The Graduation Performance of Technology Business Incubators in China's Three Tier Cities: The Role of Incubator Funding, Technical Support, and Entrepreneurial Mentoring

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Abstract

This study examines the effects of technology business incubator (TBI)'s funding, technical support and entrepreneurial mentoring on the graduation performance of new technology-based firms in China's three tier cities. Using new dataset on all TBIs and incubated new technology-based firms from government surveys conducted over five consecutive years from 2009 to 2013 combined with archival and hand-collected data, we find the effects of incubator services on the early growth of new technology-based firms vary according to the local context. Technical support facilities and entrepreneurial mentoring from TBIs are found to have significantly and positively influenced the early development of the firms in the four most affluent tier 1 cities, whilst these effects become less pronounced for the tier 2 and tier 3 cities. These two services are also found to influence graduation performance in the government and university types of TBI respectively. Results support the notion that the effectiveness of an incubators services is shaped by the level of a city's socio-economic development and that the city location of a TBI does impact the graduation performance of its incubatees.

Key words: Graduation performance; TBIs; new technology-based firms; incubator research facilities, funding and mentoring; China

1. Introduction

The principal drivers for establishing technology business incubators (TBIs) are to facilitate the formation and growth of early stage technology-based firms and to promote regional economic development by providing much needed support services (Phan et al., 2005; Ratinbo and Henriques, 2010; Markman et al., 2005; McAdam and McAdam, 2008; Siegel et al., 2007; Siegel et al., 2003). State authorities in a diverse range of both developed and developing economies have invested public resources and encouraged private investment in establishing TBIs to address the market failures associated with the early stages of firm development (OECD 1997; Phan et al, 2005) and/or to accelerate the entrepreneurial process through institutionalising the support for ventures with high growth potential (Hansen et al, 2000). The main focus of TBIs is on helping to raise early stage technology-based ventures up to a level where they can seize business opportunities and compete in the market without further support (Rothaermal and Thursby, 2005a; Bollingtoft and Ulhoi, 2005; Schwartz, 2012). As such, the effectiveness of a TBI is often gauged by the graduation performance of the incubated ventures, as measured by the number of viable early stage firms that leave an incubator over a specified period of time (Phan et al, 2005: Aernoudt, 2004).

One of the central features of TBIs is the provision of various resources that are essential to new technology-based ventures, but not available internally and/or externally (Aerts et al., 2007; Bruneel et al., 2012). They are usually allocated to individual resident firms to compensate for limited access to key resources from the local economy or to facilitate access to a shared research and technical infrastructure for lowering the research/operation costs of firms (Storey and Tether, 1998; Aerts et al, 2007; Bruneel et al., 2012), thereby reducing the 'liability of newness' (Ferguson and Olofsson, 2004). Increasingly in western countries, TBIs are acting as mediators between entrepreneurs and providers of key resources (e.g. business angels, venture capitalists, academic scientists, experienced entrepreneurs). Although scholars agree on the critical role that incubators in the USA, UK, and other European countries play in building networks that can be transformative to the development of their incubatees (Mian, 1996; Hansen et al 2000, Colombo and Delmastro, 2002; Bollingtoft and Ulhoi, 2005; Sa and Lee, 2012), it is not evident that these factors have been so important in Asian countries (Chan and Lau, 2005). Literature on incubators in these countries indicates that support associated with cost reductions (e.g. free or subsidised rental and testing facilities) is far more important than the provision of network opportunities to early stage technology-based ventures since technological entrepreneurs are likely to rely on their own networks with scientists (Chan and Lau, 2005; Zhang and Sonobe, 2011). There is therefore a need, particularly in Asian countries, for further investigation on which specific support services provided by TBIs accelerate the early growth of new technology-based ventures and contribute to their graduation (Phan et al., 2005). Moreover, it has been noted that the influence of different geographic contexts on TBIs has been an under-explored research area, requiring survey data covering multiple regions (McAdam et al., 2016).

This paper examines whether the three most established support services provided by TBIs in China influence the graduation performance of their resident firms over a five year period as well as addressing the relatively neglected aspect of comparing TBIs within different geographical contexts. TBIs in China help technological entrepreneurs create, scale up, and grow new technology-based ventures by offering a wide range of support services. The support infrastructure evolves over time and includes low cost office space, business registration and patenting services, networking with other government services, facilities for R&D and innovation and financial capital. The quality and scale of each type of support are associated with a TBI's ownership, operational model, objectives, and geographic contextas well as beiing driven by public resource allocation at different government levels. Given the rapid growth of TBIs in China over the last decade, it presents a fascinating context in which to study the influences of both TBI services and other external factors on the early development of new technology-based enterprises.

The effects of TBIs on the graduation performance of incubatees may also vary according to the economic and social development of a city where a TBI is located (Folta et al., 2006; Fritsch and Slavtchev, 2011). TBIs located in those cities with a more entrepreneurial culture and support infrastructure are likely to have an advantage over those cities lacking in these respects. The 90 Chinese cities covered by our research are characterised by large disparities in terms of socio-economic development. Moreover, the inequalities between them have widened as the Chinese economy has grown. Our study combines unique TBI survey datasets with archival data relating to the socio-economic development of cities to compare the graduation performance of TBIs in three tiers of Chinese cities.

