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Research article

Women in the sustainability new ventures in the digital era: Out from the shadow of the small country male-dominated startup ecosystem

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Abstract: Environmental sustainability has become one of the key issues for the future development of the European Union (EU). Estonia's startup entrepreneurship contributes prominently to innovative ideas in energy technology and information and communication technology (ICT) applications, essential for sustainability. Research and education are prerequisites for innovation in both fields. The gap in educational levels between Estonian women and men, favoring women, is among the largest in the EU. However, the proportion of women in entrepreneurship is significantly lower, even though the share of women in ICT personnel is among the highest in Europe. This study sought to determine women's contribution to sustainability (technology) startups in the context of these contrasting gaps. The article's dataset was based on sources such as the Global Entrepreneurship Monitor, Ministry of Education and Science, Business Register, and Startup Ecosystem. It qualitatively analyzed the sustainability orientation of ventures and the gender structure of founders across nearly 1300 startups and clarified the share of selected startups' fundraising within the entire ecosystem. Through a simple regression analysis, we uncovered some short-term trends. Our findings indicate that 92% of the accumulated €4.46 billion in startup funding is foreign capital, and 171 sustainability startups account for nearly 63% of the ecosystem's total fundraising. Among the founders of top-invested startups, only 6% are women, whereas women constitute 23% of the founders of sustainability startups. Despite this, sustainability startups with female participation have secured only 2.2% of the total investments in the sustainability group, highlighting a drastic gender disproportion. However, the fundraising trend for women's sustainability startups founded in the last five years is more positive, reaching 24% of this group's investments. Although their overall share remains significantly lower compared with the entire

startup ecosystem, this emerging trend is a promising sign of the breakthrough for female entrepreneurs in a traditionally male-dominated sector. The article's conclusion summarizes the study's results and suggests future gender-based research and development opportunities.

Keywords: sustainable entrepreneurship; green funding; female entrepreneurship; startup ecosystem; female founders; STEM career; gender gap; Estonia

JEL Codes: M13, O16, O31, O44, O52

1. Introduction

The role of female entrepreneurs in creating new growth-oriented companies has gained relevance beyond the celebration of Women's Day on March 8. Women's contribution to technology-based startups is considered an untapped societal reserve in the European Union (EU) (EC, 2019). Consequently, national governments significantly emphasize science, technology, engineering, mathematics (STEM), and entrepreneurship education. Women's participation is viewed as a potential growth source in ICT and STEM fields (Szelényi et al., 2013; Gorbacheva et al., 2019). The European Commission has highlighted the under-representation of women in the digital economy (EC, 2019), noting:

- 53% of companies report difficulties in recruiting qualified ICT specialists.
- Only one-third of STEM graduates are women.
- Only 17% of ICT specialists in the EU are women.
- Women earn almost 20% less than men in ICT.
- Women make up only 19% of ICT entrepreneurs in Europe.
- Companies founded by all-male teams in Europe receive 93% of total investments.

The EC report shows that the share of women in ICT entrepreneurship slightly exceeds their employment in the sector. Data for the USA indicates that funding for all-women teams decreased from $7.3 billion [2.1% of total venture capital (VC)] in 2021 to $3.1 billion (1.8%) in 2023, while funding for mixed teams increased to 26.1% (Davis, 2024). In Germany's startup ecosystem, 20% of founders are female, with all-women teams receiving 1% and mixed teams 12% of total funding (Hirschfeld et al., 2022). The share of female founders in the technology startup ecosystems of EU countries is relatively modest compared to North America. According to a 2015 review, the world's top five cities for female tech founders include Chicago (30%) as the leader. Paris, the first representative of the EU, ranks sixth (21%), and Berlin ranks twentieth (9%) (Berger and Kuckertz, 2016). These numbers indicate significant regional differences in female technology entrepreneurship.

At the same time, the gender gaps in general entrepreneurship indicators are not as drastic as in the technology field. For example, in the USA in 2023, the Global Entrepreneurship Monitor (GEM) total early-stage entrepreneurial activity (TEA) index for women was 13.4, compared to 16.0 for men, and for established business ownership (EBO), the figures were 5.9 for women and 7.6 for men. In Germany, the TEA value is 6.0 for women and 9.3 for men, and the EBO is 2.7 for women and 5.5 for men (GEM, 2024).

