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Sources of Knowledge Used by Entrepreneurial Firms in the European High-Tech Sector

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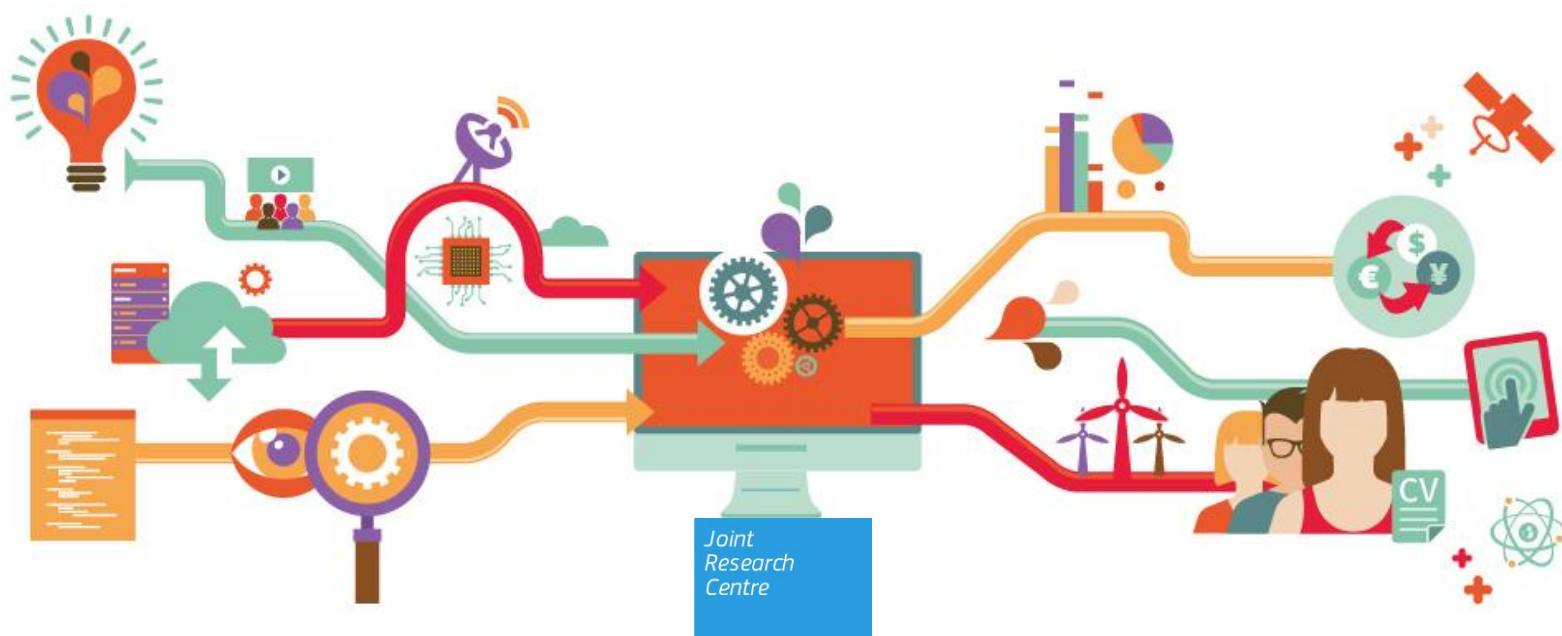
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Sources of Knowledge Used by Entrepreneurial Firms in the European High-Tech Sector

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Sara Amoroso, David B. Audretsch, and Albert N. Link

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Sources of Knowledge Used by Entrepreneurial Firms in the European High-Tech Sector¹

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Abstract

The purpose of this paper is to explore the relationship between an entrepreneur's experience and education and his/her reliance on alternative sources of knowledge for exploring new business opportunities. The extant literature that is at the crossroads between sources of knowledge and the experiential and intellectual base of an entrepreneur (i.e., dimensions of his/her human capital) suggests that it is through experience and through education that an entrepreneur obtains knowledge. Using information on a sample of high-tech manufacturing firms across 10 European countries, we explore heterogeneities in the influence of experience, age, and education of the firm's primary founder on the perceived importance of (i.e., use of) alternative sources of knowledge. We find that the association of these characteristics differs significantly across sources of knowledge, and across European regions. Education is positively related to the importance of knowledge from research institutes and internal know-how, while age is negatively related to the importance of research institutes and positively related to publications and conferences. On the one hand, in South/East European countries, the importance of internal know-how is positively associated with age and education, but negatively associated with experience. On the other hand, the characteristics of primary founders of North/West European firms are more linked to the importance of the participation to funded research programmes. This source of knowledge is related positively with age and education and negatively with experience.