The rest of the paper is organised as follows. The next section explores the theoretical background and empirical evidence relating to the influence of TBIs' support services and venture capital on the performance of new technology-based firms, leading to hypotheses relating to their likely effects on the graduation of incubated firms. The datasets used for the empirical study are then introduced together with a description of our methodology. The modelling results are then presented and discussed before considering their implications for the future development of TBIs in China.

2. Influence of TBIs' support services and venture capital on graduation performance

Studies that examine the effects of an incubator on the successful development and growth performance of new technology-based firms have emphasised the importance of the incubator's support services (Mian, 1996; Phan et al., 2005; Ratinho and Henriques, 2010; Lundqvist, 2014). Some studies reveal that the links between the support services and new firm formation depend upon the local context in which an incubator is located (Cruz and Teixeira, 2010; Zhang and Sonobe, 2011; Hendry et al., 2000). The business incubator concept has had to adapt in order to fit varying local needs and conditions (Kuratko and LaFollette, 1987) such that the degree of fit between the facilities and services offered by a TBI and the needs of the local economy is likely to be an important determinant of incubator success (Autio and Kloftsen, 1998; Hackett and Dilts, 2004).

There are a number of observations that can be made about existing research on TBIs which have influenced the direction of our study. First, Mian et al. (2016) carried out a survey of the existing literature and found that the most researched theme is incubator value added, covering tenant support, economic and regional development impact, and university-industry technology transfer. Second, previous studies tend to focus on one or more TBI case studies and are therefore unable to consider the effect of different contextual factors on the impact of TBIs. In other words, they do not provide comparative findings which take account of geographical variations that may contribute to the innovation activities and early growth performance of technology-based start-ups (Phan et al., 2005; Cruz and Teixeira, 2010). Third, the measure of performance used varies according the purpose of the research but may include the creation of incubatees, the extent of innovation activity, the graduation performance, and the subsequent survival and growth of incubated firms. For example, Rothaermel and Thursby (2005a) regard successful and timely graduation as an important milestone in an incubatees development but also warn that this is not a guarantee of subsequent success. Fourth, given that existing research is heavily focused on the western context, relatively little is known about whether the effects of TBI support services on the performance of the resident firms in Asian countries is the same as that in more developed countries. Finally, research has shown that the type of support services has evolved from offering a shared generic infrastructure for early stage firms operating in a variety of industrial sectors to shared tailored facilities for those operating in one/two specific industrial sectors (Allen and Rehman, 1985; Hisrich and Smilor, 1988; McAdam and McAdam, 2008; Rothaermel and Thursby, 2005b; Salvador, 2011). Given the focus of much of the existing literature, it is now recognised that there is a need for research on the role that TBIs are playing in emerging and transition economies (Smith and Zhang, 2012). This includes the need for investigation of the effects of TBI support services on the performance of incubated firms in different geographical contexts within China.

Whilst the allocation of resources to the specific support services that an incubator offers can be expected to be shaped by the rationale and objectives of each incubator, a key measure of success is likely to be the numbers of incubated firms that are considered to be sufficiently viable financially and commercially to be able to graduate from the incubator (Koh et al., 2005). Hackett and Dilts (2004) have developed and validated five incubator outcomes indicating the performance of incubated firms at the completion of incubation process, based on data collected from 53 incubators operating in the US. They concluded in their study that the performance of firms and incubators can be reasonably measured by failure with small losses, failure with large losses, survival with no growth, survival with growth, and survival with growth and profitability. However, whilst they regard the latter three outcomes as indicative of incubation success, they acknowledge that they are no guarantee of future success or failure. A study focusing on the relationship between firm performance and university linkage by Rothaermel and Thursby (2005b) measured the performance of incubated firms, indicated by failure, graduation, or continued incubation within three years or less of entering the TBI. Our present study therefore focuses specifically on the graduation performance of TBIs, as measured by the number of incubated firms qualifying for graduation by reaching a level of sales turnover and profitability set by TBI senior managers.

TBI support services aim to improve the ability of resident firms to gain access to key resources and advice that they are not able to provide directly for themselves. Here, we are interested in those types of support service that are most likely to positively influence the number of firms that graduate from an incubator. There are three specific services relating to laboratory/research facilities, entrepreneurial mentoring, and financial support that are most likely to be associated with the early growth of new technology-based firms (Wright et al., 2008, Shrader and Siegel, 2007) and which we focus upon:

Incubator technical service support. An extensive literature focusing on TBIs associated with universities highlights the importance of resident technology-based start-ups being able to access a university's knowledge-based assets (Acs and Storey, 2004; Audretsch and Stephan, 1996; Rothaermel and Thursby, 2005b; Markman et al., 2005; Lundqvist, 2014). TBIs associated with universities typically offer access to knowledge resources that are the product of research undertaken by academic staff and therefore owned by the universities (Mian 1996; Lofsten and Lindelof, 2002; Phillips, 2002; Siegel et al., 2003; Rothaermal and Thursby, 2005b; Ratinho and Henriques, 2010). Recent studies also reveal that TBIs help their resident firms to build networks with academic scientists in order to increase the ability of the firms to access scientific knowledge resources (Bergek and Norman 2008; Jauhiainen, 2008; Salvador, 2011). Rothaermal and Thursby (2005b) studied 79 firms incubated in the Advanced Technology Development Centre at the Georgia Institute of Technology over a six year period from 1998 to 2003 and examined the role university linkages played in influencing failure or graduation of firms located in the incubator. Their results suggested that strong ties to the sponsoring university, indicated by licensed technology or university staff managing the business themselves, reduced the likelihood of failure but also retarded graduation from the incubator, whereas weak ties to the sponsoring university (e.g. information interaction with academic researchers) seemed not to influence outright firm failure or timely graduation.

