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An Analysis of Similarities and Dissimilarities Among Categories of Deep Tech Entrepreneurship: Evidence from Turkey

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ABSTRACT

Purpose: This study aims to understand the similarities and dissimilarities among categories of deep tech entrepreneurship and to be a starting point for academia to further explore the significance of the deep tech field.

Methodology: We have surveyed 126 deep tech startups and used hypothesis testing to understand how attributes such as needs, education level of the founders, financing types differs based on deep tech startup categories.

Findings: We have discovered that while the location of the deep tech startup, the education level of the founders, the past entrepreneurship experience of the founders, and the sales footprint characteristic of the deep tech startup vary according to the deep tech category, the needs of the deep tech startups are similar for each category.

Practical Implications: The results are expected to help practitioners make their decisions more accurately while investing or collaborating with deep tech startups. Similarly, policymakers can use the results to develop more relevant policies to support the deep tech entrepreneurship ecosystem.

Originality: This study is unique in terms of; 1) defining deep tech in academia 2) understanding how deep tech attributes are related with deep tech categories. 3) exploring deep tech in a developing country.

Keywords: Deep Tech, Entrepreneurship, Startup

JEL Codes: M13, M19, M31.

Derin Teknoloji Girişim Kategorileri Arasındaki Benzerlik ve Farklılıkların Analizi: Türkiye Örneği

ÖZ

Amaç: Bu çalışma, derin teknoloji girişim kategorileri arasındaki benzerlikleri ve farklılıkları anlamayı ve derin teknoloji alanında bundan sonra gerçekleştirilecek akademik çalışmalar için bir başlangıç noktası olmayı amaçlamaktadır.

Yöntem: İhtiyaçlar, kurucuların eğitim seviyesi ve finansman tipi gibi özelliklerin derin teknoloji kategorileri bazında nasıl değiştiğini anlamak amacıyla 126 derin teknoloji girişimi ile anket yapılmış ve hipotez testi uygulanmıştır.

Bulgular: Derin teknoloji girişimlerinin bulunduğu lokasyon, kurucuların eğitim seviyesi, kurucuların geçmiş girişimcilik deneyimi ve derin teknoloji girişiminin satış ayak izi özelliklerinin derin teknoloji kategorisine göre farklılık gösterdiği görülmüştür.

Sonuç ve Öneriler: Sonuçların, uygulayıcıların derin teknoloji girişimlerine yatırım yaparken veya onlarla iş birliği yaparken kararlarını daha doğru vermelerine yardımcı olması beklenmektedir. Benzer şekilde politika yapıcılar da derin teknoloji girişimciliği ekosistemini desteklemek için daha etkili politikalar geliştirmek için bu çalışmadan faydalanabilir.

Özgün Değer: Bu çalışma şu açılardan özgündür; 1) akademik literatürde derin teknoloji tanımı yapılması 2) derin teknoloji özelliklerinin derin teknoloji kategorileriyle olan ilişkisinin anlaşılması 3) gelişmekte olan bir ülkede derin teknolojinin anlaşılması.

Anahtar Kelimeler: Derin teknoloji, Girişimcilik, Startup

JEL Sınıflandırması: M13, M19, M31

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1. Introduction

For some, deep tech is a new phenomenon and marks the future (Sinclair, 2020), while for others, it is not new at all (de la Tour et al., 2017); rather, its roots date back more than 2,500 years, starting with a thinker who sparked the development of arithmetic by using symbols to numerically keep track of objects (Gourévitch et al., 2020). Even if we do not go that far back, the technologies that have fueled the recent digital industrial revolution (de la Tour et al., 2017), or simply put, enabled college students to develop multi-billion dollar companies such as Microsoft and Facebook, can be considered deep technologies.

Nevertheless, the digital revolution is coming to an end as the tech companies run out of business models and value propositions that they can create with digital technologies; therefore, investors are seeking the next wave of opportunities to bet on (Harlé et al., 2017b). They seek opportunities not only on the next wave comprised of companies developing deep technologies, but also the following wave where post-digital tech companies will start another industrial revolution creating new value propositions and business models based on deep technologies that will be commercialized and accessible (European Startups, 2021).

