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Article
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Foresight and STI Governance

Provided in Cooperation with:
National Research University Higher School of Economics, Moscow

Suggested Citation: Fritsch, Michael; Wyrwich, Michael (2019) : Regional Emergence of Start-Ups in Information Technologies: The Role of Knowledge, Skills and Opportunities, Foresight and STI Governance, ISSN 2500-2597, National Research University Higher School of Economics, Moscow, Vol. 13, Iss. 2, pp. 62-71, http://dx.doi.org/10.17323/2500-2597.2019.2.62.71

This Version is available at:
http://hdl.handle.net/10419/210626

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Regional Emergence of Start-Ups in Information Technologies: The Role of Knowledge, Skills and Opportunities

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Abstract

We investigate the regional emergence of new information technology start-ups in Germany. The largest share of these start-ups is located in cities or densely populated regions that are well equipped with institutions of higher education and research. The empirical analysis clearly indicates the critical role of industry-specific knowledge plays for new. Hence, strengthening the regional knowledge base should be a key policy that aims at stimulating entrepreneurship in this sector.

Keywords:
innovative start-ups; information technologies; universities; regional knowledge

Citation: Fritsch M., Wyrwich M. (2019) Regional Emergence of Start-Ups in Information Technologies: The Role of Knowledge, Skills and Opportunities. Foresight and STI Governance, vol. 13, no 2, pp. 62–71. DOI: 10.17323/2500-2597.2019.2.62.71
O
ver the last several decades information technolo-
gies (IT) have emerged as an important sector that has a strong economic impact on
the economy and on our lives. It is generally expected
that the role of IT industries will become even stron-
ger in the foreseeable future. Regions that host many
viable IT firms may benefit from the growing impor-
tance of this industry in two ways. First, these firms
may grow and directly create employment and wealth.
Second, the regional economy may benefit in indirect
ways from IT knowledge, for example, through the
availability of IT skills and services.

This paper analyzes the territorial aspects of the emer-
gence of new IT firms. Why do some regions have a
relatively large number of start-ups while others have
virtually none? What is the role of knowledge, skills,
and agglomeration economies in the emergence of
IT firms? The following sections provide an overview
on the potential determinants of IT start-ups at the
regional level, introduce the data and report on the
spatial distribution of IT start-ups in Germany in the
period 2009-2016, and present the results of the em-
pirical analysis. The final section draws conclusions
from these findings.

What Determines the Regional Emergence of IT Start-ups?

Based on the literature dealing with regional determi-
nants of entrepreneurial activity, one can identify two
groups of factors that may shape the emergence of IT
start-ups: knowledge and the availability of resources.
According to the knowledge spillover theory of entrepre-
neurship [Acs et al., 2009; 2013], the knowledge
generated by incumbent firms, universities, public
research institutes, and others is a key source of busi-
ness ideas (entrepreneurial opportunities) that may
lead to the creation of a start-up. Spatial proximity
to such sources of knowledge can be important be-
cause new ideas do not flow freely across space but
tend to be regionally bounded [Asheim, Gertler, 2006;
Boschma, 2005]. Hence, people located close to such
knowledge sources are considerably more likely to
absorb and apply the relevant knowledge. Given that
founders show a pronounced tendency to locate their
firms in close spatial proximity to their residence
[Figueiredo et al., 2002; Dahl, Sorenson, 2009], start-
ups are most likely to emerge in close proximity with
the relevant knowledge sources. The availability of re-
sources includes appropriate labor, finance, and other
factors that the start-ups need to survive and grow.

In our analysis, we capture the IT-specific knowledge by
- the presence of higher education institutions (HEIs). We distinguish between regular uni-
versities and applied sciences universities (Fachhochschulen).1
- the size of these departments in terms of financial budget.
- the intensity of third-party funding measured as the share of third-party funds in the total budget of the department. Since third-party funds are almost always allocated via some kind of com-
petitive procedure, they can be regarded as an indica-
tion of research quality.2
- the regional employment shares in IT hardware and software industries.