Interestingly, research focusing on the Chinese context indicates no evidence that TBIs associated with a university lead to a better graduation performance than those not associated with a university (Zhang and Sonobe, 2011). A study looking at incubators in Hong Kong reveals that resident firms do not benefit from the provision of network opportunities with scientists since most firms regard such links as of little relevance to their business development (Chan and Lau, 2005). Those incubators that work closely with their resident firms are more likely to discover the laboratory, technical and research facilities that are most needed and can be shared with other firms in the incubator (Aerts et al., 2007). An incubator's financial resources may therefore be used to establish such facilities which compensate for limited access to technical resources and testing facilities from the local economy. A shared research infrastructure is likely to include industrial and production testing services, expensive equipment for scientific data sharing and professional technical services. The established research infrastructure enables young technology-based firms to gain access to the facilities and equipment which otherwise would be unaffordable and thus reduce the incubation time and their R&D/operation costs. A good indication of the scale of the technical service support offered by an incubator is the amount of financial resources invested in these facilities.

The better the technical infrastructure, the more conducive an incubator environment is likely to be for the establishment of technology-based firms, their early growth and innovativeness and readiness to graduate from the incubator. We therefore propose:

H1*: The graduation performance of TBIs is positively associated with the total amount invested in the technical services support.*

Incubator entrepreneurial service support. The literature on the support services offered by incubators has recently paid more attention to entrepreneurial competencies (Hjelm and Borgman, 2004; Rasmussen et al., 2011). Lundqvist (2014) studied 170 incubated firms in 16 Swedish university incubators over an 11 year period from 1995 to 2005 and examined the role of surrogate entrepreneurship i.e. the contribution that experienced entrepreneurs from outside the incubator played in influencing the performance of resident firms. The results suggested that new technology-based firms that recruited a surrogate entrepreneur enjoyed a better performance indicated by employment and revenue growth compared to non-surrogate firms (Brettel et al., 2012). This is consistent with the view that many SMEs in general and technology-based SMEs in particular suffer from a lack of the business and management skills required to operate a business successfully and to access the resources needed to grow the business (Lyon et al., 2000; Hjelm and Borgman, 2004). McAdam and Marlow (2011) found that experienced entrepreneurs help early stage technology-based ventures improve their ability to obtain venture capital by making sense of the funding application and presenting it convincingly to investors. Incubators therefore provide entrepreneurial assistance to early-stage technology-based firms through bringing in experienced entrepreneurs to work with incubated firms (Bollingtoft and Ulhoi, 2005). For their part, experienced entrepreneurs who are looking for business investment opportunities could also benefit from working closely with early-stage technology-based firms. The number of experienced entrepreneurs who play a mentoring role may provide a useful indicator of the level of practical business skills that an incubator offers to early-stage technology-based firms. Therefore, we expect that:

H2*: The graduation performance of TBIs is positively associated with the number of mentors that provide entrepreneurial service to incubators firms.*

Incubator financial support. One of the biggest challenges confronting new technology-based firms is being able to access various sources of finance in order to facilitate the early growth of the business (Carpenter and Peterson, 2002;Oakey 2003; North et al., 2013; Xiao and North, 2012). The literature suggests that a key factor accelerating the development of technology-based firms is the attraction of sufficient amounts of investment to those projects helping to commercialise technological achievements (Acs and Audretsch, 1988, Colombo et al., 2010, Perez-luno et al., 2011). TBI managers may choose to do this by providing direct financial support to technology-based start-up firms themselves (Aerts et al., 2007; Bruneel et al., 2012). In addition, they may help resident firms build up networks with suppliers of finance (e.g. business angels and venture capitalists), thus improving their ability to gain access to external finance (Salvador, 2011).

Direct financial support from a TBI to technology-based firms has been shown to be particularly important in shortening the time needed to fully develop, test, commercialise and launch innovative products on to the market and thereby have a positive effect on the number of firms graduating from a TBI (Branscomb and Auerswald, 2002). This can be essential in contexts where there is a dearth of other external sources of funding (Markman et al., 2005; Xiao and North, 2012). Incubator finance could be the only external finance source available to young technology-based firms, which are likely to be seen as very high risk investments, particularly at the start-up stage of business development. In addition, receipt of finance from an incubator could provide a positive signal to other potential suppliers of finance, reducing the risk associated with investing in new ventures and therefore putting the firm in a better position to attract external funding.

Direct financial support from an incubator to resident firms can help to accelerate the early growth of technology-based firms. Hence the amount of funding that is available to technology-based start-ups within an incubator is likely to be an important determinant of the TBI's graduation performance. We would expect that:

H3*: The graduation performance of TBIs to be positively associated with the amount of financial support available to new technology-based firms within an incubator.*

Venture capital

Venture capital is generally considered to be more appropriate than loan finance in funding new technology-based firms because of problems of information asymmetry associated with assets being intangible and knowledge based (Bertoni et al., 2010; North et al. 2013). In western countries, incubators that aim at improving the ability of early-stage technology-based firms to gain access to venture capital have been placing emphasis on building networks with both business angels and venture capitalists (Aerts et al., 2007; Bruneel et al., 2012). Moreover, young technology-based firms that have a close relation with business angels and/or venture capitalists may be in a better position to source other finance and gain entrepreneurial expertise (Wright et al., 2004). Ahlstrom and Bruton (2010) report that in transition economies informal investors usually employ a network-based approach to assess an investment opportunity. Evidence suggests that equity finance from informal investors tends to be highly 'local' in origin in both more advanced and emerging economies (Colombo et al., 2010; Xiao and Ritchie, 2011). For these reasons, the availability of venture capital to technology-based start-up firms is likely to depend on the geographical context (Colombo and Delmastro, 2002).

