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Infrastructure and entrepreneurship

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Abstract This paper is one of the first studies to examine the link between infrastructure and entrepreneurship. Because infrastructure can enhance connectivity and linkages that facilitate the recognition of entrepreneurial opportunities and the ability of entrepreneurs to actualize those opportunities, a hypothesis is developed suggesting that startup activity is enhanced by infrastructure. However, not all types of infrastructure have a homogeneous impact on the entrepreneurial decision, so that a second hypothesis is developed suggesting that certain types of infrastructure which facilitate connectivity and linkages among people are more conducive to startup activity. The empirical results suggest that startup activity is positively linked to infrastructure in general, but that certain specific types of infrastructure, such as broadband are more conducive to infrastructure than are highways and railroads. Finally, we hypothesize that the types of infrastructure have varying influences in different sectors. Our empirical analyses support this view and we conclude that particular infrastructure policies can be used to facilitate regional startup activities and, furthermore, to foster startup activities in desired industries.

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1 Introduction

Why do some regions exhibit a greater degree of entrepreneurial activity than others? This key question pointed out by a set of studies shifting the unit of analysis from individuals to regions (Sternberg 2009; Audretsch and Keilbach 2007; Parker 2009; Reynolds et al. 1994; Sternberg and Wennekers 2005; Fritsch and Falk 2007; Feldman 2014). As Lofstrom et al. (2013, p. 2) put it, "The multiple circumstances that may either promote or inhibit new firm formation have for decades attracted the attention of researchers interested in understanding the determinants of entrepreneurial entry." Audretsch and Keilbach (2007) suggest that such spatially dependent characteristics may influence entrepreneurial opportunities available to individuals and the ability and their willingness to pursue those opportunities. The exhaustive review of the literature by Sternberg (2009) identifies a multitude of spatial influences on entrepreneurial activity, spanning from the extent of physical capital and human capital, to social capital and knowledge capital. When interpreted from the lens of Audretsch and Keilbach (2007), the latter three can be interpreted as enhancing entrepreneurial opportunities and capabilities, while the first limits such entrepreneurial opportunities and capabilities.

However, virtually no study to date has considered the impact of (physical) infrastructure on entrepreneurship in the form of startup activity. As Woolley (2013, p. 2) observes, "The development of infrastructure for entrepreneurship remains elusive." Such an omission in the literature is striking and surprising, for at least two key reasons. The first is that a multitude of studies in other fields have found that infrastructure plays a key role in economic processes, and in particular, in generating opportunities for growth and productivity (Morrison and Schwartz 1996; Canning and Pedroni 2008; Aschauer 1989). The second is that, in particular, such investments in infrastructure may be particularly conducive to entrepreneurial opportunities. Infrastructure investment typically enhances the connectivity of people, which in turn, is beneficial to entrepreneurial activity. As Woolley (2013) points out, in one of the few existing studies linking infrastructure to entrepreneurship, infrastructure can spur entrepreneurial opportunities along with the ability of nascent entrepreneurs to act upon those opportunities in the form of starting a new firm.

The impact of broadband as a "new" infrastructure on economic growth has drawn particular attention in policy-making for more than 15 years. For example, the EU's "Digital Agenda for Europe" considers broadband as the key prerequisite for startups in telecoms and ICT and, beyond, as an incubator for growth in other industries.[1] A wide range of cross-country studies discusses the impact of broadband availability on national growth (e.g., Czernich et al. 2011). On the other hand, studies on the regional growth impact of broadband are lagging behind (Holt and Jamison 2009).

Based on these observations, the focus of this paper is to analyze the impact of infrastructure on entrepreneurial activity on a regional aggregation level. We consider four different types of infrastructure, highways, railways, knowledge and, in particular, broadband and their impact on the regional startup rates in Germany.