These measures, particularly the regional employ-
ment shares in IT hardware and software, also indi-
cate the availability of qualified personnel.

Agglomeration economies and diseconomies as
measured by population density may be another
important factor for IT start-ups. Agglomeration
economies are made possible by large and productive
labor markets where special qualifications are avail-
able, financial institutions are present, and there is a
rich supply of supportive services [Helsley, Strange,
2011]. Agglomeration diseconomies emerge as a re-
sult of intense competition for resources that results in comparatively high rents and wages. The density
and proximity of people increases the frequency of
(face-to-face) interactions among heterogeneous ac-
tors, which provides an important basis for knowl-
edge sharing and effective learning (e.g., [Jacobs,
1969; Helsley, Strange, 2011; Glaeser, Sacerdote, 2000;
Storper, Venable, 2004]).

Based on the knowledge spillover theory of entrepre-
neurship, we expect a positive relationship between
the different measures of knowledge and the regional
levels of new business formation. The estimated coef-
ficients for these knowledge sources can be regarded
as an indication of their relative importance. Is edu-
cation and research at regular universities more or
less important than education and research at the
universities of applied sciences? Is it more the sheer
presence of the HEIs, their size, or the quality of their
research that is more important? We also expect a

1 Regular universities and universities of applied sciences are different in many respects, including purpose, scope and size, teaching, and research [Warn

2 We have no information about the number of students and professors in computer science, which could have been a good alternative indicator.

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positive relationship between population density and new business formation in IT. Table 1 provides an overview of the different indicators and their interpretation.

**Data Description**

Our data source for new business formation is the Enterprise Panel of the Center for European Economic Research (ZEW-Mannheim). These data are based on information from the largest German credit-rating agency, Creditreform (for a more detailed description see [Bersch et al., 2014]). As with many other data sources on start-ups, these data may not be considered comprehensive given that very small start-ups, such as those that do not have any regular employees (‘solo entrepreneurs’) are overlooked. However, once a firm is registered, hires employees, requests a bank loan, or conducts reasonable economic activities, even solo entrepreneurs are included in this dataset and information about their activities is gathered beginning with the ‘true’ date the firm was established. Hence, many solo entrepreneurs are captured along with the correct business founding date. This information is limited to the set-up of a firm’s headquarters and does not include the establishment of branches. In our empirical analysis we use these data for the years 2009-2016.

Based on these start-up data, we distinguish between all IT start-ups and the sub groups (1) start-ups in software, hardware & consulting and (2) start-ups in IT retail and leasing. The former group can be further separated into (1a) software, (1b) hardware, and (3) other services. Our main variables of interest are the numbers of new businesses according to the different sectoral definitions.

Data on HEIs come from the German University Statistics of the German Federal Statistical Office, which provides information about every university in Germany³ and contains, for example, information on whether a HEI has teaching and research facilities in computer sciences. It also provides information on third-party funding and the general financial budget for computer sciences. This allows us to construct a measure for the quality of computer science facilities by comparing the amount of third-party funding to their actual size as captured by the total budget. HEIs are divided into two categories: regular universities and universities of applied sciences. For both types of universities, we count their number, which we include in the analysis as categorical variables. Among the regions hosting a higher education institute with a computer science department the maximum number of regular universities and of universities of applied sciences is two (Table 2). As a control for the size of HEI’s computer science departments we also consider the general budget for regular universities and universities of applied sciences in the respective region.⁴

Data on regional specializations were obtained from the Establishment History Panel which is based on German employment statistics. This dataset contains every German establishment that employs at least one person that is obliged to pay social insurance contributions [Spengler, 2008]. With this dataset, it is possible to identify regional specializations in IT-related manufacturing and services that we consider in our analysis. More precisely, we used the total number of employees in both IT-related industries and the share of IT-related services within this overall employment as a percentage.

In the empirical assessment we investigate the time period of 2009-2016. Since we are interested in the recent developments of start-up activity, we take the average values for the regional determinants for the period of 2000-2008 to explain the average start-up

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³ https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Hochschulen/_inhalt.html. For details, see also [Fritsch, Aamoucke, 2013].