Research focusing on financing technology-based firms in the USA found that the attraction of venture capital enabled early-stage technology-based firms to speed up R&D and the product innovation process, meet the financing demands imposed by growth, and improved their chances of survival and growth (Copper et al., 1994). A study looking into technology-based start-ups located in American university incubators found that obtaining venture capital was the key to accelerating their early-stage growth (McAdam and McAdam, 2008). Colombo and Grilli (2010) found that venture investors providing finance to young technology-based firms in Italy also generally played a 'coaching' role in offering additional resources and capabilities that drove the growth of their portfolio firms. In the Chinese context, it remains unclear whether informal investors who play an increasingly important role in providing equity finance to young technology-based firms contribute positively in other ways as well (Xiao and North, 2012). Nevertheless, it has been generally agreed that the availability of venture capital has been a necessary although not sufficient requirement for the growth of new technology-based firms (Colombo and Grilli, 2010). We therefore propose:

H4*: The graduation performance of TBIs is positively associated with the amount of venture capital received by new technology-based firms within an incubator.*

3. Methodology

The three tier Chinese Cities

Four decades of implementing policies under the initiative'the reform and opening' designed to open up the Chinese economy to world trade and competition has led to marked disparities in the levels of economic and social development between cities (Dollar, 2007). It has been argued that these disparities have been exacerbated by the decentralisation of control of universities to local government as this has favoured knowledge transfer in those cities with leading universities and research institutes and marginalised those cities in less favoured regions previously relying on central government for knowledge support (Hong, 2008). These geographical disparities suggest that those TBIs and incubated firms located in the more advanced and wealthy cities benefit from the greater abundance of those resources required for creating and supporting technology-based business including sources of finance, an educated workforce, and a supportive business climate compared to those located in the less prosperous and lagging cities. Our study addresses this issue through a comparison of the various influences on the graduation performance of TBIs across 90 Chinese cities.

The first TBI, Wuhan Donghu Pioneers Centre was formally established in 1987 and was located close to Wuhan University, one of the leading universities situated in the Central region of China. Since its establishment the Centre has been a model for other major Chinese cities mainly in the Eastern region. Approximately 30 TBIs were created over a period of two years between 1989 and 1990. By 1997, 80 TBIs had been established and were disproportionately centred on five Eastern provinces (Beijing, Suzhou, Shanghai, and Tianjin), one Central province (Wuhan), and three Western provinces (Xi'an, Chengdu, and Chongqing), supporting 2,670 tenant firms with 45,600 employees (China Torch Statistical Yearbook, 2000). Recently, more TBIs have been established in a wide range of Chinese cities, taking advantage of a business environment more conducive to technology-based start-ups. Both the more and less wealthy cities have encouraged private investors to establish TBIs by making use of abandoned state-owned plants that may not be near to leading universities. The geographic distribution pattern of TBIs remains focused on the more advanced cities and this also applies to the establishment of the latest generation of specialised business incubators (i.e. industry-specific, university-related, and international incubators).

Table 1 about here

In order for us to examine the graduation performance of TBIs at the city scale, we draw upon China's latest city tier system which captures each city's economic development level, economic position relative to the country and region, and its historic and cultural significance. It has been widely used in the media and is now generally accepted by business people and citizens. By combining the commonly accepted tier city system with our TBI distribution, we group the 90 Chinese cities hosting a total of 215 TBIs in our study into the three tiers of cities. Tier 1 cities include the four most affluent cities namely: Beijing, Shanghai, Guangdong, and Shenzhen. Tier 2 comprises 15 cities in the more advanced provinces namely: Chengdu, Chongqing; Dalian, Hangzhou, Ningbo, Kunming, Nanjing, Suzhou, Wuxi, Qingdao, Tianjin, Zhuhai, Wuhan, Xiamen, Xi'an. The remaining 71 cities comprise Tier 3. As Table 1 shows, we found considerable differences in GDP per capita between the three tier cities.

Data and variables

This study makes use of 1) survey data on all TBIs and new technology-based firms within each of the TBIs in China, 2) official data sources and 3) hand-collected data from TBIs' websites. The survey data was collected by the Ministry of Science and Technology (MOST) for China in five consecutive annual surveys undertaken from 2009 until 2013. We have restricted our subsequent analysis to the 215 TBIs that existed in 2009 and participated in all five successive surveys. The secondary data (e.g. the number of universities with the host city of each TBI and GDP per capita at a city level) was collected from Statistical Yearbooks produced by various levels of government. We also collected data relating to each TBI (e.g. the ownership and age of TBIs) from their websites. Table 2 shows the incubator and firm distribution by city tier. It reveals that the four tier 1 cities host 24% of the total TBIs, which are older and smaller (measured by the number of resident firms) than those in the tier 2 and tier 3 cities. It also shows that there are 150 government TBIs, 46 private TBIs, and 19 university TBIs in our sample. The larger size of TBIs in the tier 2 and tier 3 cities may reflect the fact that some of them still operate like the first generation state owned and managed TBIs with new ventures operating in various industrial sectors and a strong focus on new business formation rather than on supporting innovative ventures with high growth potential. The dataset that we use to the analysis includes observations that are a combination of an incubator and year. In other words, each incubator was observed for 5 years, the total observations thus are 215*5. We dropped observations with missing values, so our regression models use 310 cases. The survey data set covers a five year period thereby enabling us to capture both marked and subtle changes in the scale of various specific support services and the availability of venture capital offered to TBI resident firms in the three city tiers. Moreover, it enables this work to examine the relations between the three incubator factors and the graduation performance of the incubated firms.