This has given deep tech enough prominence that even governments are starting to pay attention: Governments are noticing because deep tech is expected to create a significant number of new, highly skilled jobs, which will trigger nation-wide economic growth (Luca, 2020; Kirchhoff & Spencer, 2008; Steenhuis & de Bruijn, 2006; Frenkel, 2012; Adhikari et al., 2014), create new markets (Boston Consulting Group & Hello Tomorrow, 2019), and promote the global economy (Adhikari et al., 2014). On top of these, deep tech has the potential to solve the most pressing global challenges, including ones involving the environment, society, and health (Portincaso et al., 2020). Biontech is a great example of deep tech's potential to solve a global health, societal and economic crisis starting with the COVID-19 pandemic (European Startups, 2021). Moderna and Ginkgo Bioworks have also shown a similar potential to change the shape of the future of humanity (Portincaso et al., 2020).

To realize these benefits, an entrepreneurship mindset is needed to transform inventions from lab science to commercial products in the market (Portincaso et al., 2020), as in the COVID-19 case. In this respect, European Commission (2021) emphasizes the importance of providing resources for innovators to be able to boost the economy in the years to come. According to Harlé et al. (2017b), what deep tech entrepreneurs need the most are market access, technical knowledge and expertise, business knowledge, talent acquisition, funding and access to facilities. These requirements arise from functional needs that are very specific to deep tech: the long time to market, the intensity of procuring high capital, the building of complex and risky technologies, and the uncertain path to commercialization (de la Tour et al., 2017).

However, most of these insights have come from technical reports on deep tech industry analysis published by consulting/research companies or institutions, which were conducted in specific regions for business purposes. To the best of our knowledge, there is no empirical research study that profiles deep tech start-ups, especially based on their deep tech categories. Therefore, our aim is to present our observations about the deep tech industry in Turkey and to interpret them in a way that is meaningful for global practices.

In the pages that follow, the relationship between the deep tech categories and the aspects that are critical to the success of deep tech entrepreneurship is explored. The study is organized as follows: Section 2.1 gives an overview of deep tech and high tech literature, discusses various definitions of deep tech and proposes a deep tech definition that is used throughout the article. Section 2.2 gives an overview of deep tech entrepreneurship throughout the world. Section 2.3 gives an overall picture of deep tech in Turkey, where the survey data was collected. Section 3 gives details regarding data collection method, survey participants, research hypotheses and results. Finally, in Section 4, the results and their implications are discussed. We believe that the findings of this study shed light on research in the deep tech field and that it will be significantly useful for researchers, practitioners, and policymakers.

2. Literature Review

2.1. Definition of Deep Tech

Despite the fact that the roots of the term “deep tech” go back a few decades to a book on technical and scientific communication (Lutz and Storms, 1998), the term itself was first used by Chaturvedi (2015), the venture capital firm Propel(x)’s CEO, in its current meaning. Later on, it was widely adopted by the business world and is gaining traction with academia, albeit only recently.

To help clarify what deep tech is and isn't, according to Chatuverdi (2015), deep tech is about scientific discovery and meaningful engineering innovation. It is not a business model innovation on digital technologies, such as what Uber Technologies, Inc., and other companies which are based on the sharing economy approach. Deep tech is also not a process, product, service, or function innovation that uses digital technologies (Harlé et al., 2017a). In other words, deep tech companies are not traditional technology startups that create a customer experience (Tavşan & Erdem, 2018). They do not focus on quickly building a minimum viable product (MVP) and acquiring customers (Sinclair, 2020), or relying on the Internet, which made its first debut in the 1990s (SGInnovate, 2019).

Yet, "what deep tech isn't" seems clearer than "what it is" (European Startups, 2021). When we look at what deep tech means and what a deep tech company is doing, we see that one of the most essential qualities of a deep tech company is that it aims to solve the most critical global problems in areas such as health, mobility, agriculture, environment and business (Harlé et al., 2017a; SGInnovate, 2019; Chaturvedi, 2015; European Startups, 2021) and to transform the world by solving them (Chaturvedi, 2015; Different, 2020; Sinclair, 2020). While aiming to achieve these challenges, deep tech companies push the scientific and engineering limits (Chaturvedi, 2015; Harlé et al., 2017a; Biert, 2020; Deep Tech Europe, 2020), conducting scientific research in labs with teams of gifted research scientists and engineers (SGInnovate, 2019; European Startups, 2021; Gourévitch et al., 2020) to come up with advanced technologies that are unique and difficult to imitate (de la Tour et al., 2017; Luca, 2020; Kingon et al., 2002) and providing a significant competitive edge (Biert, 2020). They aim to change either the technology or the product field (Aleixo and Tenera, 2009). Science and engineering go hand in hand throughout the innovation process (Portincaso et al., 2020) and novel science and R&D-heavy products are developed (Different, 2020; Boston Consulting Group and Hello Tomorrow, 2019).