⁴ We have no information on the number of students and professors in computer science, which would have been a good alternative indicator.
率在不同的IT部门在2009-2016。通过平均这些时期，我们的结果不被2008年经济危机的影响所驱动，我们避免了同质性偏差。

我们使用规划区来创建空间框架来实施我们的实证分析。有97个德国规划区，代表功能整合的单位，类似于美国的劳动力市场区域。汉堡和不来梅的城市经济区域也包括其邻近规划区，合并计算。

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通过这样做，我们剩下的有93个规划区在德国，71个在原先的西德，22个在东部。

图1. IT创业率每10,000劳动成年人，在德国2009-2016

地区的IT创业分布

大多数德国的IT创业集中在IT软件、其他IT服务、IT零售和租赁（见表2）。只有3.7%的公司在生产IT硬件。平均每年创业人数在地区之间有很大差异。毫不奇怪，在大城市的IT创业人数远多于农村地区。简单的原因是城市中有更多潜在创业者，可以在更大的劳动力中找到。

为了比较各地区创业水平，我们计算了创业率。IT行业的地区创业率是2009-2016年创业人数的平均数。

Table 2. Summary Statistics

|                           | Mean  | Standard deviation | Minimum | Maximum |
|---------------------------|-------|--------------------|---------|---------|
| **Number of IT start-ups**|       |                    |         |         |
| All                       | 88.323| 129.867            | 4       | 776     |
| Software, hardware & consulting | 68.763| 108.723           | 2       | 671     |
| Hardware                  | 3.366 | 4.045              | 0       | 23      |
| Software                  | 32.419| 54.069             | 1       | 368     |
| Other services            | 33.118| 51.557             | 1       | 280     |
| Retail & leasing          | 19.602| 23.019             | 2       | 109     |
| **Number of universities with computer science education & research** |   |                    |         |
| Regular universities      | 0.677 | 0.628              | 0       | 2       |
| Universities of applied sciences | 0.699 | 0.586             | 0       | 2       |
| **Size of computer science department** |   |                    |         |
| Regular universities      | 6 985.305 | 6 009.895     | 12.718  | 29 415.537 |
| Universities of applied sciences | 1 875.802 | 1 455.731   | 11.657  | 5 575.184  |
| **Third-party funding intensity of computer science education & research** |   |                    |         |
| Regular universities      | 1 708.215 | 2 059.328     | 0       | 12 725.612 |
| Universities of applied sciences | 452.137 | 1 487.645   | 0       | 13 464.313 |
| **Other indicators**       |       |                    |         |
| Employment share manufacturing IT hardware | 4 395.527 | 7 197.911   | 145.222 | 44 668.332 |
| Employment share IT services | 0.887 | 0.147            | 0.276   | 0.997   |
| Population density        | 5.33  | 0.754              | 3.887   | 8.246   |

Source: authors.

The Regional Distribution of IT Start-ups in Germany

大多数的德国IT创业集中在IT软件、其他IT服务、IT零售和租赁（见表2）。关于3.7%的公司在生产IT硬件。这些地区创业人数有显著的差异。令人惊讶的是，在大城市的IT创业人数远大于农村地区。一个简单的原因是城市中潜在创业者更多。

为了比较各地区创业水平，我们计算了创业率。IT行业的地区创业率是2009-2016年创业人数的平均数。汉堡和不来梅的城市经济区域也包括其邻近规划区，合并计算。通过这样做，我们剩下的有93个规划区在德国，71个在原先的西德，22个在东部。

汉堡是合并的区域，包括Schleswig-Holstein South和Hamburg-Umland South。Bremen也合并了Bremen-Umland。Berlin可以也合并其它邻近规划区，这表明合并的区域是城市经济区域比柏林的更大。

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Figure 1. IT Start-up Rates per 10,000 Working Adults in Germany between 2009 and 2016

Source: authors.
The Demand for Skills: Local Strategies

The Demand for Skills: Local Strategies

Figure 1 shows that, even when controlling for the size of regional workforce, start-up rates in IT industries tend to be considerably higher in regions with larger cities such as Berlin, Frankfurt, Hamburg, Munich, and Stuttgart than in less densely populated areas. There is a corridor of regions with high levels of new business formation in IT industries along the Rhine from Duesseldorf to Karlsruhe. It is quite notable that IT start-up rates tend to be particularly low in East Germany, the formerly socialist GDR. This observation corresponds to a generally low level of new business formation in this part of the country in the period of analysis.