Worldwide stereotypes are seen as contributing to this disparity, creating inequality in the choice of STEM and entrepreneurship careers (Baltà-Salvador et al., 2024; Gupta and Etzkowitz, 2021; Braches and Elliott, 2017; Gill et al., 2008). Investigating whether such prevailing stereotypes could also be a problem for startups with sustainability or green orientation would be challenging. Bhatnagar et al. (2022) suggested that the percentage of women in the green field is higher than average. We suppose stereotypes are weaker in societies experiencing dynamic changes, especially in emerging areas like sustainability-oriented entrepreneurship. Estonia is a fitting example, having regained independence from Soviet occupation in 1991 and transitioned to a market economy.

Estonia, one of the smallest countries in the EU, is known for its preferential development and use of ICT, high level of entrepreneurship, and well-developed entrepreneurial ecosystem (Marquardt and Harima, 2024; Startup Genom, 2023; Trabskaja and Mets, 2019; Dumas, 2014). Among Estonian university graduates, there are twice as many women as men, which is significantly above the EU average. However, men dominate STEM fields (Valk, 2015). Regarding the proportion of women among specialists in the IT sector, Estonia ranks among the top three in the EU (EC, 2021). Additionally, two Estonian women are among Europe's 100 most influential women in startup entrepreneurship (Escárzaga, 2024). Given these facts, could it be considered that female entrepreneurs in Estonian technology entrepreneurship are also more successful in both domestic and international contexts? Do the same challenges exist in fundraising for women's startup ventures in Estonia as in the EU concerning their contribution to the digital economy? Scientific discussions generally cover these topics but only partially address women's entrepreneurship in the region (Rugina, 2019; Petrović and Radukić, 2018), with the absence of focus on ICT and other technologies, sustainable venture founders, and the startup ecosystem.

In seeking answers to the raised questions, we aim to discover the main trends in technology-based sustainability female entrepreneurship in the Estonian startup ecosystem.

To achieve this goal, we have formulated the following tasks:

1. Create an overview and analyze women's involvement in technology and entrepreneurship careers in Estonia.
2. Examine the gender and sustainability entrepreneurship perspective of the Estonian startup ecosystem.
3. Investigate seed and early-phase investment practices in startup ventures, including the influence of the entrepreneur's gender on funding decisions by investors.
4. Analyze the gender-based structure of sustainable technology startup founders, investment patterns, and trends within the Estonian startup ecosystem.

In the following introductory chapters, we provide an overview of the concept of a sustainable startup and the role of women in the sustainable startup ecosystem based on previous studies (section 2). We also examine the career choices of women in entrepreneurship and technology in countries with regional and historical backgrounds similar to Estonia (section 3). Section 4 outlines the research methodology. Section 5 presents findings on the Estonian startup ecosystem and the role of women in sustainability technology startups. The results are discussed in section 6. The article concludes with conclusions and recommendations.

2. Startup ecosystem—an enabler of female sustainability entrepreneurship

2.1. Understanding sustainability startup

According to the Cambridge Dictionary (n.d.), sustainability is defined as "the quality of causing little or no damage to the environment and, therefore, able to continue for a long time". In the context of startup entrepreneurship, sustainability orientation means integrating the framework of social, environmental, and business considerations, known as the triple bottom line, into the venture (Belz and Binder, 2017). The United Nations (UN, 2015) formulated corresponding environmental priorities as 17 Sustainable Development Goals (SDGs). Tiba et al. (2021) defined sustainability startups as those innovatively meeting the SDGs.

However, the interpretation of SDGs is not unambiguous from the startup ecosystem's point of view. In a narrower sense, sustainability-oriented startups are those whose primary goal is environmental sustainability, including combating the waste of material and energy or other resources and primarily introducing more economical technological solutions. There are partly conflicting challenges to overcome in this endeavor. For example, while introducing electric cars aims to reduce the use of non-renewable fossil fuels and CO_2 emissions, modern battery technology requires raw materials that are costly and environmentally damaging to mine. Mining can also exacerbate social inequality in poorer countries. These and many other circumstances highlight the need for new ways of energy storage, such as hydrogen fuel technology (e.g., Ers et al., 2024). Therefore, any better technological solution applied by new ventures may have some sustainability component.

New venture (NV) creation is understood as the sequence of lifecycle stages from startup (defining and validating the business concept), business development and scaling, to exit (harvest: IPO, sale, or acquisition) (Picken, 2017). Such growth-oriented companies have come to be known as startups (Olek, 2023). The prerequisite for growth is usually an NV's innovativeness, which is often related to some technological application, regardless of the type of innovation (technological, process, business model, or social) or their combination. Nowadays, any idea in any field can be considered a startup if it involves some form of technology, including ICT. Thus, the term startup has become synonymous with tech NV. Consequently, innovative NVs are referred to as startups (Cusumano, 2013), and their operating environment is a startup ecosystem (Olek, 2023), a form of an entrepreneurial ecosystem.