Table 2 about here

Table 3 provides a summary of the definitions and descriptive statistics for the variables used in this study. These comprise:

Dependent variable. As discussed earlier, an important function of incubators is to improve the early growth of technology-based start-up firms and ensure that these firms become established in the market without further support from the incubator. Our work uses the number of firms that met the graduation requirements and left the incubator as an indication of success. TBIs generally follow the guidelines set by the MOST in judging whether an incubatee is ready to graduate, taking account of sales turnover, profit, asset size, and giving particular recognition to high-tech firms. The application of these criteria is made by each TBI's managers and will vary depending upon industrial sector and each incubatee's circumstances. For firms that decide that they want to go it alone, this would count as a graduation only in a situation where they have reached the required threshold levels. New technology-based firms that meet the graduation criteria are considered to reach a certain level of competitiveness 'vis-a-vis' their counterparts in the market without further support being required from the incubator.

Table 3 about here

Independent variables. These include the three incubator-specific support services and venture capital. The direct financial support (InFund) provided by an incubator is measured by the total amount of incubator funding available to all the resident firms. The scale of technical support (Techinvestment) is indicated by the amount of investment in laboratories, technical and research facilities to be used by incubated firms. The level of entrepreneurial mentoring (ENTR) is measured by the total number of experienced entrepreneurs who work with the resident firms. The availability of venture capital (VC) is measured by the total amount of venture capital received by all the resident firms within an incubator.

Control variables. We control for incubator size (Size), incubator age (Age) and scale of city-level scientific knowledge resources (No.Uni) since these three variables are likely to influence the graduation performance as measured by the number of firms that met the criteria and left the incubator. The number of incubated technology-based firms resident within an incubator is used to indicate size. Age is measured from the year an incubator started incubating firms. The scale of scientific knowledge resources (No.Uni) is indicated by the number of universities and colleges located in the host city of each TBI. We use this number to indicate the local availability of technology resources, which may influence relations between support services and the early stage of new ventures.

***Types of TBI*:** Literature on incubators maintains that the TBI ownership influences the overall objectives, resources available internally and externally, management team composition, and the allocation of resources to specific support services to facilitate the early growth of new technology-based ventures (Pauwels et al., 2016). We therefore distinguish between three types of TBI in our regression modelling to examine if there are any differences between them in the effects of the three support services on the early growth of new technology-based ventures. The three types of TBI ownership are government TBIs, university TBIs, and private TBIs. Government TBIs refer to those funded by government, and operated by a government agency whereas university TBIs refer to those funded by government but operated by a management team from a university.

Data analysis

Observations that are used to conduct regression tests are a combination of an incubator and year as discussed. This method enables this work to be more general and better handle the data set in which the value of a particular variable for some observations stay pretty much the same and missing values for a particular variable exist over a period of five successive years. The hypotheses proposed earlier are estimated by the Maximise Likewise Estimation (MIE) and tested with negative regression models for each set of independent variables. As the dependent data is count data rather than continuous variable, negative binomial regression model is the most appropriate model to use. We first conduct regression tests for the entire sample and then repeat the models for the tier 1, tier 2, and tier 3 cities in order to investigate whether there are any differences in the effects of incubator factors and venture capital between the three tier cities. The same test is also conducted for the three ownership types of TBIs.

4. Empirical Results

Entire sample

In Table 4, we report the results of negative binomial regression analysis to examine the effects of incubator funding, technical support facilities and entrepreneurial mentoring as well as venture capital on the number of incubated firms that graduated over the 2009-2013 period. Model 1 applies to the entire national sample of TBIs and resident firms and covers the three incubator specific factors i.e. the magnitude of incubator funds (InFund); the amount invested in the shared laboratory and technology platform (Techinvestment); the number of mentors providing entrepreneurial expertise to the resident firms (ENTR); venture capital (VC); and three control variables including incubator size and age as well as number of universities located in the host city of each TBI (Size, Age, and No.Uni).

Table 4 about here

Interestingly, as model 1 shows, we find that the amount of incubator funding that is available to new technology-based firms located in each incubator has no statistically significant effect on the number of graduated firms, controlling for incubator size and age as well as the number of universities in the host city. The amount of investment in the shared laboratory and technical service platform for the use of resident firms at no or low cost does have a statistically significant ($p<0.01$) and positive effect on the number of firms that met the graduation criteria and left the incubator. This could be because spending on the technical support services brings forward the time that it takes to produce marketable products or services. The number of mentors helping the firms also has a statistically significant and positive effect on the number of firms graduating ($p<0.05$). This indicates that the entrepreneurial expertise provided by incubators to advise the owner-managers of incubatees does play an essential role in helping the early development of new technology-based firms. Table 4 also shows that the amount of venture capital received by incubatees does have a significant ($p<0.01$) and positive effect on the early growth of new technology-based firms as indicated by the number of firms that graduate. This finding suggests that those investors that provide equity finance seek out those resident firms with growth potential and may also offer hands-on assistance to speed up their growth. Model 1 also confirms that the number of graduated firms is positively influenced by incubator size and age ($p<0.01$ and $p<0.01$), but not affected by the size of the local scientific knowledge base as measured by the number of universities in the host city.