There may be a number of reasons for higher IT start-up rates in large cities. First, start-ups in IT industries require knowledge that may be regionally bounded, particularly if this knowledge is tacit in nature [Boschma, 2005]. Since all larger cities in Germany host at least one HEI that often has special departments for computer science, this knowledge is more likely to be present in these regions than in rural ones. Second, research in computer science may be an important source of entrepreneurial opportunities [Acs et al., 2009; 2013]. As previously mentioned, the founders of new businesses show a pronounced tendency to set up their venture close to their residence. Accordingly, new businesses tend to be locat-

Table 3. Determinants of IT Start-up Activity in 2009-2016

| Number of universities of applied science with computer science education & research | Number of regular universities with computer science education & research | Size of computer science department at universities | Third-party funding intensity of computer science education & research at universities | Other indicators |
|---|---|---|---|---|
| No university (Yes=0) | Ref | Ref | Ref | Ref | Ref | Ref |
| One university (Yes=1) | 0.619*** (0.182) | 0.451** (0.214) | 0.249 (0.344) | 0.617*** (0.224) | 0.313 (0.278) | 1.024*** (0.243) |
| Two universities (Yes=1) | 0.913*** (0.247) | 0.779*** (0.279) | 0.625 (0.417) | 0.825*** (0.298) | 0.747** (0.347) | 1.200*** (0.316) |
| No university (Yes=0) | Ref | Ref | Ref | Ref | Ref | Ref |
| One university (Yes=1) | 0.694** (0.277) | 0.467 (0.318) | 0.614* (0.365) | 0.521 (0.356) | 0.405 (0.313) | 1.410*** (0.268) |
| Two universities (Yes=1) | 0.855*** (0.295) | 0.613* (0.330) | 0.803** (0.393) | 0.689* (0.368) | 0.507 (0.333) | 1.566*** (0.319) |
| Regular universities | −0.0298 (0.0498) | −0.00689 (0.0537) | 0.0318 (0.0730) | 0.00433 (0.0626) | −0.00986 (0.0516) | −0.126** (0.0516) |
| Universities of applied sciences | −0.0896*** (0.0324) | −0.0561 (0.0375) | −0.0379 (0.0496) | −0.0764* (0.0397) | −0.0444 (0.0479) | −0.177*** (0.0371) |
| Regular universities | −0.0682 (0.0512) | −0.0655 (0.0547) | −0.126* (0.0673) | −0.0714 (0.0563) | −0.0677 (0.0554) | −0.0544 (0.0503) |
| Universities of applied sciences | −0.00618 (0.0204) | −0.0199 (0.0240) | −0.0152 (0.0272) | −0.0216 (0.0272) | −0.0176 (0.0263) | 0.0314 (0.0208) |
| Number of employees in IT manufacturing & services | 0.603*** (0.0608) | 0.623*** (0.0661) | 0.477*** (0.0770) | 0.625*** (0.0754) | 0.650*** (0.0722) | 0.571*** (0.0709) |
| Employment IT service/ Employment IT manufacturing & services | 0.552*** (0.121) | 0.595*** (0.141) | 0.320 (0.218) | 0.577*** (0.150) | 0.677*** (0.158) | 0.451*** (0.138) |
| Population density | 0.245*** (0.0885) | 0.231** (0.107) | 0.255** (0.102) | 0.245** (0.123) | 0.226** (0.0992) | 0.274*** (0.0650) |
| Constant | −1.735*** (0.305) | −2.083*** (0.361) | −3.960*** (0.375) | −3.016*** (0.417) | −2.900*** (0.350) | −3.053*** (0.302) |
| Number of observations | 93 | 93 | 93 | 93 | 93 | 93 |
| Log likelihood | −388.2 | −370 | −151.9 | −309.7 | −309.2 | −275.2 |
| Pseudo R-squared | 0.239 | 0.240 | 0.290 | 0.259 | 0.264 | 0.256 |

Notes: Negative binomial regressions. The dependent variable is the number of start-ups in the respective industry. Robust standard errors in parentheses.