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¹ The authors wish to thank the AEGIS consortium for providing data of the AEGIS survey which supported the empirical investigation of knowledge-intensive entrepreneurship in Europe in different sectoral, country and socioeconomic contexts. This survey was conducted in the context of the AEGIS research project (Advancing Knowledge-Intensive Entrepreneurship and Innovation for Economic Growth and Social Well-being in Europe) co-funded by the European Commission under Theme 8 "Socio-Economic Sciences and Humanities" of the 7th Framework Programme for Research and Technological Development.

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JEL Classification: L26; J24; D83

Let us then suppose the mind to be, as we say, white paper, void of all characters, without any *ideas*; how comes it to be furnished? Whence comes it by that vast store, which the busy and boundless fancy of man has painted on it, with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer, in one word, from *experience*; in that, all our knowledge is founded; and from that it ultimately derives itself.

—John Locke, *An Essay Concerning Human Understanding* (1690)

1. Introduction

In its policy mandate dictating that Europe needs to spur economic growth to reduce unemployment, the Lisbon Council of Europe turned to knowledge and entrepreneurship. Policy leaders in Europe reached a virtual consensus not only that the comparative advantage of Europe had shifted to knowledge, but also that entrepreneurship is essential to provide the conduit enabling the spillover of new ideas for commercialization and innovation that ultimately drive economic growth and employment.

The field of entrepreneurship has generally recognized that entrepreneurship revolves around opportunities—creating, recognizing, and acting upon them. Case studies and anecdotal studies emphasize that the knowledge spillover theory of entrepreneurship (KSTE) is indeed a foundation for understanding the perception and action of an entrepreneur (Audretsch, 1995; Acs et al., 2013; Ghio et al., 2015). The KSTE maintains that entrepreneurs and entrepreneurship are the key conduit taking knowledge and ideas generated in one organizational context (i.e., perception) and commercializing them in another organizational context (i.e., action). While much has been written about who the entrepreneur is and what he/she does, Hébert and Link (2009, p. 105) have synthesized scholarly thought on that topic as follows:

Does it matter that the entrepreneur is the person who provokes change or merely adjusts to it? If we rely on the most elemental features of entrepreneurship—perception, courage, and action—the answer is, probably not. Entrepreneurial action means creation of opportunity as well as response to existing circumstances. Entrepreneurial action also implies that entrepreneurs have the courage to embrace risks in the face of uncertainty. The failure of perception, nerve, or action renders the entrepreneur ineffective. For this reason, we must look to these elements for the distinctive nature of the concept, not to the circumstances of action or reaction.

An entrepreneur is one who perceives an opportunity and has the courage to act on that perception; entrepreneurship thus involves both perception as well as action. However, empirical research has generally not been able to rise to the conceptual standard posited by Hébert and Link (2009) largely due to measurement constraints. In fact, empirical studies approximated the perception of an opportunity by three available measures of sources of knowledge, namely human capital, research and development (R&D), and university research. What is problematic is that these limited

variables do not correspond to the wider concept of opportunities suggested by Hébert and Link (2009). Without systematic measurement, it has remained, until now, impossible to subject the importance and significance of a much broader and nuanced set of knowledge sources for entrepreneurial ventures to empirical scrutiny. Below, and throughout the empirical section of the paper, we focus on perception rather than action. That is, as discussed in Section II, our delimited focus being only on the perception of entrepreneurs to use one source of knowledge over another is necessitated by data limitations characterizing the performance of knowledge intensive entrepreneurial (KIE) firms.²

The purpose of this paper is to provide one of the first broad measures of knowledge sources of entrepreneurship in and among European countries and to identify characteristics of entrepreneurs who rely on these sources. As such, it extends the KSTE in that it goes beyond why new ventures are started or why new opportunities are pursued; it explores how new high-tech firms compete and why knowledge and its sources matter.³ Specifically, a survey of KIE firms across 10 European countries offers the response to a question that is, in our opinion, at the heart of understanding an important dimension of entrepreneurial activity, namely that importance associated with different sources of knowledge that influences the perception of and action on new opportunities. We relate the importance of alternative knowledge sources to the experience, age, and education of the primary founder of the firm.