2.2. Women in the sustainability startup ecosystem

The concept of the entrepreneurial ecosystem is closely related to the incubator-accelerator environment of growth-oriented new technology ventures (e.g., Goswami et al., 2018). We support the understanding that the entrepreneurial ecosystem exists regardless of the level of institutionalization (e.g., Lahikainen et al., 2019; Acs et al., 2015). Berger and Kuckerts (2016) found that factors such as gender equality, access to funding, and management explain the proportion of female startup founders in the worldwide context of ecosystems. Despite this, the proportion of women in technology startups remains lower than that of female entrepreneurship in general, as evidenced by the GEM dataset. This suggests that female entrepreneurs are more engaged in local ventures rather than global technology startups. One reason for the lower fundraising of women's startups is the small proportion of female

investors (Ewens and Townsend, 2020) and women's involvement in sustainability startups (Tiba et al., 2021). Therefore, it is reasonable to examine the factors within the entrepreneurial ecosystem that affect female technology entrepreneurship.

Stam and van de Ven (2021) divided the components of the entrepreneurial ecosystem into three institutional (formal institutions, culture, networks) and seven resource endowment elements: physical infrastructure, demand, intermediaries, talent, knowledge, leadership, and finance. This model has been the basis for analyzing the Estonian entrepreneurial ecosystem (Trabskaja and Mets, 2019). The dynamics of its development have been characterized by reaching maturity in the country's innovation-based development phase (as defined by the World Development Forum) since 2014. The small size of the Estonian market is compensated by entrepreneurs with a global orientation from the early startup phase, marked by success stories starting with Skype (Mets, 2017, 2016, 2012). Estonian startups have gained international investors' trust, with up to 98% of investments coming from foreign funding in 2017 (Trabskaja and Mets, 2019). Despite the high-level indicators of startup investments per capita and successful exits in international comparison (Prohorovs, 2020), a study by Kutsenko et al. (2022) showed that the migration of unicorn founders out of Estonia is greater than the number of unicorn founders migrating to Estonia. Unfortunately, there are no studies on the share of Estonian women entrepreneurs in these developments.

Although the entrepreneurial ecosystem, including Estonia's, has been extensively studied in the above sources, we pay additional attention to specific functions. Startup accelerators and their leaders play a specific role in the ecosystem's success. They structure and mediate knowledge and resource flows and provide social network support to startups from both local and global networks (Marquardt and Harima, 2024; Guerrero and Espinoza-Benavides, 2021; Hakala et al., 2020). These accelerators often act as bridge builders between ecosystems with different contexts (e.g., business, innovation, education, sectoral, etc.) and funding institutions (Trabskaja and Mets, 2019).

For women founders, obtaining the necessary VC funding for the growth of a startup is more critical compared to men. This disparity is attributed to cultural and institutional factors (Avnimelech and Rechter, 2023; Snellman and Solal, 2023; Welsh et al., 2023; Orser et al., 2020; Malecki, 2018). Gender inequality is linked to cultural stereotypes, resulting in fewer female leaders and STEM career decisions (leadership and talent aspects). SDG 5, which focuses on gender equality and women empowerment, relates to the sustainability aspect of society, even if it does not directly serve other SDGs. Jonsson (2024) points out that power dynamics in academic entrepreneurship are reflected in the number of university spinoff founders in Scandinavia, which increases proportionally with the number of full professors, less directly depending on the entrepreneur's gender.

At the same time, Gupta and Turban (2012) provided evidence that gender stereotypes may impact the evaluation of new business ideas. For example, this phenomenon can manifest in the (unconscious) difference between the investor's questions to male and female entrepreneurs, which sets a framework for financing decisions (Kanze et al., 2018). A similar gender-dependent difference in early-stage startup assessment was observed by Ewens and Townsend (2020).

Schmidt et al. (2023), analyzing 911 Norwegian ventures, found evident gender differences in entrepreneurship support combinations by evaluating the business idea's quality. They noted differences in financial support (more needed by females than males), smaller team sizes, lower

planning levels, and smaller but higher-quality networks for women. These findings indicate the need to understand VC criteria for (female) startup financing.