***: statistically significant at the 1 % level; **: statistically significant at the 5 % level; *: statistically significant at the 10 % level.

Source: authors.
Table 4. Correlation Matrix

|                  | [1]  | [2]  | [3]  | [4]  | [5]  | [6]  | [7]  | [8]  | [9]  | [10] | [11] | [12] | [13] | [14] | [15] |
|------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| [1] Number of IT start-ups |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| [2] Number of IT start-ups in software, hardware, & consulting | 1    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| [3] Number of IT start-ups in hardware | 0.997 (0.000) |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| [4] Number of IT start-ups in software | 0.955 (0.000) | 0.953 (0.000) |      |      |      |      |      |      |      |      |      |      |      |      |      |
| [5] Number of IT start-ups in other services | 0.987 (0.000) | 0.993 (0.000) | 0.94 (0.000) |      |      |      |      |      |      |      |      |      |      |      |      |
| [6] Number of IT start-ups in retail & leasing | 0.992 (0.000) | 0.993 (0.000) | 0.944 (0.000) | 0.971 (0.000) |      |      |      |      |      |      |      |      |      |      |      |
| [7] Number of regular universities with computer science education & research | 0.932 (0.000) | 0.901 (0.000) | 0.886 (0.000) | 0.878 (0.000) | 0.911 (0.000) |      |      |      |      |      |      |      |      |      |      |
| [8] Number of universities of applied sciences with computer science education & research | 0.484 (0.000) | 0.471 (0.000) | 0.492 (0.000) | 0.472 (0.000) | 0.459 (0.000) | 0.507 (0.000) |      |      |      |      |      |      |      |      |      |
| [9] Size of computer science department at universities | 0.273 (0.008) | 0.264 (0.011) | 0.308 (0.003) | 0.226 (0.030) | 0.295 (0.004) | 0.292 (0.004) | 0.206 (0.048) |      |      |      |      |      |      |      |      |      |
| [10] Size of computer science department at universities of applied sciences | 0.386 (0.000) | 0.378 (0.000) | 0.397 (0.000) | 0.374 (0.000) | 0.374 (0.000) | 0.39 (0.000) | 0.895 (0.000) | 0.218 (0.036) |      |      |      |      |      |      |      |      |
| [11] Third-party-funding intensity of computer science education & research at universities | 0.351 (0.001) | 0.34 (0.001) | 0.359 (0.001) | 0.337 (0.001) | 0.335 (0.001) | 0.376 (0.000) | 0.886 (0.000) | 0.213 (0.041) | 0.985 (0.000) | 0.256 (0.013) |      |      |      |      |      |
| [12] Third-party-funding intensity of computer science education & research at universities of applied sciences | 0.195 (0.060) | 0.184 (0.077) | 0.221 (0.033) | 0.159 (0.128) | 0.204 (0.050) | 0.232 (0.025) | 0.256 (0.013) | 0.901 (0.000) | 0.262 (0.011) |      |      |      |      |      |      |
| [13] Share of employment in manufacturing IT hardware | 0.171 (0.101) | 0.159 (0.128) | 0.183 (0.080) | 0.139 (0.184) | 0.175 (0.094) | 0.212 (0.041) | 0.193 (0.064) | 0.738 (0.000) | 0.242 (0.020) | 0.833 (0.000) | 0.244 (0.018) |      |      |      |      |
| [14] Share of employment in IT services | 0.075 (0.473) | 0.072 (0.491) | 0.045 (0.671) | 0.073 (0.485) | 0.073 (0.486) | 0.083 (0.429) | 0.065 (0.539) | -0.098 (0.349) | 0.041 (0.697) | -0.065 (0.555) | 0.038 (0.717) | -0.048 (0.646) | -0.104 (0.320) |      |      |
| [15] Population density | 0.68 (0.000) | 0.656 (0.000) | 0.661 (0.000) | 0.655 (0.000) | 0.645 (0.000) | 0.739 (0.000) | 0.514 (0.000) | 0.25 (0.016) | 0.469 (0.000) | 0.28 (0.007) | 0.471 (0.000) | 0.276 (0.007) | 0.784 (0.000) | 0.091 (0.387) | 1      |