Other scholars have relied on national data sets (e.g., Eurostat's Community Innovation Survey) to investigate sources of knowledge, as Vivas and Barge-Gil's (forthcoming) important survey of the literature ably documents. However, the extant literature on the use of alternative sources is thin as evidenced by Vivas and Barge-Gil having identified only 36 scholarly articles, and it has narrowly focused on firm characteristics (e.g., the size of the firm) rather than on characteristics of the entrepreneur (i.e., the founder of the firm in our case).⁴ Thus, building on the purpose of this paper, the scope of our analysis represents a first step toward a broader understanding of the relationship between the entrepreneur and his/her emphasis on alternative knowledge sources. Following the literature on entrepreneurial action, we focus on a founder's experience—work experience and experience that comes from age—and education to discriminate among the importance of alternative sources of knowledge. In particular, as the epigram at the start of this paper notes, one's experience is the basis for one's base of knowledge.

Schultz, for example, bridged the connection between experience and entrepreneurial behavior in terms of the connection between knowledge and education (1975, p. 827):

² We also use the acronym KIE to refer to knowledge intensive entrepreneurship.

³ For an excellent discussion of the importance of knowledge spillovers and building key relationship with suppliers as well as drawing on their market knowledge, see Audretsch and Lehmann (2016).

⁴ Vivas and Barge-Gil (forthcoming) do identify numerous studies that examine the impact of alternative sources of knowledge on firm performance, whereas we do not.

The main purpose of this study is to explore how education and experience influence the efficiency of human beings to perceive, to interpret correctly, and to undertake action that will appropriately reallocate their resources. The central questions to keep in mind are: To what extent are these allocative abilities acquired? Are education and experience measurable sources of these abilities? What factors determine the economic value of the stocks of such abilities that various individuals possess?

In fact, Schultz answered his own questions from the previous passage (1975, p. 828):

Our knowledge of a person's abilities consists of inferences drawn from his performance. An ability is thus perceived as the competence and efficiency with which particular acts are performed.

The remainder of this paper is outlined as follows. In Section II, we describe the data and explore the responses to our key survey question from firms in the high-tech sectors of the countries included in the AEGIS survey.⁵ Our focus on the high-tech sector is motivated by survey response categories that deal specifically with sources of research knowledge. As well, one might argue that high-tech manufacturing firms, compared to low-tech manufacturing firms and/or to firms in the knowledge-intensive business services sector, are now the engines of growth across European countries. In Section III we present the results of our empirical analysis. In Section IV, we offer brief concluding remarks, and we discuss future research based on our findings.

2. Data on Founder Experience, Education and the Importance of Sources of Knowledge

The European Commission under Theme 8 "Socio-Economic Sciences and Humanities" of the 7th Framework Programme (FP7) for Research and Technological Development funded the AEGIS (Advancing Knowledge-Intensive Entrepreneurship and Innovation for Economic Growth and Social Well-being in Europe) project.⁶ The focus of the AEGIS project was on KIE. The implicit assumption was that KIE is one potential means through which to obtain economic growth and societal well-being.

According to AEGIS (2012, p. 4):

Knowledge-intensive entrepreneurship is [the] core interface between two interdependent systems: the knowledge generation and diffusion system,

⁵ The high-tech manufacturing sector is defined to include the following: aerospace, computers and office machinery, radio-television and communication equipment, manufacture of medical, precision and optical instruments (scientific instruments), pharmaceuticals, manufacture of electrical machinery and apparatus, manufacture of machinery and equipment, and the chemical industry.

⁶ In Greek mythology the word Aegis refers to the powerful shield carried by Athena and Zeus.

on the one hand, and the productive system, on the other. Both systems shape and are shaped by the broader social context—including customs, culture and institutions—thus also pointing at the linkage of entrepreneurship to that context.

And, to elaborate on this definition of KIE, Malerba (2010, p. 4) wrote:

Knowledge-intensive entrepreneurship concerns new ventures that introduce innovations in the economic systems and that intensively use knowledge. From this broad definition, it follows that knowledge-intensive entrepreneurship may take place in various ways: through the foundation of new firms or through the display of entrepreneurial spirit with existing firms or through the action of single individuals within non-profit organizations such as universities or public laboratories.