Morawczyński (2020), as the result of the experiment, listed the criteria for Polish VC decision-makers in the following importance ranking: the entrepreneur's (1) trustworthiness, (2) passion and enthusiasm, (3) startup company creation, management, and (4) industry experience, (5) ability to perceive and manage risks, (6) personal likeability, (7) mature company management experience, and (8) industry education. Rather than individual entrepreneurs, the team increased the project's attractiveness for VC managers. The low importance of the innovativeness of the project was surprising. Gender is not mentioned among the criteria. To summarize the review, there is little coverage of the combined approach of female entrepreneurship, funding, and the sustainable startup ecosystem.

3. Women in entrepreneurship and technology careers in Estonia

To understand gender distribution in the Estonian startup ecosystem, we should compare the proportion of women as entrepreneurs/founders of companies with similar geographical locations, historical backgrounds (former socialist system), and relatively small size. This comparison helps contextualize Estonia's situation within a broader European framework (Table 1).

Table 1. Women share in entrepreneurial activity in selected countries, 2014–2023.

Country	TEA (total early-Stage entrepreneurial activity)						EBO (established business ownership)					
	Men		Women		Women, %		Men		Women		Women, %	
	2014	2023	2014	2023	2014	2023	2014	2023	2014	2023	2014	2023
Estonia	11.2	16.2	7.7	9.9	40.7	37.9	7	9.7	4.4	6.1	38.6	38.6
Denmark	7.1		3.8		34.9		7.5		2.7		26.5	
Sweden	9.5	11.1	3.8	7.3	28.6	39.7	8	8	4.9	2.8	38.0	25.9
Norway	7.3	8.8	4	4.9	35.4	35.8	7	8.2	3.7	6.9	34.6	45.7
Finland*	6.6	9.4	4.6	6.4	41.1	40.5	9.2	11.4	4	6.3	30.3	35.6
Slovenia	8.3	9	4.3	5	34.1	35.7	6.6	12.9	2.8	4.6	29.8	26.3
Slovakia	14.4	12.6	7.4	8.9	33.9	41.4	11.7	4.4	3.9	3.4	25.0	43.6
Hungary	13.5	12.7	5.3	7.1	28.2	35.9	11	9.7	5	5.1	31.3	34.5
Poland	12.5	2.8	6	2.4	32.4	46.2	10	12.4	4.6	10.9	31.5	46.8
Latvia**	18.6	16.5	9.8	12.2	34.5	42.5		13.8		7.5		35.2
Lithuania	16.2	6.1	6.8	7.2	29.6	54.1	11.6	16.7	4.3	12.7	27.0	43.2

Note: *2021; **2015; Source: Authors based on GEM (2024).

Table 1 shows that Estonian female entrepreneurship is at the top compared with men and women from comparison countries, including (better than) the average of innovation-based countries, to which Estonia belongs in terms of its level of development. The share of women as starting and operating (mature) entrepreneurs is lower than men's in all countries. In addition, Estonian female entrepreneurs stand out as having the highest level of education in the EU countries (Rugina, 2019).

The topic of women in the fields of science, technology, engineering, and mathematics (STEM) has become relevant, mainly due to the rapid growth of the information communication technology

(ICT) industry and the shortage of professional personnel (Gorbacheva et al., 2019). The problem can be not only gender imbalance but even its growth because of the career decisions made by women (Gill et al., 2008). Women's participation is seen as a potential source for growth in ICT and STEM fields (Gorbacheva et al., 2019; Szelényi et al., 2013). Estonia does not stand out in Europe in terms of the number of female STEM graduates, but it has a small number of men in this category (Table 2).

Table 2. Women STEM graduation and ICT employment in selected countries.

Country	per 1000 STEM grad, 2019			ICT specialists in employment, 2020					Women pay gap, 2019		Women in Digital Index	
	Women		Men	Women			Men	Total				
	value	rank	value	%	rank	sector	%	%	%	rank	value	rank
Estonia	14	12	19	2.9	3	23%	9.8	12.7	26	21	65.1	4
Denmark	16	4	30.8	2.6	5	24%	8.1	10.7	16	9	69.3	3
Sweden	12	19	19.6	3.4	2	23%	11.2	14.6	9	1	71.6	2
Finland	14	11	35.1	3.7	1	25%	11.2	14.9	13	5	76.9	1
Slovenia	14	9	26.6	1.7	15	20%	6.7	8.4	20	15	53	14
Slovakia	9	21	16.6	1.5	19	19%	6.5	8	28	23	47.7	20
Hungary	7	25	16.8	1.1	26	15%	6.1	7.2	24	19	43.6	25
Poland	17	2	22.6	1.1	25	17%	5.2	6.3	28	24	43.7	24
Lithuania	13	16	26.5	1.6	17	24%	5	6.6	30	25	52.6	16
EU	14		28	1.7		21%	6.5	8.2	19		53.2	

Source: compiled by authors from EC (2021).