Source: authors.
Table 5. Robustness Check. Determinants of IT Start-up Activity: University Effects Only

|                  | I       | II                     | III                    | IV                    | V                     | VI                     |
|------------------|---------|------------------------|------------------------|-----------------------|-----------------------|------------------------|
|                  | All IT start-ups | Startups in IT Software, Hardware, & Consulting | All | IT hardware | IT software | Other IT services | IT retail & leasing |
| No university (Yes=0) | Ref (0.165) | Ref (0.173) | Ref (0.176) | Ref (0.177) | Ref (0.183)       | Ref (0.158)          |
| One university (Yes=1) | 0.452*** (0.165) | 0.459*** (0.173) | 0.245 (0.176) | 0.492*** (0.177) | 0.438*** (0.183)       | 0.425*** (0.158)          |
| Two universities (Yes=1) | 1.170*** (0.361) | 1.216*** (0.359) | 1.014*** (0.341) | 1.108*** (0.363) | 1.320*** (0.362)       | 0.989** (0.386)          |

Number of universities with applied science with computer science education & research

|                  | I       | II                     | III                    | IV                    | V                     | VI                     |
|------------------|---------|------------------------|------------------------|-----------------------|-----------------------|------------------------|
| No university (Yes=0) | Ref (0.171) | Ref (0.180) | Ref (0.148) | Ref (0.179) | Ref (0.194)       | Ref (0.165)          |
| One university (Yes=1) | 0.788*** (0.171) | 0.827*** (0.180) | 0.616*** (0.148) | 0.922*** (0.179) | 0.762*** (0.194)       | 0.661*** (0.165)          |
| Two universities (Yes=1) | 2.017*** (0.418) | 2.103*** (0.453) | 1.585*** (0.339) | 2.282*** (0.492) | 1.972*** (0.442)       | 1.705*** (0.319)          |

Number of regular universities with computer science education & research

|                  | I       | II                     | III                    | IV                    | V                     | VI                     |
|------------------|---------|------------------------|------------------------|-----------------------|-----------------------|------------------------|
| Constant         | 3.306*** (0.130) | 2.997*** (0.138) | 0.377*** (0.152) | 2.145*** (0.145) | 2.327*** (0.147)       | 1.997*** (0.127)          |
| Number of observations | 93        | 93                    | 93                    | 93                    | 93                    | 93                     |
| Log likelihood   | -473    | -449.7                 | -187.5                | -379.6               | -385.3                | -341.4                 |
| Pseudo R-squared | 0.0726  | 0.0768                 | 0.124                 | 0.0916               | 0.0824                | 0.0774                 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: authors.

Empirical Analysis

To identify the factors that determine the regional emergence of innovative start-ups, we performed multivariate analyses. Our dependent variable is the average number of innovative start-ups in a region over the 2009-2016 period. We run these models for all IT start-ups as well as for a number of sub-categories: IT software, IT hardware, IT consulting, and IT retail & leasing. Due to the count character of the independent variable, the number of start-ups, we employed a negative binomial estimation technique. In order to avoid any reverse causality issues, all other independent variables are log-transformed. The results (see Table 4) are rather similar to those of the full model of Table 3.