Differences between three tier cities

We now repeat the above regression models to see if there are any differences in the effects of incubator factors and venture capital between the three tiers of cities. As discussed earlier, we have used this threefold classification for the 90 cities hosting the 215 TBIs included in this study: models 2, 3 and 4 relate to the TBIs located in the tier 1, tier 2 and tier 3 cities respectively.

As shown in Table 4, we find some differences in the results for the cities in the three tiers. We first look into the incubator funding available to resident firms. As models 2, 3, and 4 show, we find that this has no significant influence on the number of graduating firms across all three tiers, being consistent with the regression results for the entire sample. Thus direct financial support from an incubator appears not to result in more firms meeting the graduation criteria and leaving an incubator. This could be because incubator funding (e.g. in the form of a grant related to the amount of VC received or payment towards a patent application) is carefully directed towards either a few fast growing firms that have proved their competitive advantages and/or a few advanced R&D projects that promise to result in highly innovative ventures (Xiao and North, 2013).

We now turn to consider investment in the shared laboratory and technical facilities and control for size, age, and the number of universities in the host city. Interestingly, models 2 and 4 reveal that the effect of investment in the technical service platform on the number of firms that met graduation criteria and left the incubator is statistically significant and positive in both the tier 1 cities ($p<0.01$) and tier 3 cities ($p<0.05$), whilst model 3 shows no significant effect in the tier 2 cities. As far as the most developed cities are concerned, this is possibly an indication that a significant proportion of TBIs have focused on a specific industry, building upon local economic strengths, thereby increasing the effectiveness of investment in the technical service platform as reflected in the number of incubatees graduating.

In terms of the number of entrepreneurial mentors, models 2 and 3 for the tier 1 and tier 2 cities show that the graduation of new technology-based firms is positively and significantly ($p<0.05$ and $p<0.10$) influenced by the scale of entrepreneurial support. However, as model 4 shows, this appears not to apply to the TBIs in the tier 3 cities. This would seem to indicate that entrepreneurial support increases the number of resident firms that are ready to graduate in the tier 1 and tier 2 cities by better strengthening business capabilities and market readiness compared to the experience of TBIs in the tier 3 cities.

We now repeat the above regression models to see if the effects of incubator services and venture capital differ between government, university, and private TBIs. As shown in Table 4, models 5, 6 and 6 refer to the government TBIs, university TBIs, and private TBIs respectively. We find some interesting differences in the results for the three types of TBI.

As all three models show, the amount of incubator funding has no significant influence on the number of graduating firms across all three types of TBIs, this being consistent with the regression results for the entire sample and the three tiers of cities. With respect to technical service support, the effect of investment in the technical service platform on the number of firms that met graduation criteria and left the incubator is statistically significant and positive in both government TBIs ($p<0.05$) and university TBIs ($p<0.1$), whilst there is no significant effect in private TBIs. This confirms that both government and university TBIs received funding from public sources much of which they invested in shared laboratory, research and technical facilities to help the early development of new ventures. With much less public funding, it is possible that the private TBIs prioritised (i) rent-seeking to cover their operation expenses, even if it meant holding onto tenants rather than helping them to graduate; or (ii) the selection of entrepreneurs who are likely to be more self-sufficient in terms of resourcing and accessing expertise. With regards to entrepreneurial mentoring, model 6 for the university TBIs shows that the graduation of new technology-based firms is positively and significantly ($p<0.01$) influenced by the scale of entrepreneurial support. However, as models 5 and 7 show, this appears not to apply to the other types of TBI. This could indicate that the founding entrepreneurs of resident firms located in university TBIs are more likely to possess scientific or technological expertise but lack entrepreneurial experience and business acumen compared to their counterparts in government or private TBIs.

Concerning venture capital, we find that it has a significant influence on the numbers of firms graduating from the government TBIs, as shown in Table 4. One possible explanation could be that the financial incentives provided by government TBIs are quite often linked to obtaining VC externally, thereby encouraging resident firms to actively seek out sources of VC. It is perhaps surprising that VC does not emerge as a significant influence upon graduation in the private TBIs as we might have expected one of the advantages of locating in this type of TBI to be the private owners ability to be able to network with potential investors.

Turning to the number of universities located in a host city, we find no significant effect in the tier 1 and tier 2 cities on the number of firms graduating, but a negative and significant effect in the tier 3 cities. Interestingly, model 6 shows a significant positive influence for university TBIs. It is perhaps unsurprising that incubated firms' linkages with universities are stronger within university TBIs compared to those firms within government and private TBIs. Although it is interesting to note here that Rothaermel and Thursby (2005b) found in their US research that strong ties to the sponsoring university in the form of licensed technology, intellectual property rights, and academic staff managing the businesses tended to retard graduation from the incubator.