The following section of this paper develops the main hypotheses linking infrastructure to entrepreneurship in the form of startup activity. The third section is concerned with measurement issues involving the main data base. The main hypotheses are subjected to empirical scrutiny in the fourth section and the most salient findings are discussed and interpreted. In the last section of the paper, a summary and conclusion are provided. In particular, this paper finds that infrastructure has a positive impact on startup activity. However, certain types of infrastructure, such as broadband, have a greater impact on new firm startups than do other types of infrastructure, such as highways and railroads. In addition, investment in broadband is more conducive to startup activity in some industries, such as software, than in others, such as manufacturing.

This paper makes three important contributions to the entrepreneurship literature. It is virtually the first study to link the startup activity of new firms to infrastructure. Second, infrastructure is not considered to be homogeneous, but rather we recognize the heterogeneity inherent in different types of infrastructure. Third, the inherent heterogeneity of different industry contexts is explicitly considered, leading to the finding that the impact of infrastructure on startup activity depends upon the particular industry.

2 Linking infrastructure to startups

It is well documented that physical infrastructure generally consists of large scale capital projects requiring large financial investments (Aschauer 1989). The conventional thinking would suggest that such large scale projects and high financial expenditures required would pose a barrier to entry or, more specifically, a barrier to startup. As Lofstrom et al. 2013, p. 3 point out, "To compete head on with incumbent firms adopting a Porter (1990) cost leadership and enjoying economies of scale, entrants need to amass sufficient fixed capital to avoid being placed at a cost disadvantage". However, there is a key distinction between investment in physical capital and investment in infrastructure. The first distinction is

[1] http://ec.europa.eu/digital-agenda/digital-agenda-europe.

that in the former case the investment is made by the firm itself, while in the latter case the startup would not make the investment itself. Rather, infrastructure is a typical example for a natural monopoly for which it is most efficient to have only one supplier because of subadditivity of costs. As investments in infrastructure are mostly of large scale, sunk and irreversible the investment is typically made by the public sector or different kinds of public–private partnerships reaching from public subsidies for private infrastructure projects to public ownership shares in the investor.

Thus, infrastructure, although it is highly capital intensive, should actually serve to reduce barriers to startup in that it facilitates connectivity, interaction and the exchange of knowledge and ideas that potentially could fuel entrepreneurial ventures. As Ghio et al. (2014) and Acs et al. (2013) point out, such knowledge flows are conducive to knowledge spillover entrepreneurship. As Lofstrom et al. (2013, p. 3) make clear, that in order to compete against incumbent firms, "entrants need sufficient cognitive skills and knowledge to create new market niches." Saxenien (1994) points to the ability of people to interact and connect with others as facilitating new firm startups. In particular, she emphasizes the high degree of entrepreneurial activity in California's Silicon Valley is attributable to a high degree of interactions among people in the region who "continue to meet at trade shows, industry conferences and the scores of seminars, talks, and social activities. Relationships are easily formed and maintained, technical and market information is exchanged, business contacts are established, and new enterprises are conceived.... This decentralized and fluid environment also promotes the diffusion of intangible technological capabilities and understandings" (Saxenien 1994, pp. 96–97). This leads to.

Hypothesis 1 Infrastructure is positively related to new firm startup activity.

While there is a paucity of studies examining the impact of infrastructure on entrepreneurship in general, and startup activity in particular, Aschauer (1989), Morrison and Schwartz (1996), and Canning and Pedroni (2008) found compelling empirical evidence linking infrastructure to economic growth. However, in their studies, infrastructure was treated as being homogeneous, in that a dollar invested in any type of infrastructure was assumed, or modeled to have exactly the same impact on the dependent variable, economic growth. However, there is little reason to think that all types of infrastructure facilitate connectivity and therefore have an identical impact on startup activity. Certain types of infrastructure, such as broadband, are presumably more conducive to accessing information and other people, which in turn are also more conducive to startup activity. This leads to.

Hypothesis 2 The different specific types of infrastructure are related to new firm startup activity in disparate ways, reflecting their inherent heterogeneity.

Not only is infrastructure inherently heterogeneous, but so too is the industry context in which the entrepreneurial decision is made. In some industry contexts, such as software, being able to access the community of software engineers and related programmers may be essential for obtaining information and new ideas and approaches. Thus, types of infrastructure such as broadband would be expected to be particularly conducive to startup activity in industry contexts such as software. In other industry contexts, such as manufacturing, more traditional types of infrastructure, such as railroads and highways, would be expected to play a more important role in the decision to start a new firm. This leads to.