Given that the share of ICT graduates and, as a result, employees is relatively high, these numbers show the low popularity of other STEM disciplines among young people in Estonia. According to some estimates, two-thirds of the required engineers are missing in the Estonian industry (Estonian Qualifications Authority, 2023). The lack of popularity of STEM education is seen as the reason for the shortfall. In Estonia, women comprised 22.8% of ICT specialists in 2020, slightly higher than the relative value of the sectoral average and in third place within the total employment level of the EU countries.

4. Methodology

4.1. General approach

The empirical study had a triple purpose. First, we collected data to describe and analyze the Estonian Startup Ecosystem in general. Data collected for this purpose was also partly used for statistical analysis. Second, we aimed to determine how the startup ecosystem participants—entrepreneurs, investors, and decision-makers of the support structure—perceive the gender issue in investment decisions. Third, by analyzing the indicators and metrics of sustainability startups in the context of the ecosystem in general, we sought to identify statistically significant gender-based patterns among Estonian startup founders and fundraising efforts. For the first and third tasks, we analyzed the data collected from various sources, and for the second task, we conducted interviews with the involved parties.

The methodological basis for identifying a startup as belonging to the sustainability class is the formulated or implemented goal by the venture or entrepreneur in alignment with the UN SDGs (Brundtland, 1987), except Goal 5, "Achieve gender equality and empower all women and girls". In the context of Goal 5, the topic of analysis should be the role of women across the spectrum of ventures, which may not correspond to the rest of the SDGs. Therefore, based on the article's purpose, the study focuses on startups with sustainability activities according to the UN and the contributions made by women to these activities.

4.2. Datasets and sources of qualitative and quantitative information

Startup Estonia, a national project, gathers data on accelerators and startup ventures through its platform, including the Deal Room service aimed at potential investors (Startup Estonia, 2024). Currently, the platform hosts information on 25 accelerators and 1289 startup and scaleup ventures (March 24, 2024). This substantial number is notable for a country with a population of 1.3 million, contrasting with German Startup Monitor (GSM), which reports 1976 startups for a population of 84.1 million (GSM, 2022). The database primarily features startups and scaleups within their first decade of operation, although exceptions exist for companies engaged in continuous development stemming from earlier deep technology research phases. In some cases, these ventures originate from previously closed development companies, with the same team or entrepreneur now focusing on more advanced technology phases within their startup endeavors. Startup Estonia regularly publishes reports akin to Germany's GSM.

The Startup Estonia database categorizes ventures into 25 industries, with some easily identified as green or sustainability-oriented, such as those in energy, food, and health. However, classification can be complex, particularly for businesses leveraging circular economy principles within sectors like fashion. These startups often employ social, software, robotics, material technologies, or combinations thereof to achieve sustainability goals.

While the database assigns SDG labels based on entrepreneurs' motivations during voluntary registration, the categorization may not always align perfectly with formal vocabulary-based approaches. Our assessment focused on the technological basis of startups, especially those leveraging ICT such as software, data processing platforms, internet and telecom services, robotics, and mobile apps. This categorization differs somewhat from Startup Estonia's approach, which categorizes AI under deep tech (De la Tour et al., 2021). Other startups rooted in fundamental research and hardware development were classified as deep tech (Chaturvedi, 2015), distinct from ICT-based technologies. Our categorization process involved two researchers' manual content analysis and coding to minimize subjective errors, recognizing that startups often integrate multiple technologies and competencies, prioritizing those central to their business models or novel outcomes.

Startup Estonia's database is incomplete; not all startups are registered there, and some investment information is missing. However, our search from various sources only added a few startups to our list. Our confidence in the platform's data and the founder community is bolstered by the fact that respectable technology startups seek visibility to potential investors. Additionally, the database includes entries labeled "Companies discovered by AI", which broadens the list even if the entrepreneur does not register the startup themselves.

We did not differentiate the type and source of funding—grant, seed, venture capital, or crowdfunding. Public funding, typically provided in the early phase of a startup project with relatively modest amounts (a maximum of a few tens of thousands of euros), does not significantly affect the total amounts reaching millions. Much important investment information can be found in the Startup Founders' community database (not public). This database aggregates data collected voluntarily from members and public, private, or governmental sources. Founders might finance their startups with founding share capital and loans or use crowd fundraising (e.g., Zhao et al., 2021), which is not reflected in our study.