Taken together, these findings suggest that TBIs in the tier 1 cities are more capable of helping the early development of new ventures by spending on technical support services including shared laboratory and research facilities compared to their counterparts in the tier 2 and tier 3 cities, as indicated by the number of firms graduating. Entrepreneurial mentoring is also a key influence on the number of firms graduating in the tier 1 and tier 2 cities. So the level of economic development reached by a city that hosts TBIs would seem to matter to the graduation of new technology-based firms. Models 5, 6, and 7 also suggest that the effects of incubator factors on the early development and graduation of incubated firms are associated with the ownership type of the TBI.

5. Conclusions and policy implications

This paper empirically compares the influence of three incubator support services on the graduation performance of incubated firms by use of a dataset comprising 215 TBIs operating over five successive years from 2009 and distributed across 90 Chinese cities grouped into three tiers according to their level of development. As such, it makes three contributions to the literature. First it addresses the plea (e.g. Phan et al., 2005; Mian et al., 2016) for more international research on TBIs by being one of the few studies to date to focus on their role within China, a fast growing Asian transition economy. Second, much of the existing research on TBIs focuses on detailed evidence from single or multiple case studies, limiting the possibility of generalising results beyond a specific context (McAdam et al., 2016). Using government survey data covering TBIs throughout China, our research has been able to examine TBIs in different geographical contexts reflecting the marked regional disparities that exist within the country. And third, whilst previous studies have drawn attention to the wide range of mechanisms and operational practices found amongst TBIs, our research advances our understanding of the role played by TBIs in supporting the early development of new technology-based firms by examining three incubator services that have been shown to be the most needed by new technology-based firms in Asian countries (Chan and Lau, 2005; Zhang and Sonobe, 2011).

Of the three incubator specific services, we have found that the most influential one in speeding up the early development of resident firms is investment in the technical support platform, including the provision of shared laboratory, research and technical facilities, followed by entrepreneurial mentoring. In other words, it is the technical and entrepreneurial assistance provided by TBIs that plays a particularly important role in speeding up the early development of new technology-based firms to a point where they are able to graduate from the incubator. Incubated firms benefit from the shared facilities and entrepreneurial mentoring in order to reach a level where they can survive and grow without any further assistance from a TBI (Lundqvist, 2014; Rothaermel and Thursby, 2005a). In contrast, any direct financial support that TBI managers are able to give resident firms appears not to have improved graduation performance overall. According to TBI managers themselves, their financial assistance, perhaps in the form of grant or equity finance, has been largely directed towards supporting either radical innovation activities or a few fast growing firms. Indeed, as commented elsewhere (Xiao and North, 2013), it was often the intention of TBI managers to focus their financial assistance on a relatively small number of firms which they considered to have the potential to become leading market players, not least because this boosted their own self-image and reputation.

With regards to possible differences between the three tier cities, our results point to some differences in the effectiveness of the three most established services provided by incubators on the early development of incubated firms. We also found that TBI ownership plays a role in influencing relations between support services and early development of new ventures. Regression estimates show no associations between the amount of incubator direct funding and the number of graduated firms across all three tier cities and all three types of TBI. In the top four affluent cities and the tier 3 cities, investment in the technical services platform does have a positive and significant effect on the early development and graduation of new ventures whereas entrepreneurial assistance contributes to the early development of incubated firms in the tier 1 and tier 2 cities. The combination of public investment in shared research and technical facilities and entrepreneurial mentoring appear to be most effective in influencing the number of firms graduating from TBIs in the most advanced cities where the external conditions are most conducive to new venture creation anyway. Further research should explore whether the differences in the effects of the support services provided by TBIs on the early development of new technology-based firms is due to other contextual factors and/or gaps (e.g. incubators in less developed cities have difficulties in focusing on a main technology theme (Chan and Lao, 2005)) that amplify or abate the effect of the TBIs' own efforts.

Our empirical results give rise to some important policy implications for governments at the national and provincial level as well as for incubator management teams. First, whilst our findings indicate that both the technical and entrepreneurial support provided by Chinese TBIs have a positive effect on the early development of technology based firms and their graduation from the incubator, it nevertheless raises an important question as to whether this is leading to the formation of those kinds of businesses (e.g. in the digital and media sectors) which do not require long periods of R&D and testing before launching products to the market. In other words, are other kinds of business (e.g. in the life sciences, bio-tech, and alternative technologies sectors) that are more likely to undertake advanced, higher level innovations being adversely affected by the emphasis given to these TBI support services. Admittedly such a change of emphasis may result in fewer firms graduating over a period of time, although those that do might have greater growth potential in the long term.

Second, recording the number of firms that graduate from TBIs is a key measure that MOST, provincial, and local governments use for measuring the success of TBIs in China. Yet because an incubatee has satisfied the stipulated graduation criteria (sales level, profitability etc.), it does not guarantee the launch of a successful business (Rothaermel and Thursby 2005a). In research on post-graduation survival conducted in East Germany, Schwartz (2009) drew attention to a high risk period starting with the completion of incubation and lasting up to three years after leaving the incubator. His evidence showed that just under a third of firms were unlikely to survive a period of six years after graduation.Without further research focused on the post-graduation experience, we have no means of knowing from existing data sources what has happened to graduating firms from Chinese TBIs and whether the long term survival rates are any different from those found in western countries.