As part of the AEGIS project, a broad-based survey of 4,004 KIE firms established between 2001 and 2007 across 10 European countries was conducted from late 2010 into 2011. The countries included in the survey were (alphabetically): Croatia, Czech Republic, Denmark, France, Germany, Greece, Italy, Portugal, Sweden, and the United Kingdom. Firms from the high-tech and low-tech sectors, and from the knowledge-intensive business services sector, are represented in the database although on 420 firms are in the high-tech manufacturing sector and are examined in this paper.⁷

Unique to the AEGIS database are responses to a question that is, in our opinion, at the heart of understanding an important dimension of entrepreneurial activity, namely that dimension associated with sources of knowledge that influences the perception of and action on new opportunities. The survey question is:

Please evaluate the importance of the following sources of knowledge for exploring new business opportunities on a 5-point scale, where 1 is not important and 5 is extremely important.

1. Clients or customers
2. Suppliers
3. Competitors
4. Public research institutes
5. Universities
6. External commercial labs/R&D firms/technical institutes
7. In-house (know-how, R&D laboratories in your firm)

⁷ The architects of the AEGIS database realized that firms in smaller countries would need to be over sampled. To account for non-random sampling across countries, sampling weights are used in the econometric analysis below. See Caloghirou et al. (2011) and Link and Swann (2016) on this issue. However, we relied on unweighted data for the construction of the descriptive tables below in an effort to facilitate replication of our results by others who might use the AEGIS database.

8. Trade fairs, conferences and exhibitions
9. Scientific journals and other trade or technical publications
10. Participation in nationally funded research programmes
11. Participation in EU funded research programmes (Framework Programmes)

In this section we explore the relationship between an entrepreneur's perception of an opportunity, as reflected through his/her evaluation of the importance of alternative sources of knowledge for exploring new business opportunities, and his/her experience, age, and education.

This survey question allows us to have a more nuanced look at knowledge sources than other researchers, as summarized by Vivas and Barge-Gil (forthcoming). In particular, a significant portion of the extant literature has focused dichotomously on knowledge gleaned from cooperation with other firms or not (e.g., Chun and Mun, 2012) or knowledge gained from the use of other firms' knowledge or not (e.g., Fritsch and Lukas, 2001). And, the use of this variable focuses the intent of the use of alternative sources of knowledge on exploring new business opportunities as opposed to performance in general.

Table 1 shows the importance of the sources of knowledge listed above for the 420 KIE firms in the high-tech manufacturing sector using the survey Likert responses of 1 through 5, where 1 is not important and 5 is extremely important. However, for econometric purposes we transformed these responses into a dichotomous variable where 1 is important (a survey response of 4 or 5) and 0 is not important (a survey response of 1, 2, or 3). See Table 2. These tables alone expand our understanding of knowledge sources relied on by entrepreneurs. In both tables clients or customers are the most important sources, but also important based on a mean response greater than 3.00 are suppliers, in-house know how, and to a lesser extent, competitors and participation at trade fairs, conferences, and exhibitions.

Insert Tables 1 and 2 about here

The literature on knowledge spillovers considers a narrower categorization of sources of knowledge than the 11 categories on the AEGIS survey questions (e.g., Kaiser, 2002; Belderbos et al., 2004). Moreover, the averages of importance of knowledge sources (Table 2) are similar among homogenous sources. For example, public research institutes, universities, external R&D labs have been ranked as important by a mean percentage of firms ranging from 13.3 to 16.9; scientific journals and conferences have been ranked as important by 31.4 to 43.1 percent of firms, and so on. Thus, following this literature, and the clustering of homogenous sources, we created 6 categories

from the above 11:⁸ Vertical sources, Horizontal sources, Research Institutes, Internal sources, Research Programmes, and Publications & Conferences. See Table 3.

Insert Table 3 about here

We recomputed the importance of alternative sources of knowledge in Table 4 using the newly constructed 6 categories. As in the previous tables, the most important sources of knowledge are the Vertical sources (clients or customers or suppliers) and Internal sources (in-house know how).

Insert Table 4 about here

The experience level of the primary founder was measured in terms of his/her years of work experience in the high-tech sector and his/her age.⁹ Overall, the mean level of work experience of the primary founders is 15.2 years with a range from 0 to 46 years (n=410). For descriptive purposes, we divide the 410 of 420 responses roughly into six groups as defined in Table 5. We will discuss these experience groupings below.

Insert Table 5 about here

Regarding the age of the primary founder, the AEGIS survey asks about the age of the primary founder in terms of age ranges, and we retain those age ranges. See Table 6. The categorical mean age is 3.16 (n=417), meaning that the mean age of the primary founder is early 50s or so. We will discuss these age groupings below.