Hypothesis 3 Startup activity is linked to infrastructure in a manner that is specific to the particular industry context.

In summary, this paper is perhaps the first to suggest that, in making the entrepreneurial decision to start a new venture, infrastructure matters. Infrastructure not only can facilitate accessing entrepreneurial opportunities and capabilities to implement those opportunities through linking nascent entrepreneurs to key sources of information, knowledge and insights, but that different types of infrastructure will not have the same impact on the entrepreneurial decision. Similarly, the industry context matters in the extent to which the connectivity provided by infrastructure facilitates the entrepreneurial decision, so that we expect startup activity to be specific to both the type of infrastructure as well as the industry context.

3 Data

In order to test our three hypotheses examining the impact of infrastructure on startup activity, we constructed a data set using different sources providing data at the smallest regional authority level of counties in Germany. An advantage of undertaking the analyses at the regional level within a single country enables us to control for country-specific factors, conditions and institutions, such as shifts in national public policy.

Broadband is a relatively new type of physical infrastructure compared to highways or railways. The study therefore considers the rollout period of broadband, i.e., the period of 2001–2005, to control for shifts in startup activities which come from the growing availability of this new infrastructure type. The descriptive statistics and correlation table can be found in the "Appendix".

To begin with, the principal data set is the Mannheim Enterprise Panel (MUP).[2] The credit rating agency *Creditreform* collects comprehensive data on German firms provided biannually to the Centre for European Economic Research (ZEW). The MUP is the baseline for the calculation of regional startup activities which can be identified for different specific sectors. This enables us to use representative information for the county-sector level. In particular, we examine the startup rate, which is defined as the number of a county's startups divided by the labor force. This measure could be interpreted as the startup activity relative to the county's potential for new firm creation.

Four types of infrastructure are considered to affect the startup rate: The first two types of infrastructure reflect physical infrastructure in the form of highways and railways. OpenStreetMap and the Geographical Information System (GIS) enable us to identify the number of highway interchanges[3] and their location within each county. The second type of physical infrastructure involves railroad infrastructure. Information on long-distance train stations is taken from the route map (*Streckenplan*) in 2010 provided on the *Deutsche Bahn* website.[4]

Another crucial type of infrastructure is knowledge infrastructure as provided by universities and research institutions. As pointed out by Lofstrom et al. (2013) individual educational resources play an important role in the decision to start a firm. Audretsch and Lehmann (2005) have shown that geographical distance to universities and research institutes differently affects innovations in scientific areas, such as the natural sciences and social sciences. Knowledge infrastructure is measured as the minimal distance to a public research institute or university focusing on the areas of mathematics, computer science, natural science and engineering as sustaining startup activities are predominantly found in more technical growth fields.

The fourth type is communication infrastructure. In particular, our measure reflects the provision of broadband infrastructure during the rollout period.[5] We use information on the date of the upgrade of main distribution frames (MDFs). The average broadband penetration index in a county is calculated as the share of households in a county with subscriber lines to MDFs times the share of subscriber lines at upgraded MDFs.[6]

Additional county-specific data are matched to these four measures of infrastructure based on a variety of different data sources, such as the German Federal Statistical Office (*Statistisches Bundesamt*) and the Federal Office for Building and Regional Planning (*Bundesamt für Bauwesen und Raumordnung*). A short description of the variables along with the descriptive statistics is included in the "Appendix".

As control variables we include measures reflecting the local firm structure, opportunities for startup activities, necessity entrepreneurship and a shift in the labor market policy which took place during the period of observation. The local firm structure is reflected by the county's share of employees working for companies with more than 249 employees (*big firms*). As Glaeser et al. (2010, p. 2) point out, "Saxenien (1994) classic analysis of Silicon Valley

[2] The MUP is implemented by the Centre for European Economic Research (ZEW) in cooperation with Creditreform, the largest credit rating agency in Germany.