Another aspect of deep tech is that it needs relatively larger funds than most other start-ups (SGInnovate, 2019; Harlé et al., 2017a; Portincaso et al., 2020) and burns cash over a longer period of time (European Startups, 2021) compared to other technologies. The deep tech startups need large investments (de la Tour et al., 2017) to get their products to market (Biert, 2020). In 2018, developing prototypes cost between $200,000 to $1.4 million each (Gourévitch et al., 2020).

Commercialization risk is another area where things work differently for deep tech companies. It is uncertain whether the commercial application of the technology will even work (de la Tour et al., 2017; Aleixo and Tenera, 2009) especially at the beginning. The R&D risk level is also a critical aspect that defines deep tech; it is faced even before the market and commercialization risks, which are equally important yet suspended at the beginning of the development process (Sinclair, 2020; European Startups, 2021; Deep Tech Europe, 2020). Most of the time, deep tech involves R&D risk and commercialization risk simultaneously, except for some cases like biotech that has mostly R&D risk (European Startups, 2021) because the market is there right at the beginning. Long development cycles that prolong the time to commercialization also determine the very nature of deep tech startups. It requires a considerable time to develop a working product (Biert, 2020; Harlé et al., 2017a; de la Tour et al., 2017; Boston Consulting Group & Hello Tomorrow, 2019) and come up with a working value proposition and business model (SGInnovate, 2019).

Putting it all together, to be able to call a tech "deep," it should: 1) Be a unique and advanced technology requiring extensive scientific & engineering research, 2) Aim to tackle critical global issues that traditional technologies cannot solve, 3) Need a large investment that is spent over the long term, 4) Involve massive commercialization and R&D risk, and 5) Have long development cycles.

On the other hand, there already exists a concept similar to deep tech that has a wider and older footprint in the literature: high tech. According to some, high tech and deep tech are almost the same concept (Gourévitch et al., 2020; Luca, 2020). Almost all the high tech definitions revolve around R&D cost intensity (Steenhuis and de Bruijn, 2006), which is calculated as R&D expenditures divided by a denominator, such as value-added or production (OECD Directorate for Science, Technology and Industry, 2011) indicating the high tech level of a product, company (Luca, 2020) or process (Steenhuis & de Bruijn, 2006). Newness and complexity are also referred to as aspects of high tech (Steenhuis and de Bruijn, 2006). Long development periods, high risk & high returns are other aspects of high tech (Hervé, 2010). Some researchers identify high tech criteria such as "computer intensity" (Upward et al., 2013), making the concept limited for a narrow time frame, which means it can become obsolete quickly.

By exploring the literature more fully, it becomes apparent that the definition of high tech seems to have a broad range (Steenhuis and de Bruijn, 2006) that not only includes deep tech, but crosses the border into the traditional technology arena. For instance, the life-cycle-based definition by Bacon et al. (1994), explains that high tech industries have short development cycles, as opposed to the long term cycles necessitated by deep tech characteristics. This is understandable, since it refers to the continuously updated computer hardware products and the fierce competition that pushes the companies to make incremental improvements and market the technologies constantly at the time. However, technology has phases where it starts raw at first, then becomes an infrastructure, and then creates new business models and marketplaces (Sinclair, 2020). In the first phase, radical innovation occurs where there is high risk and uncertainty (Aleixo and Tenera, 2009). In the second and third phases, the technology is being improved by using innovation approaches that are less radical and more incremental, making the product life cycles shorter and shorter. The technology, which started as deep, becomes a commodity (Sinclair, 2020). Therefore, radical innovation creates a pioneering deep tech product within a long product life-cycle and transforms into incremental innovation with shorter life-cycles as the product becomes more and more commercial. Therefore, the deep tech product emerges as a traditional tech product on this journey. Because of this, in this article, tech products in the phase of short life cycles will not be referred to as "deep tech." The semi-conductor sector is an excellent example of this journey, which started in 1951 as deep tech and became the fastest-growing sector with short development cycles and huge competition. As a result, The Santa Clara Valley became known as Silicon Valley (Huffman and Quigley, 2002).

As much as it would be convenient for high tech to finally have a settled definition, it is still inconsistent and relative (Steenhuis and de Bruijn, 2006) despite the long history. Some high tech definitions have very high inclusivity ranges, revealing that high tech industries are about innovation and entrepreneurship (Hsiao et al., 2013). Considering the broadness of definitions of high tech throughout the literature, it can be determined that deep tech is a subset of the high tech ecosystem. In this study, articles from the high tech literature have been used based on the similarity of their high tech definition to this study's proposed deep tech definition, that is: Deep tech is a unique and advanced technology which requires extensive scientific and engineering research, aims to deal with the most critical global issues that cannot be solved by traditional technologies, needs large investments that are used over the long term, has huge commercialization and R&D risk, and is developed in long cycles.