Table 3 shows the main results. We find significantly positive relationships between the total number of IT start-ups and the number of regular universities as well as universities of applied sciences. According to the estimated coefficients, the effect is more pronounced if a region is hosting two universities of applied sciences or two regular universities. For both types of universities, having two of them is associated with one more IT start-up per 10,000 people in the workforce as compared to regions that do not host a HEI. The effect for hosting at least one university of applied science or a regular university is around 0.5 more start-ups per year as compared to regions without HEIs. In order to test whether the findings for the presence of HEIs are driven by multicollinearity with size measures and other regional variables like population density, we ran models with only the indicators for both types of universities and no other indicator related to size. The results (see Table 4) are somewhat surprising as the size of universities of applied sciences is negatively related to overall start-up activity in the IT sector while neither the size of computer science departments at regular universities nor the third-party funding intensity are significantly related to IT start-up activity. This result clearly suggests that the size of local computer science departments does not play a role.

The regional number of employees in the IT sector has a positive effect on IT start-up activity. This effect is more pronounced if IT employment is concentrated in IT services. A 10 percent increase in this employ-

ed in geographic proximity of the knowledge sources that are highly concentrated in the larger cities. Third, there are larger volumes of demand in large cities that may be particularly relevant for IT services that require face-to-face contact.

There are no negative values. The original variables are scaled up to the extent that the smallest values that are larger than zero assume a positive value after log-transformation. Values that were zero before this transformation are then kept as zeros. More precisely, we multiplied size and third-party funding intensity of computer science education & research by the factor of 10,000.
Looking into the IT sub-categories reveals further interesting findings. The effect of HEIs on IT start-up activity seems to be driven by IT software and IT retail & leasing whereas the effect is particularly pronounced for the latter type of IT industries. For IT hardware, there is only a statistically significant effect for regions having two regular universities. For other IT services, the presence of two universities of applied sciences is significant only. In the models that consider only indicators for the presence of HEIs, all indicators are statistically significant (Table 5).

The size and quality of computer science departments do apparently not matter while the number of employees in the IT sector is positively related to the level of start-up activity in all IT sub-categories. The same applies to specialization in IT services. There is one exception namely that the coefficient estimate for the regional employment share in IT services on the number of start-ups in IT hardware is insignificant. This may be an indication that industry experience in IT software is less relevant for the production of IT hardware. Finally, there is a significantly positive

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**Table 6. Robustness check. Determinants of IT Start-up Activity: No Control for Population Density**

|                      | I All IT start-ups | II Startups in IT Software, Hardware, & Consulting | III Other IT services | IV IT retail & leasing |
|----------------------|--------------------|-----------------------------------------------|---------------------|------------------------|
|                      | Ref                | Ref                                           | Ref                | Ref                    |
| No university (Yes=0)| Ref                | Ref                                           | Ref                | Ref                    |
| One university (Yes=1)| 0.649*** (0.181)   | 0.474** (0.207)                               | 0.133 (0.327)      | 0.634*** (0.219)       |
| Two universities (Yes=1)| 0.899*** (0.229)   | 0.758*** (0.253)                              | 0.396 (0.391)      | 0.778*** (0.263)       |
|                      | Ref                | Ref                                           | Ref                | Ref                    |
| No university (Yes=0)| Ref                | Ref                                           | Ref                | Ref                    |
| One university (Yes=1)| 0.622** (0.261)    | 0.391 (0.300)                                 | 0.536 (0.368)      | 0.446 (0.348)          |
| Two universities (Yes=1)| 0.896*** (0.262)   | 0.649** (0.294)                               | 0.778** (0.385)    | 0.734** (0.340)        |

**Number of regular universities with computer science education & research**

|                      | Ref                | Ref                                           | Ref                | Ref                    |
| Regular universities| -0.0537 (0.0560)   | -0.0290 (0.0589)                              | 7.30e-05 (0.0818)  | -0.0205 (0.0675)       |
| Universities of applied sciences| -0.104*** (0.0338) | -0.0691* (0.0380)                             | -0.0372 (0.0463)   | -0.0899** (0.0401)    |

