms with those in Northern Ireland, South East England, and Massachusetts

As this study extends the bootstrapping literature in general, and that pertaining to software firms in particular, it is instructive to compare our findings with previous studies. We compare bootstrapping techniques used by firm founders in the software sector with those identified by Freear, Sohl, and Wetzel (1995) and Harrison, Mason, and Girling (2004), using the product/business bootstrapping categorisation proposed by the latter. This facilitates examination of how bootstrapping methods have changed over time, and the likely impact of technological innovation in this rapidly changing sector, as it is almost two decades and one decade since these studies respectively. A summary of the principal product and business bootstrapping techniques is provided in tables 4 and 5 respectively. The profile of our firms is similar to the small software firms in Northern Ireland and South East England in the Harrison, Mason, and Girling (2004) study, and the Massachusetts firms of the Freear, Sohl, and Wetzel (1995) study. Our sample size (18) is considerably smaller than that of the South East England (32),

Northern Ireland (40) and Massachussets (103) in these studies.

The most prominent change in product development bootstrapping techniques over time relates to acquisition of hardware. As cloud computing precludes purchasing equipment, firm owners do not require special deals for access to hardware that was of primary importance to the Massachusetts firms, and of lesser importance to the firms in Northern Ireland and South East England. Technological innovation has resulted in a lower initial capital requirement, although regular payments are required for access to cloud services. Customers are an important resource in the nascent stages in all three studies. A subtle difference lies in the bootstrapping of this resource. Whereas income from customer funded research and development is the primary resource for firms in South East England and of lesser importance for the Massachusetts firms, customer feedback and suggestions for product improvement is the principal value of customers in our study. This is an important distinction in the value emanating from this resource, and is reflective of the iterative nature of software development.

Realising a commercial product from a consulting project is important for firms in Northern Ireland and the South East of England, and to a lesser extent Massachusetts, although it does not figure as prominently in our study. This may reflect the changing nature of software provision and procurement, whereby entrepreneurs who perceive an opportunity are willing to develop a product in anticipation of a market need. Testing a 'minimum viable product' in the marketplace with a number of customers facilitates a test for validation and suggestions for improvement before general launch. The advantage of this strategy is that it facilitates agile iterative development of the product at minimal cost, although firms do not gain income as received by those with consulting projects in Northern Ireland and South East England. The latter have an income and

reputational advantage in this regard, although it is tempered by potential difficulty in adapting bespoke software for wider general use.

Table 4. Comparison of top ranked product development bootstrapping techniques in Ireland, Northern Ireland, South East England and Massachusetts software industries.

Irish software firms	**Massachusetts software firms**	**Northern Ireland Smaller software firms**	**South East England smaller software firms**
Adopt cloud computing for development and delivery of product	Special deals for access to hardware	Developing products at nights/weekends	Customer funded research and development
Customer feedback, requirements, suggestions (iterative)	Prepaid licenses, royalties, advances from customers	Turning consulting project into commercial product	Turning consulting project into commercial product
Employ developers on contract; Employ developers overseas.	Customer funded Research and development	Using public domain development tools	Free/subsidized access to hardware
Subsidised collaboration with university faculty	Free/subsidized access to hardware	Special deals for access to hardware	Special deals for access to hardware
Reduced fees from developers through work/social network	Turning consulting project into commercial product	Prepaid licenses, royalties, advances from customers	Developing products at nights/ weekends
Using specially licensed development products	Developing products at nights/weekends		

Source: Adapted from Harrison, Mason, and Girling (2004).

Comparison of business bootstrapping methods across the three studies reveals a number of similar techniques, although they rank differently in terms of importance. As noted in Harrison, Mason, and Girling (2004), taking reduced or no wages is the principal bootstrapping method use by entrepreneurs in the Massachusetts sample. We find the same result, although Harrison, Mason, and Girling (2004) note that this method is used by less than 8% in Northern Ireland firms.

Table 5. Comparison of top ranked business development bootstrapping techniques in Ireland, Northern Ireland, South East England and Massachusetts software industries.

Irish software firms	**Massachusetts software firms**	**Northern Ireland Smaller software firms**
Foregone, reduced and delayed compensation	Reduced compensation	Below market or very low rent space
Grants from the national development agency	Forgone or delayed Compensation	Working out of home
Personal savings	Personal savings	Personal savings
Matched funding from the national development agency	Personal credit cards and home equity/mortgage loans	Special terms with customers (discounted advances, pre-payments, larger deposits)
Consultancy income	Working from home	Personal credit cards and home equity/mortgage loans
Below market or very low rent space	Below market or very low rent space	
Personal guarantees for loans and warranties on equity	Deals with professional service providers at below competitive rates	

Source: Adapted from Harrison, Mason, and Girling (2004).

Other techniques used in both the Massachusetts and Northern Ireland firms are prominent in our study also, and are of similar rank in importance, including use of personal savings and securing office space at very low or below market rent. It is interesting to note that, although there is a significant change in bootstrapping methods used over time in relation to product development, firm founders use largely the same bootstrapping resources to acquire tangible assets as two decades ago. The most prominent difference between the three studies is the prevalence in acquisition of financial assistance from the Irish development agency, Enterprise Ireland. Grant funding, although it is not a large amount, is of critical importance for start-up firms in the application software sector. These small amounts of funding sustain firm founders

over the initial years of development, when entrepreneurial endeavour is concentrated on product development and income from products is minimal. The implication of this finding for policy makers eager to build capacity in the high technology sector is to ensure supply of small amounts of grant funding to encourage and sustain start-up activity and increase the number of new ventures.