2.2 Deep Tech Entrepreneurship in The World

The underlying idea of treating deep tech as an entrepreneurial subject is to find a way to respond to the challenging task of taking a complex technology out of the lab and making it available to industries and people (El Ghak et al., 2020). Deep tech entrepreneurship is the tool for highly educated scientists and engineers (Braguinsky et al., 2012) to transform new scientific knowledge and cutting-edge technologies into economic and social benefits (El Ghak et al., 2020). After a long period of investing in digital technologies that have been relatively simple to understand and fast to scale, in recent years investors have turned toward investing in intensive science and engineering deep tech startups (SGInnovate, 2019).

Merging scientific knowledge and experience to create innovations (Braguinsky et al., 2012), deep tech entrepreneurship has been the most significant factor spurring current economic growth (Luca, 2020). It has footprints mostly in the US and Europe, followed by China (SGInnovate, 2019). Deep tech companies have been recently getting more investments than other types of tech companies: According to Boston Consulting Group & Hello Tomorrow (2019), there are 8,682 companies in 69 markets globally, and private investment in deep tech has shown 22% growth between 2015 and 2018, from a size of $9,854 billion to $17,886 billion (Gourévitch et al., 2020). The investments rose by ten times in a broader time scale between 2012 and 2017 (SGInnovate, 2019) and have been directed towards several sectors.

In the US, $35.7 billion were invested in deep tech, and half of the amount went into the life sciences sector (Portincaso et al., 2020; Different, 2020), showing that the US will be leading deep tech in the foreseeable future (SGInnovate, 2019). In Europe, the European Union is funding deep tech with €10 billion annually. As a result, the total value of European deep tech companies has reached €700 billion. A small portion of these companies has had more than $1 billion valuations (European Startups, 2021), 40% of the companies in the growth phase are profitable, and almost the same number of them are on their way to break even in 2 years (Bogen et al., 2020). The trend seems destined to keep its upward direction considering the supportive actions of The Advisory Board of the European Innovation Council (European Commission, 2021).

Deep tech entrepreneurship exists for a wide range of specialties, such as Internet of Things (IoT) and Industry 4.0 technologies (Alonso, 2021), aircraft and spacecraft technologies (OECD Directorate for Science, Technology and Industry, 2011), distributed-ledger and blockchain technologies (Shoeibi, 2021), biotechnology (Portincaso et al., 2020), advanced materials, nanotechnology (Different, 2020), photonics (Boston Consulting Group and Hello Tomorrow, 2019), electronics (Sinclair, 2020), augmented & virtual reality (AR & VR) (Different, 2020), medical technologies, quantum computing technologies, renewable energy technologies, artificial intelligence (AI), robotics, agriculture technologies, and autonomous technologies (SGInnovate, 2019; Chaturvedi, 2015). As it may seem, the problems that can be tackled with deep tech range from autonomous governance of data (Yanık and Kılıç, 2018) to curing cancer (Portincaso et al., 2020).

Although they appear to be successfully working with a broad range of technologies, deep tech startups have several challenges that may cause them to fail (Krishna and Subrahmanya, 2015). Collaboration is one of the areas where deep tech companies struggle. An ecosystem of startups, universities, government agencies, venture capital investors, foundations, and corporations, which is a value network rather than a value chain (Rosenstand, 2020), is crucial for deep tech startups (Portincaso et al., 2020) because they need access to information, talent, expertise, and funds (de la Tour et al., 2017; Bogen et al., 2020) that are distributed in terms of geography, sector, and function (Boston Consulting Group and Hello Tomorrow, 2019). To overcome the difficulty of connecting with those scattered resources, many deep tech companies choose to reside in clusters (Adler et al., 2019), such as in science and technology parks (Chen and Altantsetseg, 2017), the most famous example being Silicon Valley (Rosenstand, 2020). However, there are many discussions about whether these parks actually deliver the value initially promised (Kılıç, 2020), meaning that these challenges still persist for deep tech at a certain level.

As far as partnerships with established corporations go, deep tech companies need them to supply critical business skills, such as procurement, achieving scale

(Harlé et al., 2017b) and internationalization (Bogen et al., 2020) because most of deep tech entrepreneurs are scientists who are phenomenal at research and development, but may lack marketing knowledge on how to package their new technology as a commercial product or service (SGInnovate, 2019), which is the key to success (Marvel, 2013). Almost all of the deep tech entrepreneurs want to work with corporations, yet only 57% of them are doing so in practice (Harlé et al., 2017b), and half of these companies rate their experience as "mediocre or worse" (de la Tour et al., 2017). In comparison, European startups find Small-Medium Enterprises (SME) more flexible than established corporations for partnerships.