Insert Table 6 about here

The educational level of the primary founder is reported categorically on the survey instrument rather than in specific years of education. See Table 7. The mean of the categories is 2.78 (n=400), meaning that on average a primary founder has less than a bachelor degree level of education. We will discuss these educational groupings below.

Insert Table 7 about here

⁸ Each category takes the value of 1 if at least one of the sub-categories is equal to 1. For example, if at least one of the sources among Clients and Suppliers take value 1, then the source of knowledge Vertical is equal to 1.

⁹ The AEGIS survey asks for the experience (and education) of up to four founders. We are assuming that the first listed founded is the primary founder, and we used his/her experience (and education) for this analysis. Our findings are unchanged if we used the average experience (and education) of all founders. These results are available from the authors on request.

Finally, Table 8 shows the distribution of KIE firms in the high-tech manufacturing sector by country. Our sample is dominated by French, German, and Italian firms.

Insert Table 8 about here

Tables 9 through 11 show the mean level of importance of alternative sources of knowledge by the experience, age, and education categories discussed above. Regardless of the amount of experience of the primary founder (Table 6), Vertical sources are the most important for exploring new business opportunities.¹⁰ This is also the case for the age of the primary founder (Table 10) and for alternative levels of education (Table 11). The pattern in these tables shows that the importance of Vertical sources of knowledge decreases with greater experience (> 24 years), with greater age (>50), and with greater education (PhD). The importance of Research Institutes and Internal know how is least for primary founders between the ages of 18 and 29. Regarding education, the importance of Research Institutes, Internal know how, and Research Programmes is least for primary founders with only and elementary educations. The importance of Internal know how increases with education.

Insert Tables 9 – 11 about here

Table X – This is a table			
	Financial constrains	Collective thinking	Heterogeneity
Financial constrains	1		
Collective thinking	0.456	1	
Hetherogeneity	-0.123	-0.369	1

Source/Note: Blab bla bla.

¹⁰ This finding may reflect proximity to clients, customers, and suppliers, but we do not have such data.

3. Empirical Analysis

To estimate econometrically the relationship between primary founders' experience, age, and education and the importance of alternative sources of knowledge for exploring new business opportunities, we employed a multivariate probit model. Differently from the estimation of separate probit models, the various sources of knowledge are treated here as interdependent thus allowing for possible correlations between the sources of knowledge and their importance that could be due to complementarities (a positive correlation). Positive correlation also arises if there are omitted firm-specific characteristics that affect the importance given to the various knowledge sources, but that are not observed or available. If a correlation exists, the estimates of separate probit regressions would be inefficient.

Another econometric issue may derive from omitting unobserved cultural and institutional characteristics that are potentially correlated with both the educational and professional background of the primary founder and the importance given to the sources of information. Assuming that cultural background varies only with the country, we partially control for this endogeneity problem by including country dummies. Moreover, we estimate cluster-robust standard errors as the correlation of firms within countries induces correlation in the error term of the model.

The marginal effects of our multivariate probit regression model are in Table 12. While the experience is not statistically associated with the importance of sources of knowledge, age and education are. For example, being older by one age class corresponds to a 5.7 percentage point decrease in probability of ranking Research Institutes as important sources of knowledge, and to an increase in the probability of attributing importance to publications and conferences by 9.7 percentage points. Finally, the marginal effects of education on Research Institutes and Internal know how should be interpreted as the average percentage increase in probability of ranking these sources of knowledge as important (3.9 and 8.9 percentage points, respectively) due to a one-stage increase in the educational attainment of the primary founder.

Insert Table 12 about here

Table 13 shows the correlations among the relevance of various sources of knowledge for high-tech manufacturing firms. The majority of correlation coefficients are positive and statistically significant, ranging from 0.111 to 0.694. This pattern supports the assumption of interdependence between sources of knowledge and their relevance, which may due to complementarities between the different knowledge sources or to omitted factors. The highest interdependence is between research institutes and participation to national/European research programmes.

Insert Tables 13 here

To explore the heterogeneity across countries of the relationship between sources of information and experience, age, and education, we estimate the multivariate probit model across country groups. In particular, we split the sample by two country groups to have a sufficient number of observations, while retaining salient information. The groups are North/West European countries (France, Germany, United Kingdom, Denmark, and Sweden) and South/East European countries (Italy, Portugal, Greece, Czech Republic, and Croatia).