**Size of computer science department at universities**

| Regular universities| -0.0373 (0.0500)   | -0.0356 (0.0520)                              | -0.0887 (0.0680)   | -0.0398 (0.0530)       |
| Universities of applied sciences| 0.000488 (0.0194)  | -0.0147 (0.0224)                              | -0.0120 (0.0253)   | -0.0159 (0.0254)       |

**Other indicators**

| Number of employees in IT manufacturing & services| 0.730*** (0.0409)   | 0.743*** (0.0442)                              | 0.629*** (0.0573)   | 0.757*** (0.0520)       |
| Employment in IT services/ Employment in IT manufacturing & services| 0.682*** (0.126)    | 0.713*** (0.144)                               | 0.438* (0.236)      | 0.703*** (0.149)        |
| Population density| Her                | Her                                           | Her                | Her                    |
| Constant| -1.319*** (0.271)   | -1.695*** (0.297)                              | -3.630*** (0.388)   | -2.633*** (0.346)       |
| Number of observations| 93                | 93                                           | 93                 | 93                     |
| Log likelihood| -394.1             | -374.5                                        | -154.7             | -313.7                 |
| Pseudo R-squared| 0.227              | 0.231                                        | 0.278              | 0.249                  |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: authors.

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The population density is associated with an about 6 percent higher number of overall IT start-ups. Thus, consistent with the knowledge spillover theory of entrepreneurship [Acs et al., 2009; 2013] a high share of employees with industry experience in IT increases the level of new firm formation in that sector. Finally, population density is significantly and positively related to the number of start-ups. A 10 percent higher population density is associated with an about 2.5 percent more IT start-ups. The coefficient estimates for the other variables are relatively similar when population density is excluded from the model (Table 6).
relationship between population density and start-up activity in the different IT sub-categories. The coefficient estimates do not change remarkably when population density is removed from the models (see Table 6).

As a final robustness check, we replicated the results of our baseline models of Table 2 using OLS regression with the log-transformed number of start-ups as an outcome variable. The results are in line with our baseline models. One notable exception is that the effects for HEIs come out more clearly. Furthermore, there is no positive effect for population density in the models on start-up activity that is independent of population density and the associated agglomeration economies.

## Summary and Conclusions

The main results of our empirical analysis of the determinants of regional new business formation in the IT sector can be summarized as follows.

- First, IT start-ups are concentrated in large cities. The propensity of an IT start-up to emerge in a rural area is rather low.
- Second, a main reason for the geographic concentration of new IT businesses is the presence of HEIs with education and research in computer science. HEIs with computer science departments may be important for the qualification of the regional workforce in IT and as a source of
new knowledge that opens up promising entrepreneurial opportunities in this technological field.

- Third, it is not the size of the computer science departments at HEIs nor the quality of the research but more their sheer presence that is important for the number of regional IT start-ups.
- Fourth, there is a significantly positive relationship between the regional employment share in IT services and the number of IT start-ups. This is a further indication of the important role industry-specific knowledge plays in the level of entrepreneurship in a certain sector.
- Fifth, population density and resulting agglomeration economies may be conducive to the regional formation of new IT businesses. The effect of population density as such is, however, much smaller than for the presence of HEIs.

All in all, these results are consistent with the knowledge spillover theory of entrepreneurship [Acs et al., 2009; 2013] that emphasizes the role of knowledge for new business formation. Accordingly, strengthening the regional knowledge base should be a key strategy of any policy that aims at stimulating the number of regional IT start-ups. Since there are good reasons why HEIs in computer sciences are located in larger cities, such high-density regions have a locational advantage in this sector as compared to rural regions.

A limitation of the study is the fact that the data for start-ups do not necessarily cover very small firms such as new businesses that consist of only the founder and have no further employees (solo entrepreneurship). This neglect of micro firms can, however, be also regarded an advantage in the sense that the analysis includes start-ups that may have an effect on the development of the respective region. Future research should complement our findings with a qualitative assessment of location choices of IT founders and the role that local conditions such as the regional knowledge base have for their decision-making and the venture process.

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