[3] We use the logarithm because the distribution of interchanges is highly skewed.

[4] Because some railway stations changes their status during the observation period, we checked the respective city's webpage. For more details regarding the *Deutsche Bahn* route map refer to the following link: http://www.bahn.de/p/view/mdb/bahnintern/fahrplan_und_buchung/streckenplaene/MDB84831-ice_2011.pdf.

[5] We are grateful to *Deutsche Telekom AG* which provided us with information on the broadband rollout in Germany between 2000 and 2004.

[6] The calculation of the broadband penetration index is considerably more complicated. A more detailed description is provided in the "Appendix".

noted its abundance of smaller, independent firms relative to Boston's Route 128 corridor. Following Chinitz (1961) and Jacobs (1970), Saxenian argued that these abundant small firms themselves caused further entrepreneurship by lowering the effective cost of entry through the development of independent suppliers, venture capitalists, entrepreneurial culture and so on." A plethora of studies have found that employees are better able to identify entrepreneurial opportunities and possess the skills to act on those opportunities when they have employment experience in smaller firms rather than larger companies (Parker 2009; Fritsch 2013; Glaeser et al. 2010).

Furthermore, we control for the growth of entrepreneurial opportunities in the region. In the entrepreneurship literature, it has been consistently found that higher regional growth rates tend to generate higher rates of entrepreneurship, which has generally been interpreted as reflecting enhanced entrepreneurial opportunities (Audretsch and Keilbach 2007; Fritsch 2013; Acs and Armington 2006). Entrepreneurial opportunities generated from growth in manufacturing is distinguished from those in services by including two separate variables measuring the county growth rate of gross value added in each of these sectors.

High unemployment has been found to be associated with necessity entrepreneurship, while low unemployment rates are more associated with opportunity entrepreneurship rate (Thurik et al. 2008; Fritsch 2013). We control for this effect with the regional short-term unemployment rate. The "Ich AG" dummy isolates the specific influence of a policy introduced in 2003 to induce unemployed people to start a firm.

4 Empirical results and discussion

The objective of our analysis is to figure out the impact of different types of infrastructures on startup activities. Therefore, we test our main hypotheses by estimating OLS regressions with standard errors clustered by county for the years 2000–2004.[7] We cleaned the data from observations with missing values and outliers and base our analyses on 1,194 observations. The first step was to address Hypotheses 1 and 2. To test these hypotheses, the dependent variable is the overall startup rates in all German counties across all sectors. Startup rates are linked to the different measures of infrastructure for each county. We include four different independent variables reflecting different types of infrastructure. The first two reflect the physical infrastructure, motorway interchanges and long-distance train stations. The third infrastructure measure reflects knowledge infrastructure, measured as the distance to the closest university or research institution. The communication infrastructure is represented by broadband availability.

The empirical results are shown in Table 1. In the first column, the regression results are given for a basic specification which includes the four infrastructure variables, a dummy variable indicating a location in the eastern part of Germany—controlling for the enhanced entrepreneurial opportunities existing in west compared to east Germany—and year dummies reflecting cyclical patterns in the aggregate economic activities. The other columns in Table 1 show regression results where we included control variables, reflecting the local firm structure, opportunities for startup activity, necessity entrepreneurship and a shift in the entrepreneurship policy which took place during the period of observation (see the description in the previous section).

As the positive and statistically significant coefficients of railway infrastructure and broadband infrastructure in the first column suggest, investments in these two types of infrastructure are conducive to new firm startups. By contrast, there is no empirical evidence that investments in highways and universities promote the startup of new firms. These results do not change with the inclusion of additional control variables in the subsequent four columns.[8]

Investments in highway infrastructure in Germany may yield little or no impact in terms of additional entrepreneurial activity because of the existing very dense motorway network, enabling access to even the most remote areas within reasonable time. Similarly, the results that additional investments in knowledge infrastructure have no statistically significant impact on

[7] As a number of counties exhibit no new firm formation in high technology manufacturing, we check whether OLS might result in biased estimation results due to left-truncation of the dependent variable. Therefore, we estimate the model for high technology manufacturing using the Tobit regression model. As Table 5 in the "Appendix" shows results discussed in this section remain basically unchanged (see Table 5 in the "Appendix").