Table 14 reports the marginal effects of experience, age, and education for North/West countries. A one-year increase in the experience of the primary founder corresponds to a decrease of the probability of ranking Vertical or Research Programmes as important sources of information (0.5 and 0.4 percentage point, respectively). Being older is positively associated with the importance given to Research Programmes as source of knowledge, while it is negatively related to ranking Research Institutes as important. Finally, an increase in the education stage increases the probability of attributing importance to knowledge coming from Research Institutes, Internal know-how, and Research Programmes.

Insert Tables 14 here

Table 15 shows the results of the multivariate probit estimations for the subsample of South/East countries. For firms located in this set of countries, having a greater number of years of previous experience in the sector and being younger are statistically associated with the importance of knowledge deriving from clients, suppliers, and competitors (Vertical and Horizontal). The situation is reversed for the relationship with internal knowledge sources. Finally, higher education corresponds to increases in the probability of ranking as important Horizontal, Internal, Research Programmes, and Publications & Conferences sources of knowledge.

4. Discussion and Conclusions

A large and robust finding in the literature is that just as entrepreneurship matters for the commercialization of knowledge, knowledge matters as a source generating and driving entrepreneurial activity. However, data and measurement constraints have left scholars with preciously few sources of knowledge to consider and evaluate, most notably human capital, research and development and university research. By utilizing a unique and novel source of data, the AEGIS database, this paper has been able to introduce the first analyses suggesting that, in fact, a considerably broader and more nuanced set of knowledge sources generate the opportunities fueling entrepreneurship. In particular, this study finds that while the more traditional source of knowledge matter for entrepreneurs, such as clients or customers, other sources, such as suppliers, in-house know how, competitors and trade fairs also contribute to entrepreneurship.

As scholars and thought leaders in policy and business place increased emphasis on the key role played by entrepreneurial firms in driving the economic performance of

cities, regions, and even countries, the results of this study clearly suggest that a much broader spectrum of sources of knowledge than had been previously been identified matters for entrepreneurship. It remains for subsequent scholars and research to continue to identify additional key sources of knowledge for entrepreneurs, both within but also beyond the European context, and to link those sources to entrepreneurial performance.

In this paper we have taken a first step in the direction of understanding alternative sources of knowledge based on the experience, age, and education of the firm's primary founder. Our results show that these characteristics matter for the choice and preference of the sources of knowledge. For the overall sample, more educated founders rely more on research institutes, probably due to their higher level of absorptive capacity. Also, we find a positive association between the level of education and the importance of in-house know how, suggesting that founders with higher levels of education tend to invest their own research. We obtain a clearer picture of the type of primary founders who banks on internal resources, when we divide the sample of firms into two groups according to their countries. In South/East European countries, the importance of internal R&D is positively associated with primary founders that have less experience in the sector of the firm, but that are older and educated. Conversely, the probability of choosing vertical and horizontal knowledge sources (clients, suppliers, and competitors) is associated with founders that are younger and less educated, but that have previous experience in the sector. On the other hand, among North/West European firms, the characteristics of the primary founders are mainly linked to importance of the participation to nationally or EU funded Research Programmes, and public and private Research Institutes. Being less experienced, older, and more educated is related to a greater reliance on Research Programmes, while being younger and more educated increase the probability of sourcing knowledge from Research Institutes. This could be a consequence of the better industry-research knowledge transfer systems present in North/West European countries.

In conclusion, we find that these human capital attributes of a founder matter in some instances and in some parts of Europe, but not in others. Much more research needs to be done on the relationship between these human capital attributes and knowledge sources as well on the relationship between the use of alternative knowledge sources and the performance of knowledge intensive entrepreneurial firms.

Table1 – Importance of Alternative AEGIS Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector (n=420)

AEGIS Sources of Knowledge	Mean	Standard Deviation
Clients or customers	4.429	0.878
Suppliers	3.626	1.189
Competitors	3.334	1.148
Public research institutes	2.157	1.160
Universities	2.212	1.226
External commercial labs / R&D firms / technical institutes	2.176	1.241
In-house know how	3.438	1.497
Trade fairs, conferences, and exhibitions	3.136	1.247
Scientific journal and other trade or technical publications	2.845	1.227
Participation in nationally funded research programmes	2.083	1.283
Participation in EU funded research programmes	1.048	1.310

Notes:

The high-tech manufacturing sector is defined to include the following: aerospace, computers and office machinery, radio-television and communication equipment, manufacture of medical, precision and optical instruments (scientific instruments), pharmaceuticals, manufacture of electrical machinery and apparatus, manufacture of machinery and equipment, and the chemical industry.