Another challenge that deep tech entrepreneurs face is getting access to funds. The investment journey is somewhat different from regular tech startups (Boston Consulting Group and Hello Tomorrow, 2019). Although digitalization and artificial intelligence are expected to make deep tech's development cycles faster (European Startups, 2021; Gourévitch et al., 2020), the current situation shows very long commercialization cycles—hence the need for investor patience (SGInnovate, 2019), which, unfortunately is difficult to find. There is a heterogeneous capital gap in deep tech (Different, 2020), and deep tech founders quickly discover that they must procure their own financing, get financial help from friends and family, or seek government sources for the first stage of funding (Bogen et al., 2020; Harlé et al., 2017b). Because the evaluation of complex technologies creates barriers (SGInnovate, 2019) and high information asymmetries (Grilli, 2014) for investors, along with the extended return periods and high failure rate (Krishna & Subrahmanya, 2015), obtaining early public funding is critical for deep tech entrepreneurship (European Startups, 2021).

Regulations are also another challenge for deep tech entrepreneurship (Krishna and Subrahmanya, 2015). In Europe, for example, regulations are complex and prevent companies from transferring their technology into business (El Ghak et al., 2020). Policies can also make internationalization difficult for deep tech startups (Hsiao et al., 2013). In addition to the content of the regulations, their transparency and the predictability of regulations is critical, as well (Bogen et al., 2020). Licensing, which is a prerequisite for deep tech companies to attract funds (Phillips and Brigham, 2007), is another area that needs simplification, as the current processes are very complex and tiring (SGInnovate, 2019).

Overall, deep tech entrepreneurship is developing significantly worldwide, especially in America, Europe, and China, with the sizes of investment playing a critical role. Deep tech entrepreneurs are trying to solve a wide range of problems, and several deep tech categories have evolved over time. In the meantime, deep tech entrepreneurs have been facing challenges that are specific to the nature of deep tech in areas of collaboration, funding, and regulations.

2.3. Deep Tech Entrepreneurship in Turkey

With a population of 82.6 million, Turkey generated $761.8 billion GDP within 2020 (World Bank, 2021). The country has 84 science and technology parks where 5,846 firms reside with 58,922 employees executing 36,535 R&D projects as of 2020 (Duran et al., 2021). The deep tech scene itself is not very deep at all. Most being located in one of these parks, there are 1,200 deep tech startups, 131 of which have received a total investment of $126 million from various sources (Duran et al., 2021). Other Turkish deep tech startups that chose to locate in foreign locations such as the US, Europe, and the UAE have received a total investment of approximately $1.7 billion (Duran et al., 2021). The situation of Turkey's local deep tech startups compared to the ones located abroad supports the fact that transnational startups have a better chance of survival (Krishna and Subrahmanya, 2015).

According to the data collected in this study, it is seen that Turkish deep tech companies are developing technologies in categories of *Artificial Intelligence & Data, IoT & Sensors & Augmented/Virtual Reality, Drones & Robots*, and *New Materials & Nanotech & Biotechnologies*. More than 70% have founders who have a M.Sc. or Ph.D. degree, and almost all Ph.D. degree founders are academicians. The companies are not performing well in terms of funding: Almost 65% of them haven't received any funds. They are mostly dependent on founders' money or get support from family and friends just like their peers in other countries (Grilli, 2014).

Having examined the overall picture of deep tech entrepreneurship in Turkey, it can be stated that the total deep tech market is quite small compared to developed economies in the world. In addition, the deep tech investment environment is not well developed in Turkey and may not be currently working well for deep tech entrepreneurship in Turkey.

2.4. Hypothesis development

The majority of the deep tech companies are located in a science and technology park or an incubator (Grilli, 2014). In order to analyze this fact based on the deep tech categories, the following hypothesis was constructed:

H_1: There is a relationship between the location of a deep tech company (being in science and technology park, incubator) and deep tech category.

Deep tech is a know-how and technology-intense industry. Hence, the founders tend to be at high education levels. However, in order to see if this expectation differs among deep tech categories, we analyzed the following two hypotheses:

H_2: There is a relationship between the education level of the founder and the deep tech category.

H_3: There is a relationship between the presence of an academician among deep tech company founders and the deep tech category.