A possible deviation, although significant for individual startups, is less critical when considering the overall startup ecosystem and the volume of VC funding (see subsection 5.1). The platform also reflects the support given to startups through grants by the state and EU institutions, which we cross-checked with public databases. Although the data may not be exhaustive, they are the best available. For instance, a venture discovered from other sources was added to the startup database during our current search. We used Google, Google Scholar, Facebook, and LinkedIn to find personal data and additional information sources. In case of inconsistencies, we verified the information with the global startup databases Crunchbase (https://www.crunchbase.com/organization), the company's webpage, and the Estonian e-Business Register (https://avaandmed.ariregister.rik.ee/en).

The qualification of startups as part of the Estonian ecosystem was a separate topic. E-residency allows foreigners to establish a company without being a physical resident of Estonia and register on the ecosystem platform to search for investors. Foreign companies have the same opportunity, but their origin is more accessible to identify. We verified whether a specific company is part of the Estonian startup ecosystem by checking related persons' and companies' residence and tax payment information from public sources. From the same sources, we also clarified and coded the structure of startup founders. This information may be somewhat less accurate in our research database, as institutional founders are sometimes among the owners. In these cases, we interpreted the number and gender of the founders based on the representative of the more significant founding institutions if the founders were not mentioned in other sources.

From the perspective of statistical analysis, the sample and population of the startups we screened out practically overlapped. Therefore, the significance indicators of means, standard deviations, and correlations do not have the usual meaning in a mutual comparison (see, for example, Davidsson, 2016).

4.3. Interviews

To determine the gender-based startup funding pattern of the Estonian startup ecosystem in an international context, we interviewed entrepreneurs, consultants, investors, and industry managers (Table 3). We sought answers to questions regarding general startup investment criteria and practices, with a specific focus on gender aspects. The interviewees were selected as a convenience sample and were characterized by a university degree in various fields, including psychology, business, software development, and engineering. Their ages ranged from 28 to 71 years, with the entrepreneurs among them aged 28 to 44 (four women). We ceased expanding the sample when the responses began to show redundancy.

Table 3. Interviewees.

Interviewee's general description	Experience	Interview method
1. Professor, PhD, expert, angel investor	Invested in 12 startups, partly in the angel consortium.	Email + orally online
2. Innovation manager, MD, PhD, researcher, Sweden	Long-term technology transfer manager, management of the university innovation company, chair of innovative startup funding boards.	Email
3. Spinoff and startup consultant, MSc	Experience at the university technology transfer and spinoffs' support over 15 years.	Email
4. Woman entrepreneur, multilingual, MBA	Experience from different cultures, including Mexico, USA, and Estonia, among others.	Email
5. Woman (green technology) serial entrepreneur, MBA	Several startups, Forbes-nominated for 30 Under 30 Europe 2021: Manufacturing & Industry.	Email
6. Woman serial entrepreneur and investor, MA	Founder and co-founder of startups in the technology (ICT) field, investor, collaboration with big global companies.	Public videos and written text; by phone 16 min.
7. Serial entrepreneur (male), MSc	Founder and co-founder of ICT startups and support structures.	Public interview by the author
8. Project manager, MBA	Long-term (>18 years) experience of startup innovative firms' support in the science park.	Email
9. Woman serial entrepreneur and angel investor, MBA	Founder and co-founder, CEO and investor.	Personal + phone

Due to the popularity of the startup ecosystem and entrepreneurship in Estonia, many interviews have already been published in public media, touching on the topics of our articles. We verified contact details and entrepreneurs' business information using Google, LinkedIn, Facebook, the Business Register, and databases related to Startup Estonia. This thorough preparation facilitated smooth and efficient interviews. Coded information is disclosed and generalized in the Findings section.

5. Findings

5.1. Estonian startup ecosystem

The Estonian startup ecosystem has developed in sync with the e-environment, with key milestones including the Tiger Leap program (Internet and IT at schools) from the 1990s and various e-Governance initiatives. Significant outputs of these initiatives include the tax filing system, the Electronic Health Registry, e-Prescription, internet voting system, and e-business registry systems. All services are based on electronic identity cards, enabling citizens to sign documents electronically. Of particular interest is the e-residency legislation since 2014 (Mets and Kelli, 2015) and the startup visa enabling foreigners to run businesses remotely and work in Estonia on place (https://startupestonia.ee/).