[8] When all control variables are included in the estimated regression model, the effect of highway infrastructure investments increases and turns significant at the 10 % level.

Table 1 Results for startup activities in all sectors

	1	2	3	4	5
Highway infrastructure	0.058	0.056	0.056	0.077	0.098*
	(0.062)	(0.062)	(0.062)	(0.060)	(0.058)
Railway infrastructure	0.270***	0.265***	0.265***	0.278***	0.299***
	(0.078)	(0.078)	(0.078)	(0.077)	(0.068)
Knowledge infrastructure	−0.200	−0.169	−0.172	−0.169	−0.032
	(0.241)	(0.253)	(0.253)	(0.249)	(0.249)
Broadband infrastructure	1.123***	1.081***	1.079***	0.929***	1.040***
	(0.246)	(0.244)	(0.244)	(0.245)	(0.252)
Large firms		0.243	0.244	−0.228	−0.167
		(0.544)	(0.543)	(0.588)	(0.575)
Manufacturing growth			−0.280	−0.063	−0.120
			(0.400)	(0.404)	(0.384)
Services growth			−0.985	−1.045	−0.686
			(0.833)	(0.805)	(0.809)
Unemployment rate				−5.733**	−3.636
				(2.328)	(2.362)
Ich-AG policy					3.483***
					(0.677)
East Germany dummy	0.351**	0.370**	0.369**	0.813***	0.483*
	(0.144)	(0.154)	(0.154)	(0.234)	(0.248)
Constant	2.778***	2.737***	2.737***	3.206***	0.362
	(0.301)	(0.327)	(0.328)	(0.398)	(0.715)
Year dummies	*Included*				
No. of obs.	1,194	1,194	1,194	1,194	1,194
Log likelihood	−1,596.64	−1,596.20	−1,595.90	−1,585.03	−1,546.86
F (all)	36.83***	33.52***	27.83***	26.17***	23.41***

***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.1$

startup activity in general may be attributable to the low share that knowledge-based startups play in more general startup activity. The most prevalent form of startup is not based on knowledge spilling over from universities. This impact will be further considered when analyzing the effects on startup activities in different industry contexts in line with Hypothesis 3 later in this Section.

In terms of the control variables, the location of a county in the eastern states, the unemployment rate and the Ich-AG policy are all found to be associated to new firm startup activity. The impact of being located in the eastern states of Germany as well as of the Ich-AG granting scheme on startup activity actually is positive, whereas startup rates are linked negatively to the unemployment rate.[9]

Thus, the empirical results presented in Table 1 provide support for both Hypothesis 1 and Hypothesis 2. Infrastructure apparently is conducive to the startup of new firms, but the exact nature of the relationship depends upon the specific type of infrastructure considered and also the measure used to isolate the individual impact of the different infrastructures on startup activities.

In order to test Hypothesis 3, which suggests that startup activity in each industry context may respond in a singular way to a particular type of infrastructure,

[9] Note that the coefficient of East Germany almost doubles when we also control for unemployment. This pattern may be explained by the fact that structural differences in the unemployment existed between East and West Germany which may result in some kind of multicollinearity issue. The value of the coefficient drops again when we further include the Ich-AG policy scheme which was primarily launched to help unemployed to get self-employed if labor market opportunities were scarce. The correlation table in the "Appendix" reveals that the correlation between Ich-AG policy and East Germany is substantial and positive.