Hervé (2010) and Braguinsky, et al. (2012) state that prior entrepreneurship experience can be important in surviving in the deep tech industry. The following hypothesis was developed to test if past experience is related to the category:

H_4: There is a relationship between the presence of past entrepreneurship experience of the founders and the deep tech category.

Sales is the main motivator of companies in every industry; thus, it is especially crucial for startups. In the questionnaire, they were asked if they started selling their products in local or international markets. The hypothesis below was developed to understand the relationship of their sales footprints to the deep tech category they belong to.

H_5: There is a relationship between the sales footprint characteristic of a deep tech startup (overseas sales, domestic sales, no sales) and the deep tech category.

One of the aims of this study was to understand the needs of the deep tech startups. The goal was to enable policy makers and stakeholders in this industry to benefit from the results. Based on this goal, we developed the following hypothesis to see if there is a relationship between the needs and the deep tech category:

H_6: There is a relationship between the needs of the deep tech startups and the deep tech category.

3. Methodology

3.1. Data Collection Method and Instruments

This study is based on descriptive research through a quantitative study on data collected via questionnaires from deep tech startups in Turkey. There are 28 questions in the questionnaires which have close-ended categorical answers and can be grouped as follows:

- Company age/location, deep tech category, sector
- Human resources (number of managing partners, founders' gender/ educational level, founders' academic status, founders' previous entrepreneurship experience, number of research & development staff)
- Information on financial resources (firm's financial source type, previously raised investment amount, previously raised public grant amount, preferred future financial source)
- Sales (presence of import / export sales)
- Difficulties, barriers and needs

The deep tech concept is new and there is a lack of academic studies in the field, thus no relevant scale has been found in the literature. Therefore, we developed our survey questions based on interviews with experts in the area and the reports written by consulting companies and institutions (Boston Consulting Group & Hello Tomorrow, 2019; de la Tour et al., 2017) throughout the world.

3. 2. Sampling

1243 deep tech start-ups were identified by screening business reports and communicating with all of the science & technology parks and incubation centers via e-mails and phone calls. Surveys were sent to all of the founders via e-mails and follow-up calls were made. 126 deep tech startups responded to the questionnaire as of December of 2020. The participant deep tech startups are quite young; i.e., younger than 3 years old. Additionally, the ratio of founders having Masters and Ph.D. degrees is around 35%.

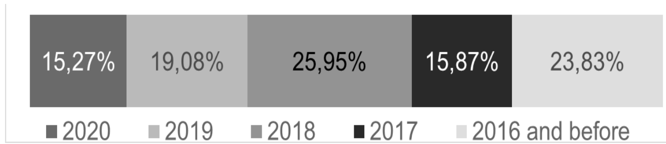

Figure 1: Deep tech startups based on foundation years

Moreover, 85% of the startups are located in science and technology parks, and the majority of them are in incubation centers. As Grilli (2014) states, technology incubators and science parks provide deep tech entrepreneurs with the physical and knowledge assets necessary for innovation and growth; therefore this profile parallels initial expectations.

Lastly, the highest number of startups that participated in our survey worked in the *Artificial Intelligence & Data* deep tech category, followed by *IoT & Sensors & Augmented/Virtual Reality, New Materials & Nanotech & Biotechnologies,* and *Drones & Robots* respectively.

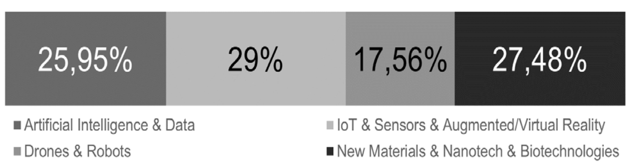

Figure 2: Deep tech startups based on categories

3.3. Hypothesis Testing and Results

We have used the Chi-square method in order to test the hypothesis since we have categorical variables in our data set. Significance level 0.10 is chosen for this study. Below are the test results:

H_1: There is a relationship between the location of a deep tech company (being in science and technology park, incubator) and deep tech category.

Chi-square analysis (Hair et al., 2006) was conducted to determine the profile of each category in terms of location. The results of the analysis show that they are (Pearson chi-square = 10.804, p = 0.095, at the $p < 0.1$ significance level) significantly related. Table 2 displays the distribution of the data, which shows that most of the *IoT & Sensors & Augmented/Virtual Reality* startups and *New Materials & Nanotech & Biotechnologies* startups are located in an incubator.