The range for all values is 1 – 5 where 5=extremely important and 1=not important.

Table 2 – Importance of Alternative AEGIS Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector (n=420)

AEGIS Sources of Knowledge	Mean	Standard Deviation
Clients or customers	0.864	0.343
Suppliers	0.588	0.493
Competitors	0.455	0.499
Public research institutes	0.133	0.340
Universities	0.167	0.373
External commercial labs / R&D firms / technical institutes	0.169	0.375
In-house know how	0.590	0.492
Trade fairs, conferences, and exhibitions	0.431	0.496
Scientific journal and other trade or technical publications	0.314	0.467
Participation in nationally funded research programmes	0.179	0.383
Participation in EU funded research programmes	0.183	0.387

Note:

The range for all values is 1 or 0 where 1=important and 0=not important.

Table 3 – Construction of Alternative New Sources of Knowledge Categories from the AEGIS Sources of Knowledge Categories

Alternative AEGIS Sources of Knowledge Categories	Alternative New Sources of Knowledge Categories
Clients or customers	Vertical
Suppliers	Vertical
Competitors	Horizontal
Public research institutes	Research Institutes
Universities	Research Institutes
External commercial labs / R&D firms / technical institutes	Research Institutes
In-house know how	Internal
Trade fairs, conferences, and exhibitions	Publications & Conferences
Scientific journal and other trade or technical publications	Publications & Conferences
Participation in nationally funded research programmes	Research Programmes
Participation in EU funded research programmes	Research Programmes

Table 4 – Importance of Alternative New Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector (n=420)

Sources of Knowledge	Mean	Standard Deviation
Vertical	0.914	0.280
Horizontal	0.455	0.499
Research Institutes	0.267	0.443
Internal	0.590	0.492
Research Programmes	0.226	0.419
Publications & Conferences	0.504	0.501

Note:

The range for all values is 1 or 0 where 1=important and 0=not important.

**Table 5 – Distribution of Sector Experience of the Primary Founders of the KIE Firms
(n=420)**

Category	Years of Sector Experience	Number of Founders
1	< 6 years	91
2	6≤ years ≤11	77
3	12≤ years ≤17	82
4	18≤ years ≤24	72
5	> 24 years	88
6	No response	10

Note: Mean years of sector experience=15.2 (n=410).

**Table 6 – Distribution of the Age of the Primary Founders of the KIE Firms
(n=420)**

Category	Age	Number of Founders
1	18 – 29	14
2	30 – 39	78
3	40 – 49	151
4	> 50	174
5	No response	3

Note: Mean categorical age=3.16 (n=417).

Table 7 – Distribution of Categorical Education Level of the Primary Founders of the KIE Firms (n=420)

Category	Education Level	Number of Founders
1	Elementary education	42
2	Secondary education	153
3	Bachelor degree	87
4	Postgraduate degree	89
5	PhD	29
6	Do not know	20

Note: Mean categorical education level=2.78 (n=400).

**Table 8 – Distribution of KIE Firms in the High-Tech Manufacturing Sector, by Country
(n=420)**

Country	Number of Firm
Croatia	35
Czech Republic	25
Denmark	34
France	68
Germany	67
Greece	22
Italy	57
Portugal	31
Sweden	34
United Kingdom	47

Table 9 – Mean Importance of Alternative New Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector by Amount of Sector Experience of the Primary Founders (n=410)

Sources of Knowledge	<6Years	6≤Years≤11	12≤Years≤17	18≤Years≤24	>24Years
Vertical	0.934	0.922	0.939	0.944	0.841
Horizontal	0.429	0.442	0.451	0.500	0.455
Research Institutes	0.308	0.273	0.305	0.222	0.250
Internal	0.527	0.610	0.634	0.542	0.648
Research Programmes	0.242	0.273	0.171	0.208	0.250
Publications & Conferences	0.451	0.636	0.488	0.444	0.523

Note: 1=important and 0=not important.

Table 10 – Mean Importance of Alternative New Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector by Age of the Primary Founders (n=417)

Sources of Knowledge		18 – 29	30 – 39	40 – 49	> 50
Vertical		1.00	0.910	0.954	0.874
Horizontal		0.714	0.436	0.464	0.437
Research Institutes		0.214	0.282	0.265	0.270
Internal		0.357	0.603	0.550	0.644
Research Programmes		0.429	0.205	0.192	0.253
Publications & Conferences		0.429	0.487	0.490	0.534

Note: 1=important and 0=not important.