Table 2 Results for startup activities in different sectors

	High tech manufacturing	Low tech manufacturing	Tech. oriented services	Consumer-related services	Retail trade
Highway	0.001	0.003	0.009	−0.007	0.017
	(0.001)	(0.003)	(0.005)	(0.023)	(0.016)
Railway	0.001	0.002	0.026***	0.121***	0.041**
	(0.001)	(0.004)	(0.007)	(0.025)	(0.018)
Knowledge	−0.005	0.001	−0.105***	0.074	0.076
	(0.005)	(0.016)	(0.025)	(0.108)	(0.069)
Broadband	0.018**	0.016	0.105***	0.422***	0.235***
	(0.007)	(0.016)	(0.026)	(0.105)	(0.069)
Big firms	−0.026***	−0.144***	−0.052	0.375*	−0.179
	(0.009)	(0.027)	(0.056)	(0.206)	(0.151)
Manufacturing	0.004	−0.004	−0.024	0.300*	−0.131
	(0.118)	(0.042)	(0.053)	(0.171)	(0.148)
Services	0.062	0.021	−0.113	−0.861**	0.432*
	(0.049)	(0.093)	(0.146)	(0.389)	(0.241)
Unemployment	−0.160***	−0.116	−1.455***	−0.740	−0.540
	(0.046)	(0.135)	(0.230)	(0.971)	(0.551)
Ich-AG	0.038***	0.111**	0.308***	0.589**	0.701***
	(0.014)	(0.046)	(0.069)	(0.260)	(0.196)
East	0.010**	0.022*	0.091***	0.103	−0.158***
	(0.005)	(0.013)	(0.026)	(0.107)	(0.055)
Constant	0.017	0.093**	0.047	0.282	0.357*
	(0.015)	(0.045)	(0.070)	(0.261)	(0.187)
Year dummies	*Included*				
No. of obs.	1,194	1,194	1,194	1,194	1,194
Likelihood	2,606.88	1,553.53	1,063.52	−476.77	−57.53
F (all)	4.15***	7.09***	16.54***	8.31***	20.53***

***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.1$

Table 4 estimates the regression model for five distinct industry contexts—high technology manufacturing, low technology manufacturing,[10] technology oriented services, consumer-related services and retail trade. The OLS with clustered standard errors reported in Table 2 suggests that, in fact, the industry context makes a considerable difference in the way in which a particular type of infrastructure influences startup activity. The empirical results provide considerable support for the third Hypothesis. Broadband infrastructure is particularly conducive to the startup of new firms in high technology manufacturing, technology oriented services, consumer-related services and retail trade but not in low technology manufacturing.

By contrast, railway infrastructure is most conducive to new firm startups in technology oriented services, consumer-related services and retail trade, but not in either high technology or low technology manufacturing. An explanation why railway is not important for manufacturing sectors may be that our measure reflects the transportation of passengers—counting the long-distance railway stations in a county, whereas, for manufacturing sectors, the transportation of goods via railway could be more important. Unfortunately, we do not have the information on this type of railway service.

Knowledge infrastructure apparently fosters the startup activity of new firms in technology oriented services. This may reflect that the proximity to knowledge sources is particularly important for

[10] The distinction between those groups of manufacturing is made by looking at the sector's R&D intensity, i.e., total sector R&D expenditures divided by the aggregate sector's sales. If this exceeds 3.5 % the sector is attributed to be a high technology industry.

technology oriented startups in service sectors as they may profit from spillovers. For technology oriented manufacturing, it turns out to have no effect on the startup rate. This may be explained by the fact that firms active in those industries need larger space at reasonable prices compared to their counterparts in service sectors, which may not be provided in the proximity of knowledge generating institutions.

A key policy implication from these results is the following: Startup activities do not depend on general infrastructure investments. In contrast, particular infrastructure policies can be used to facilitate regional startup activities and, beyond, to control startup activities in desired industries. For example, regions which are striving to generate enhanced startup activity in specific sectors, such as high technology manufacturing, technology oriented services, consumer-related services or retail trade, would be well advised to prioritize investment in an up-to-date communication infrastructure. Beyond, in line with motorway availability, the estimation results show that not the availability of infrastructure drives startup activities. Instead, one should ask how much infrastructure quality matters for startups.

As discussed in the second section of this paper, broadband is particularly conducive to entrepreneurial activities because it provides an easy way to get into contact with a broader customer community and suppliers. In addition, broadband also facilitates the access to information and stimulates innovation activities. Therefore, it opens up new opportunities for entrepreneurial activities and new business models like e-commerce and new marketing strategies.