Startup Estonia is a program and strategy (Saluveer and Truu, 2020) for startup ecosystem development, financed by the European Regional Development Fund and run by the Estonian Entrepreneurship and Innovation Agency. This initiative was started by the Estonian Development Fund in 2011. The Estonian startup ecosystem received a significant boost from the exit sale of Skype to eBay for $2.6 billion in 2005. The influx of money to local partners from this event created a foundation for new investments and established Estonia's reputation as a hub for new technology startups (Stefanuk, 2020). A brief chronology of further developments includes (https://startupestonia.ee/about-us/our-story/):

2011: The Estonian Development Fund began fostering startup entrepreneurship with the goal of establishing 1000 active startups by 2020.

2014: CleanTech program, an early-stage green technology startup initiative, was launched.

2017: The startup visa program was introduced, with nearly 6000 individuals utilizing the startup and scaleup visa, enriching the ecosystem with diverse human resources. Additionally, the CyberTech startups focus area was implemented.

2019: The Accelerate Estonia program was launched, and the EdTech (educational technology) focus area was initiated.

2020: The Estonian Startup Database was launched.

2022: DeepTech startup programs were launched.

A distinctive feature of the Estonian startup ecosystem is the large share of foreign VC, accounting for approximately 92% of the total accumulated volume, which reached €4.46 billion, with an annual maximum of €1.36 billion in 2022 (Figure 1). The annual funding by the Estonian VC has increased tenfold since 2006; its share within the total funding has dropped to a few percent in some years.

Compared to 2016 (Mets, 2017), accumulated investments have increased 17-fold. Alongside the investment processes, several startups have relocated their headquarters (HQs) to global centers. For example, 14 of the 30 Estonian-origin startups with the most significant investments (over €15 million) have moved their HQ mainly to the US and UK, although many startups with smaller investments have done the same. The motivation to move HQs out of Estonia is to attract investment and be closer to the market, while the Estonian office continues to manage business development. Consequently, investments are not always reflected in the foreign direct investment (FDI) balance of the Estonian Bank (Mets, 2018). These investments often cover development costs through subcontracting with the Estonian branch and are reflected in export statistics.

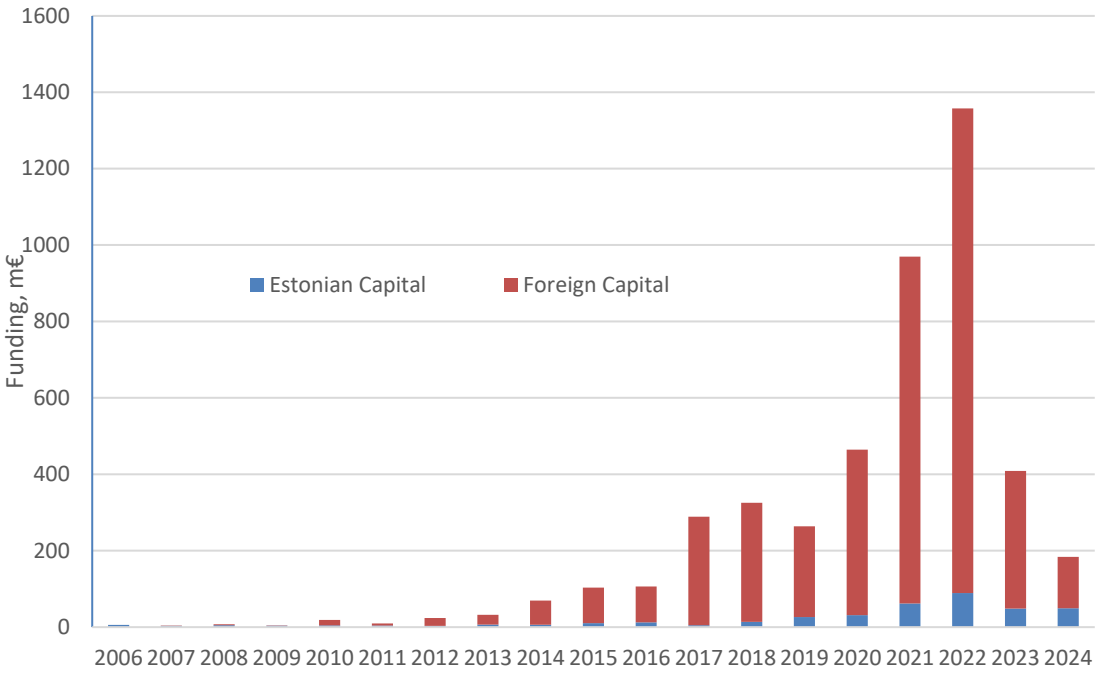

Figure 1. Funding of Estonian startups, million euros, until Q1 2024. Source: calculated by authors based on martin@bolt.eu.