Conclusion

Our study of resource acquisition by firm founders in computer software start-up ventures provides a number of interesting results. Firstly, we find that cloud computing greatly reduces the initial capital requirements of new firms, facilitating the development and launch of products without ownership of hardware resources. Secondly, the external environment has a significant direct and indirect impact on the need for, and use of bootstrapping techniques. Indirectly, high demand for particular skills in the workforce results in scarcity of potential employees, with consequent higher wage pressure. This increases the need for bootstrapping in new firms, particularly for those lacking the required product development skills, or access to networks to recruit these skills. Firm founders with access to skilled employees through social networks have a distinct advantage in being able to source critical skills for product development, a significant advantage in a tight employment market. This advantage is particularly important at the earliest stages of development in the firm, when the need for product development skills is greatest. The most important direct beneficial effect of the local environment is grant funding from the national development agency. This funding is of critical importance to sustain new ventures through the earliest period, and to investigate long term prospects through funded feasibility studies. Other funding schemes such as subsidised interaction with university faculty provides new ventures with access to skills, training and networks typically out of the reach of start-up

ventures. In the medium term, equity funding from the national development agency in the form of matched funding is vitally important as firms seek to launch their products and gain traction in the market.

Thirdly, innovation in the means by which products and services are developed result in changes in resource requirements and bootstrapping techniques. In the computer software sector, development of products through a process of iterative improvement has resulted in using early customers as an essential information element in the development stage. This contrasts with bootstrapping techniques in other sectors in which early customers are a source of income and reputation (e.g. Ebben and Johnson, 2006 Winborg and Landstrom 2001). This conception of value inherent in this resource is sector specific, and it reflects an essential need in the use of customer knowledge for development of the product. This technique may become more widely used over time with innovations in the methods of development and delivery of products and services, and it is particularly applicable to the services sector. Firm founders are adaptable in acquiring value from resources, which vary by sector according to inputs and outputs.

In summary, we find that the introduction of innovative technology, changes in product development processes, and the external environment have a significant impact on bootstrapping techniques, which change over time. Future studies should consider investigating bootstrapping activity through a life cycle perspective, as resource requirements vary considerably as the firm grows and develops. Similarly, access to resources changes with the stage of development of the firm, and scholars should take this into account when exploring heterogeneity in bootstrapping behaviour. Thus, similar to the ‘funding escalator’ proposed by Gregson, Mann, and Harrison (2013), there is also a ‘bootstrapping escalator’. Future studies should also take greater account

of the external environment. Bootstrapping studies to date have concentrated largely on techniques applied by the firm owner, with scant heed given to the challenges and opportunities posed by the external environment (although Harrison, Mason, and Girling (2004, 328) refer to the '…munificence of the local environment…'). The essence of bootstrapping is not in the techniques used, but in how firm owners respond to a resource need. Further international comparisons are required, including countries with less well developed finance systems, social networks and less generous public support programmes. Greater resource requirements in more challenging environments are likely to result in more inventive and novel bootstrapping activities, which may have wider international applicability. Additionally, comparison of public policy across countries may result in more effective support systems worldwide.

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Appendix one: Commonly used bootstrapping techniques

Bootstrapping techniques for product development
Special deals for access to hardware
Pre-paid licences, royalties or advances from customers
Development of products at nights and weekends
Research grants
Customer funded R&D
Commercializing university-based research
Commercializing public domain software
Porting fees to transfer software from one platform to another
Free or subsidized access to hardware
Commercializing an existing shareware product
Turning a consulting project into a commercial product
Using public domain development tools

Bootstrapping techniques for business development
Seek out best conditions possible with supplier/s
Practice barter instead of buying/selling goods
Personal credit cards and home equity/mortgage loans
Use interest on overdue payment from customers
Co-ordinate purchases with other businesses
Obtain capital via manager's assignments in other businesses
Below market or very low rent space
Run the business completely in the home
Share premises with others
Deals with professional service providers at below competitive rates
Lease equipment instead of buying
Buy used equipment instead of new
Share equipment with other businesses
Gifts or interest-free loans from relatives
Unpaid family member working as an assistant
Severance and parachute payments
Personal savings
Reduced, forgone or delayed compensation to owner
Deliberately delay payment of value-added tax
Withhold manager's salary for shorter/longer periods
Hire personnel instead of employing permanently
Use routines in order to minimize capital invested in stock
Special terms with customers, including discounted advances, prepayments and larger than normal deposits
Outsource key parts of the business
Obtain subsidy from County Administrative Board
Share employees with other businesses
Obtain subsidy from County Labour Board
Obtain subsidy from National Board for Industrial & Technical Development
Obtain subsidy from the foundation Innovationscentrum
Raise capital from a factoring company

Source: Adapted from Harrison, Mason, and Girling (2004) and Winborg and Landström (2001).