5 Conclusions

A large and important literature has focused on how the context in which an entrepreneurial decision is reached influences that decision. Important studies have focused on both the industry context (Lofstrom et al. 2013) and regional or spatial context (Sternberg 2009; Audretsch and Keilbach 2007; Parker 2009; Reynolds et al. 1994; Sternberg and Wennekers 2005; and Fritsch and Falk 2007). However, neither of these approaches has considered the role that infrastructure can play in the entrepreneurial decision and ultimately on startup activity. Such an omission is surprising, since a rich and vigorous literature has found compelling empirical evidence linking infrastructure to economic growth (Morrison and Schwartz 1996; Canning and Pedroni 2008; Aschauer 1989). That such infrastructure would have no impact on entrepreneurial opportunities might seem surprising and counter-intuitive.

Using a data set identifying startup activity as well as different types of infrastructure availability in Germany, this paper is one of the only studies to be able to provide a link between infrastructure and entrepreneurship. Most generally, infrastructure is found to be positively associated with startup activity. However, the association is apparently specific to both the particular type of infrastructure as well as the particular industry context within which the entrepreneurial decision is being considered.

There are a number of key qualifications and limitations inherent in this study. The first is that the study involves just one developed country, Germany. Whether this relationship holds for other national institutional contexts, especially in the less developed country context, can only be ascertained by carrying out the requisite subsequent research. The second qualification is that while this study does consider several types of infrastructure, there are clearly many more specific types of infrastructure that are not explicitly measured in our data base and therefore not analyzed in our study. Subsequent research needs to take infrastructure more seriously by creating new measures of more specific types of infrastructure. Broadband was found to be a key prerequisite in particular for high technology startups and consumer-related services and trade providing access to specific information and customers and opening up an alley for new business opportunities and models like e-commerce. While broadband is rolled out to the most extent in all developed countries up to now, a fundamental question which requires follow-on research is the impact of infrastructure quality on startups.

Still, the results of this paper do provide empirical evidence that infrastructure may be one of the most overlooked influences of entrepreneurial activity. Both public policy as well as future research would do well to recognize the key role that infrastructure plays in entrepreneurship.

Appendix

See Tables 3, 4 and 5.

Table 3 Descriptive statistics

	Mean	SD	Min	Max	Description
Startup (all)	4.174	1.013	1.787	7.773	Startup rate, all sectors
Startup (HT Manu.)	0.038	0.028	0.000	0.153	Startup rate, high technology manufacturing
Startup (LT Manu.)	0.162	0.069	0.000	0.373	Startup rate, low technology manufacturing
Startup (tech. serv.)	0.247	0.119	0.000	0.715	Startup rate, technology oriented services
Startup (Cons. serv.)	1.148	0.391	0.298	2.462	Startup rate, consumer oriented services
Startup (retail trade)	1.121	0.286	0.488	2.147	Startup rate, retail trade
Motorway	3.626	0.951	0.000	5.759	Log(number of motorway interchanges)
Railway	0.570	0.735	0.000	5.000	Number of long-distance train stations
Knowledge	0.204	0.207	0.000	1.066	Distance to closest university or research facility
Broadband	0.865	0.210	0.000	1.000	Broadband penetration index
Big firms	0.272	0.123	0.048	0.758	Percentage of employees in firms with more than 249 employees
Manufacturing	0.000	0.044	−0.147	0.159	Variation of gross value added in manufacturing sectors
Services	−0.003	0.020	−0.054	0.050	Variation of gross value added in service sectors
Unemployment	0.774	0.077	0.394	0.951	Short-term unemployment rate
Ich-AG	0.077	0.043	0.024	0.240	Subsidies for the unemployed to start a new firm introduced in 2003
East	0.184	0.388	0	1	Eastern Germany