Third, our evidence shows that technical support services involving shared laboratory and research facilities tend to work best in the tier 1 cities where TBIs have become more specialised in a particular industrial sector and where there has been a constant flow of incoming and outgoing firms. In this respect Chinese TBIs are following the path of incubator development in western countries where it has been found that building knowledge networks and realising opportunities that meet the needs of resident firms is leading to increased incubator specialisation (Dee et al., 2011). This development path also implies that TBIs become more selective in the ventures that they accept. The more limited impact of TBI services on the graduation of incubated firms in the tier 2 and tier 3 cities indicates that the TBIs in these less favourable economies face more difficult challenges if they are to help the early development of new tehnology-based firms.

Finally, future research should attempt to go beyond what has been possible in this study. Although our research has benefited from being based on a large secondary source dataset covering all TBIs in China over a recent five year period, it has been constrained by the way the various TBI inputs and outputs have been measured by the Chinese authorities. For instance, the direct financial support from an incubator to the incubated firms is measured by the amount of incubator funding available to the firms rather than how these resources have been allocated and in what form (e.g. grant, interest free loan, equity finance,) More in-depth primary research that focuses on a sample of TBIs in different types of city is now required in order to advance our understanding of their role in China's economic transformation.

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Table 1: GDP by City Tier (2013)

	GDP per capita				GDP			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
Tier 1	93097.47	15434.59	83390.27	125026	16142.37	2525.86	12423.44	19195.69
Tier 2	73184.67	21392.11	19244.58	107964.6	6870.71	2439.69	1404.93	11459
Tier 3	51763.67	24485.72	9275.08	131496.6	2822.27	1440.71	284.96	6059.24
Total	67745.65	24469.56	9275.08	131496.6	7109.50	5657.63	284.96	19195.69

Notes: calculated according to Statistics Yearbooks 2013 by government at national, provincial, and city level.

Table 2: Incubator and firm by City Tier (2013)

	Cities		**Types of TBIs**			**Hosted TBIs**		**Hosted firms**		**Age**				**Size**			
	No.	%	GTBI	UTBI	PTBI	No.	%	No.	%	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
Tier 1	4	4.4	25	8	16	51	23.7	4,794	18.2	9.6	4.45	2	21	94	41.98	26	94
Tier 2	15	16.7	38	5	21	62	28.8	7,998	30.3	8.9	4.92	1	20	129	100.00	22	638
Tier 3	71	78.9	87	6	9	102	47.4	13,566	51.5	8.8	4.84	1	20	133	88.26	15	537
Total	90	100	150	19	46	215	100	26,358	100	8.9	4.78	1	21	123	85.20	15	638

Notes: calculated according to survey data by Ministry of Science and Technology 2013.

Table 3 Variable definition and summary statistics (2009-2013)

Variable	Definition	Mean	Minimum	Maximum	Standard deviation	No. of Observations
Dependent variable						
NGF	Total number of firms graduating from the incubator	11.56	1.0	137	10.87	310
Independent variables						
InFund (1,000 Yuan)	The amount of incubator funding that is available to all the resident firms	21480	100	5000000	164357	310
Techinvestment (1,000 Yuan)	The amount of investment in the public service platform	12586	4	195800	12587	310
ENTR	The number of entrepreneurs playing a role of mentoring the firms	10	1	158	12.17	310
VC (1,000 Yuan)	The amount of venture capital received by the firms	84273	1	1900000	198858	310
Control variables						
Size	Total number of firms within each incubator	123	15	638	85.19	310
Age	The year an incubator started incubating firms	9	1	21	4.78	310
NoUni	The number of universities within in a city	37	2	91	28.00	310

Notes: average statistics of each variable exclude observation where its value were 0 over the period 2009- 2013

Table 4 Regression analyses of effects of and incubators and city characteristics on the number of firms graduating (Five years 2009-2013)

	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	Coefficient t-stats	Coefficient t-stats	Coefficient t-stats	Coefficient t-stats	Coefficient t-stats	Coefficient t-stats	Coefficient t-stats
Variables	Entire Sample	Tier 1 cities	Tier 2 cities	Tier 3 cities	GTBIs	UTBIs	PTBIs
Constant	3.928(46.51)***	3.346(10.93)***	3.650(28.01)***	4.368(34.64)***	4.177(35.79)***	2.267(4.47)***	4.013(15.20)***
Incubator							
InFund (1,000Yuan)	.053(.43)	.041(.24)	1.293(1.10)	.068(.07)	.007(.61)	1.021(.26)	-.214(-1.20)
Techinvestment(1,000Yuan)	3.078(2.40)***	1.513(3.15)***	.0456(.24)	.436(2.32)**	3.358(2.42)**	8.626(1.74)*	-2.270(-.75)
ENTR	.006(1.99)**	.017(1.84)**	.009(1.91)*	.005(1.56)	.003(.93)	.0344(2.96)***	.003(.68)
VC (1,000Yuan)	.037(2.82)***		.005(0.15)		.014(2.78)***	.058(.54)	-.002(-.25)
No of University	-.004(-.91)	.001(.22)	-.004(1.57)	-007(-2.54)**	.001(.45)	.010(3.00)***	
Control variable							
Size	.003(9.63)***	.042(2.63)***	.003(4.88)***	.003(5.20)***	.002(6.24)***	.012(4.32)***	.007(5.46)
Age	.022(3.56)***	.003(1.81)*	.0017(1.57)	-.014.(1.23)	.017(1.83)**	.014(.74)	-.060(-3.82)
Pseudo-R^2	.043	.064	.066	.036	.036	.065	.066
No. of observations	310	101	87	122	190	47	73

Notes: ***, **, and *denote the 1%, 5%, and 10% significance level respectively.