Table 2: Location of the deep tech startups based on deep tech category

Deep tech Category	Located in Science & Technology Park	Located in Incubator	None	Total
Artificial Intelligence & Data	13	13	8	34
IoT & Sensors & Augmented/ Virtual Reality	10	22	6	38
Drones & Robots	10	9	4	23
New Materials & Nanotech & Biotechnologies	11	24	1	36
Total	44	68	19	131

H_2: There is a relationship between the education level of the founder and the deep tech category.

H_3: There is a relationship between the presence of an academician among deep tech company founders and the deep tech category.

The results indicate that there is a significant relationship between the deep tech category and the education level of the founder (Pearson chi-square = 17.189, p = 0.001, at the $p < 0.05$ significance level). Moreover, presence of an academician as a founder is significantly related to the deep tech category (Pearson chi-square = 18.425, p = 0.005, at the $p < 0.05$ significance level). When the data was analyzed in detail, it can be seen that in *New Materials & Nanotech & Biotechnologies* category, both the education level and the number of academicians as a founder are higher.

Table 3: Distribution of deep tech startups based on their category and education level/having an academician as a founder

Deep tech Category	B.S.	M.S.	PhD.	Founder is an academician	Founder is not an academician
Artificial Intelligence & Data	10	10	14	11	23
IoT & Sensors & Augmented/ Virtual Reality	11	18	9	8	30
Drones & Robots	12	8	3	2	21
New Materials & Nanotech & Biotechnologies	5	11	20	20	16
Total	38	47	46	41	90

H_4: There is a relationship between the presence of past entrepreneurship experience of the founders and the deep tech category.

The hypothesis test findings reveal that they are significantly related to each other (Pearson chi-square = 6.944, $p = 0.074$, at the $p < 0.10$ significance level). The results are in parallel with the results of H2 and H3; i.e. in New Materials & Nanotech & Biotechnologies category, past experience is higher. One reason could be how challenging it can be to succeed in this category.

Table 4: The number of startups which have past past-entrepreneurship experience

Deep tech Category	Past-entrepreneurship experience	No past-entrepreneurship experience
Artificial Intelligence & Data	19	15
IoT & Sensors & Augmented/ Virtual Reality	13	25
Drones & Robots	9	14
New Materials & Nanotech & Biotechnologies	22	14
Total	63	68

H_5: There is a relationship between the sales footprint characteristic of a deep tech startup (overseas sales, domestic sales, no sales) and the deep tech category.

Chi-square analysis (Hair et al., 2006) reveals that there is a significant relationship (Pearson chi-square = 18.609, p = 0.005). One interesting result that can be derived from Table 5 is that, the highest number of companies which have no sales up to now are in the *New Materials & Nanotech & Biotechnologies* category. This is because these are relatively young companies and the technology is very complex, requiring industry-specific material and laboratories. The highest number of companies that made sales internationally were in the *AI&Data* category.

Table 5: Sales footprint characteristics based on the deep tech category

Deep tech Category	Have sales in the international markets	Have sales in the local markets	No sales up to now
Artificial Intelligence & Data	16	12	6
IoT & Sensors & Augmented/Virtual Reality	14	19	5
Drones & Robots	7	10	6
New Materials & Nanotech & Biotechnologies	5	13	18
Total	42	54	35

H6: There is a relationship between the needs of the deep tech startups and the deep tech category.

The analysis shows that there is no significant relationship between them (Pearson chi-square = 25.835, p = 0.213, at the $p < 0.05$ significance level). However, financing is the highest need with 77%, which is followed by market access with 58%, talented personnel with 36%, partnering with 25.4%, and laboratory and testing facilities with 21%, consecutively. These findings also parallel the literature review (Grilli, 2014).

4. Conclusions and Future Research

Being the sources of cutting-edge inventions and innovations (Luca, 2020), deep tech promises the world a new industrial and societal revolution. It has the potential to solve our global challenges and fix the problems humanity has faced since the first industrial revolution. However, this research's findings also provided insights as to how things seem to vary for the different categories of deep tech (Sinclair, 2020).

Firstly, it can be revealed that, startups that focus more on hardware and materials (*Drones & Robots, New Materials & Nanotech & Biotechnologies*) than software (*AI & Data*) in R&D activities, tend to locate more in science and technology parks and incubators. A reason for that might be the need for bigger initial phase support in terms of labs, physical spaces, collaboration, and tax incentives (Kılıç, 2020). Findings also show that the educational level of founders varies depending on the category of deep tech startups. The same applies to the number of academicians among the founders. *New Materials & Nanotech & Biotechnologies* category's ratio (Founder is an academician / Founder is not an academician) was 1.25, which is 2.6 times more than the closest category. *New Materials & Nanotech & Biotechnologies* depended relatively more on scientific research and hard lab activities. Therefore, the deeper the technology, the higher the need for highly educated scientists and engineers (Braguinsky et al., 2012).