Table 4 Correlations

	Startup	Motorway	Railway	Knowledge	Broadband	Big firms	Manufacturing	Services	Unemployment	Ich-AG	East
Startup	1.000										
Motorway	0.083	1.000									
Railway	0.214	0.093	1.000								
Knowledge	−0.115	−0.273	−0.054	1.000							
Broadband	0.246	0.090	0.051	−0.266	1.000						
Big firms	0.102	0.195	0.166	−0.351	0.318	1.000					
Manufacturing	0.094	0.014	0.015	−0.015	0.134	−0.008	1.000				
Services	−0.017	0.010	0.007	−0.040	−0.113	0.034	0.072	10.000			
Unemployment	−0.030	−0.089	−0.003	0.184	−0.279	−0.510	0.082	−0.097	1.000		
Ich-AG	0.327	−0.109	−0.066	−0.061	0.121	−0.047	0.137	−0.085	0.127	1.000	
East	0.060	−0.166	−0.010	0.131	−0.254	−0.361	0.048	−0.057	0.242	0.811	1.000

Table 5 Tobit regression for high technology manufacturing

	High technology manufacturing
Motorway	0.002
	(0.001)
Railway	0.001
	(0.001)
Knowledge	−0.005
	(0.006)
Broadband	0.020***
	(0.008)
Big firms	−0.027***
	(0.010)
Manufacturing	0.005
	(0.021)
Services	0.060
	(0.053)
Unemployment	−0.180***
	(0.054)
Ich-AG	0.035**
	(0.016)
East	0.012**
	(0.005)
Constant	0.015
	(0.016)
Year dummies	*Included*
Sigma	0.030***
	(0.001)
No. of obs.	1,194
Log Likelihood	2,087.25
F (all)	3.78***

***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.1$

Calculation of broadband penetration index

In contrast to publicly available information on the other types of infrastructure, details on broadband rollout and its availability are not publicly available in Europe, at least not on a county level. The impact of broadband on startups is twofold: First, broadband enables entrepreneurs to access knowledge without being close to a knowledge incubator and accessing a broad range of customers beyond regional proximity. Second, the transmission rate, i.e., the quality of broadband, is the key pre-condition to provide completely new types of services. In this second regard, broadband itself is a platform for completely new and innovative types of entrepreneurs whose business model completely depends on the high transmission rate of broadband. For our cross-infrastructure comparison, we focus on the impact of broadband availability on startups. Broadband was introduced in Germany mainly starting in 2000. Since then, no substitute infrastructure, such as cable or mobile infrastructure has been available which could have influenced the distribution of broadband in Germany.

We measure broadband availability using the date of the upgrade of MDFs. An MDF connects the local loop infrastructure and the backbone infrastructure. Thus, each MDF belongs to only one area with one common area code. As soon as an MDF is upgraded to provide access to higher-speed backbone infrastructure, this MDF can be used for local broadband access.[11] Households and companies with standard subscriber lines connected to an upgraded MDF by standard copper lines can directly switch to broadband without major physical arrangements.

Main distribution frames are not directly related to a particular county but serve households and companies also across county borders. Similarly, the capacity of MDFs is limited. Therefore, multiple MDFs are required to provide telecommunication services to a larger county. Taking into account these obstacles, we approximate broadband availability with the so-called broadband penetration index per county. Based on the area code, we know the subscriber lines per area and we also know the subscriber lines per MDF. Thus, we calculate the share of upgraded MDFs in an area as

$$shbb_{mt} = \frac{\sum_a \#sl_{amt}}{\#sl_{mt}}$$

which is the share of subscriber lines at upgraded MDFs per total subscriber lines in the area m at time t.

We use households as the linking pin between area codes and counties as households is the majority of broadband users and as households usually own one subscriber line. In so doing, we calculate the average broadband penetration based on the areas covering a county as follows:

$$PI_{it} = \sum_s \frac{\#hh_{ist}}{\sum_n \#hh_{int}} shbb_{st}$$

with $\frac{\#hh_{imt}}{\sum_n \#hh_{int}}$ as the share of households in county i with subscriber lines to MDFs in area m.

[11] Please note that we do not consider broadband with bid rates of 16 kbits or even higher but rely on the very first provision of broadband which was mainly at a transmission quality of 1 or 2 kbits.

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