Table 11 – Mean Importance of Alternative New Sources of Knowledge for Exploring New Business Opportunities among KIE Firms in the High-Tech Manufacturing Sector by Educational Level of the Primary Founders (n=400)

Sources of Knowledge	Elementary Education	Secondary Education	Bachelor Degree	Postgraduate Degree	PhD
Vertical	0.976	0.895	0.966	0.921	0.793
Horizontal	0.286	0.484	0.540	0.360	0.448
Research Institutes	0.167	0.255	0.345	0.213	0.448
Internal	0.333	0.523	0.632	0.697	0.897
Research Programmes	0.119	0.222	0.276	0.236	0.310
Publications & Conferences	0.405	0.503	0.563	0.461	0.655

Note: 1=important and 0=not important.

Table 12 – Multivariate Probit Regression Marginal Effects (cluster-adjusted standard errors) (n=395)

Variable		Alternative Sources of Knowledge					
		Vertical	Horizontal	Research Institutes	Internal	Research Programmes	Publications & Conferences
Experience		-0.002	0.005	0.002	-0.003	-0.004	-0.004
		(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Age		-0.014	-0.063	-0.057*	0.035	0.025	0.097**
		(0.0130)	(0.041)	(0.032)	(0.039)	(0.033)	(0.072)
Education		-0.011	0.006	0.039**	0.089***	0.022	0.013
		(0.017)	(0.025)	(0.019)	(0.022)	(0.019)	(0.024)
Country effects	fixed	yes	yes	yes	yes	yes	yes
Wald Chi² (68) = 217.50***							
Log-Likelihood= -63319.8							

Note: * .10-level of significance, ** .05-level of significance, *** .01-level of significance. Constants are estimated but not reported.

Table 13 – Estimated Correlations between Alternative New Sources of Knowledge for Exploring New Business Opportunities (n=395)

	Vertical	Horizontal	Research Institute s	Internal	Research Programme s	Publication s & Conference s
Vertical	1					
Horizontal	-0.053	1				
Research Institutes	-0.072	0.216***	1			
Internal	0.375***	-0.016	0.225*	1		
Research Programmes	0.012	0.111***	0.694***	0.244***	1	
Publications & Conferences	0.163	0.186**	0.190***	0.299***	0.444***	1

Note: ** .05-level of significance, *** .01-level of significance

Table 14 – Multivariate Probit Regression Marginal Effects (cluster-adjusted standard errors) – North/West Countries (n=232)

Variable	Alternative Sources of Knowledge					
	Vertical	Horizontal	Research Institutes	Internal	Research Programmes	Publications & Conferences
Experience	-0.005** (0.002)	0.005 (0.004)	0.002 (0.003)	0.002 (0.003)	-0.004* (0.002)	-0.004 (0.004)
Age	0.013 (0.025)	-0.066 (0.057)	-0.049* (0.029)	0.030 (0.070)	0.050** (0.021)	0.146 (0.116)
Education	-0.012 (0.016)	0.004 (0.023)	0.057*** (0.015)	0.098*** (0.029)	0.044*** (0.013)	0.018 (0.019)
Country fixed effects	yes	yes	yes	yes	yes	yes
Wald Chi ² (4) = 26.39***						
Log-Likelihood= -42175.8						

Note: * .10-level of significance, ** .05-level of significance, *** .01-level of significance. Constants are estimated but not reported.

Table 15 – Multivariate Probit Regression Marginal Effects (cluster-adjusted standard errors) – South/East Countries (n=163)

Variable	Alternative Sources of Knowledge					
	Vertical	Horizontal	Research Institutes	Internal	Research Programmes	Publications & Conferences
Experience	0.002** (0.000)	0.006*** (0.002)	0.001 (0.004)	-0.010*** (0.003)	-0.004 (0.003)	-0.001 (0.002)
Age	-0.039*** (0.007)	-0.069*** (0.019)	-0.056 (0.068)	0.068*** (0.024)	-0.013 (0.036)	0.001 (0.025)
Education	-0.013*** (0.005)	0.017* (0.010)	-0.010 (0.010)	0.072** (0.020)	0.042** (0.020)	0.020** (0.008)
Country fixed effects	yes	yes	yes	yes	yes	yes
Wald Chi ² (4) = 71.31***						
Log-Likelihood= -20166.0						

Note: * .10-level of significance, ** .05-level of significance, *** .01-level of significance. Constants are estimated but not reported.

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