Deep tech entrepreneurs merge scientific knowledge and experience to create innovations (Braguinsky et al., 2012). The research has demonstrated that past entrepreneurship experience varies according to deep tech categories. *New Materials & Nanotech & Biotechnologies* category was well ahead of the others with an experience/no experience ratio of almost 1.5. *AI & Data* followed with a ratio of 1.3, roughly.

The sales footprint was also found to have a relationship with deep tech categories. It was observed that the international sales ratios in the *New Materials & Nanotech & Biotechnologies* category suffered most in international and overall sales, and *Drones & Robots* came in second. Longer development cycles (Biert, 2020) and the more uncertain commercialization paths (de la Tour et al., 2017) of these two categories, in relation to the other two, can be counted as a reason for this result.

Having mentioned the dissimilarities based on deep tech categories, a notable result of this study was that all deep tech startups have similar needs. Funding is the number one need of deep tech startups; more than 75% of them mentioned that they needed more access to funding. Despite the revelation that the capital gap is heterogeneous (Different, 2020), the need for capital looks to be homogeneous. In addition, almost half of deep tech startups exhibited the need for access to markets, in consistency with the business reports (Harlé et al., 2017b). Nearly 35% of them needed skilled labor as training in specific areas, which is key to forming and sustaining a startup (Krishna & Subrahmanya, 2015). Lastly, it is known that collaboration is a crucial subject for deep tech startups (Portincaso et al., 2020) and 25% of survey participants mentioned that they needed to find partners for their startup.

These observations have several implications for research and applications on deep tech entrepreneurship. Firstly, we believe that our overall work is one of the first steps in academia to develop an academic definition of deep tech. We think that a clear definition will unlock further research studies on the topic. Secondly, to our knowledge, this study is a pioneer effort that is expected to create a bridge between the relatively mature literature on high tech and newly emerging literature on deep tech. In our view, this will help researchers to utilize the knowledge created in the high tech literature and adapt it to the deep tech literature. Moreover, we propose revealing the similarities and dissimilarities of deep tech categories, which provides a solid starting base for future research on deep tech.

The findings of our research have considerable managerial implications as well. Firstly, category-based differences identified in this research might help policymakers develop more effective regulations for deep tech startups. The *New Materials & Nanotech & Biotechnologies* category differs from other categories significantly and might require specific regulations and /or public funding processes. Actually, funding is a burning issue for all categories of deep tech. Considering the long development and commercialization periods, it is recommended that deep tech entrepreneur candidates secure a sufficient initial investment before they start developing the technology. It is also important for science and technology parks that host deep tech entrepreneurs to prioritize helping their residents have access to investors and public funds. The right policies could help deep tech startups deflect their high initial phase risks in taxation and provide simpler processes for setting up their companies (Bogen et al., 2020). Moreover, our research reveals that partnerships are critical for deep tech startups. It is recommended that policymakers foster an environment of cooperation and collaboration instead of encouraging one-to-one relationships between startups and incumbent companies (Harlé et al., 2017a). As it is known that a significant number of partnerships don't satisfy deep tech startups, focusing on the strategic and cultural fit is critical for success (de la Tour et al., 2017). Lastly, due to the high educational requirement of deep tech startups, especially in the *New Materials & Nanotech & Biotechnologies* category, employees with high qualifications are critical. We agree with El Ghak et al. (2020) that policy makers should take the necessary steps to align the university system with deep tech entrepreneurship needs.

Our work has some limitations. Despite these, we believe it could be the starting point for the developing deep tech literature. We recognize that our work is limited by insights coming from a relatively small sample size. In addition, the sample was taken from a developing country, Turkey. Even though the survey results seem consistent with global business reports, data from regions such as Europe, the US, and China can present a more precise picture of deep tech entrepreneurship. Even so, we believe that this study holds an additional value of including one of the developing countries, which has been sometimes neglected by academic or business research. Although the present study has only investigated the similarities and dissimilarities among deep tech categories, the identification of causes behind the dissimilarities and similarities among deep tech categories might have important managerial and academic implications and needs further investigation.

The current wave of deep tech entrepreneurship is a great opportunity for the world to overcome ever-increasing global challenges. It may even be a greater opportunity for developing countries because it has the potential of helping them catch up to the global economies more quickly by skipping a few steps instead of following the entire technology path (Thiel, 2014). We hope that our research will be helpful in this promising pursuit of a better world by fostering deep tech entrepreneurship and reaping its benefits equally and globally.

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