The standout of every ecosystem is unicorns—incredibly successful startups. Unicorns are considered Estonian-founded if a company has a valuation of at least $1 billion confirmed by international news sources and meets at least one of the following conditions (https://ecosystem.startupestonia.ee/lists/42730?):

- At least one founder is/was an Estonian citizen.
- The company has or had an HQ in Estonia.
- A significant part of the company's research and development operations comes from or is in Estonia.

Estonian-origin startups, including the first unicorns, were counted in the statistics of their HQ country if they registered their HQ in a new location. For example, Skype was counted in Luxembourg (reaching unicorn status in 2005), Playtech in Cyprus (2005), and Wise in the UK (2015). As HQs migrate, the location of ten Estonian unicorns in the current list may also differ (Table 4). It is a characteristic of unicorns that the base technology is ICT, regardless of the business area and business model.

Table 4. Estonian-origin unicorns.

Name (HQ)	Business model & area	Launched/unicorn	Value (last data)
Gelato (Oslo)	B2B, Printing platform for global e-commerce	2007/2021	€955m (Aug 2021)
Glia (New York/Tallinn)	B2B, Marketing, AI	2012/2022	€909m (Mar 2022)
Veriff (Tallinn)	B2B, AI-powered identity verification and KYC solutions	2015/2022	€1.4b (Jan 2022)
Zego (London/Tallinn)	B2B, insurtech	2016/2021	€1.0b (Apr 2024)
ID.me (McLean, Virginia)	B2B, Digital identity network	2010/2023	€1.4b (Apr 2023)
Playtech (London/Tartu)	B2B, Gaming software	1999/2005	€1.9b (Apr 2024)
Bolt (Tallinn)	B2B, B2C, Mobility super-app	2013/2018	€7.4b (Apr 2024)
Skype (Redmond Washington/Tallinn)	B2C, VOIP telecom	2003/2005	€11.2b (Jan 2022)
Pipedrive (New York/Tallinn)	B2B, web-based CRM & Sales+software	2010/2020	€19.6b (Jan 2024)
Wise (London/Tallinn)	B2B, B2C Money transfer	2011/2015	€8.5b (Nov 2023)

Source: Authors based on Startup Estonia, April-March 2024.

The Startup Estonia platform labels companies that meet SDGs' criteria. Among the unicorn ventures in Table 4, only Bolt is labeled as corresponding to SDGs 11 (Sustainable Cities and Communities) and 13 (Climate Action). There are no women among the founders of Estonian unicorn startups. Among the top 30 startups with the most significant investments, only two ventures were founded by women and two by mixed teams—one by a couple and one by four men and a woman—altogether involving 3.6% of this top funding. Among the sustainability deep tech flagships in the Top 30 are Skeleton Technologies, a supercapacitor company, and Elcogen, a hydrogen energy company, with investments of 306 and 102 million euros, respectively. Both companies are based on a long tradition of basic and applied research in Estonia. These two ventures represent the only areas of technology not part of the ICT application group, with approximately 10% of the total investments in the Top 30. There are no women-led sustainability startups in the Top 30.

The most significant total investments are related to Bolt, with 1.78 billion (39.74% of the total startup investment in the ecosystem), followed by Wise, with 339 million euros, and Skeleton Technologies, with 306 million euros. Four of the top 30 funded startups (Pipedrive, Zeroturnaround, Klaus, and Fits.me) have reached the exit, and Wise has gone public (IPO in 2021). Eurora announced bankruptcy in 2023.

5.2. Priorities of women's startup funding according to interviews

In the interviews, we mapped the views of both investors and female entrepreneurs. The criteria for startup evaluations varied slightly, with the ranking sequence depending on the investor's personal preference, such as the economic potential of the idea, the presence of deep technology protected by a patent, or the experience and competencies of the entrepreneur's team. All investors, however, emphasized the vital criterion of growth potential—scalability. In this regard, prior experience in starting

a new venture was considered a crucial supporting factor in decision-making. Since the answers were mainly based on the Estonian startup ecosystem, its characteristics were not mentioned separately.

These views were supplemented by Respondent 2, who noted that the board's investment capacity and the presence of subsequent financing institutions for the next startup stage were also essential components in decision-making. This was followed by the realism of the business plan (considering potential cost increases), the needed development period, and profit expectations.

According to the respondents, topics related to female entrepreneurs are not a direct problem for Estonian investors. It was noted that since most investors are men, the first presentation of a well-prepared startup idea by a woman, accompanied by a competent business plan, may even receive more support (Respondent 1). Respondent 1 also mentioned that the share of women in IT ventures could potentially grow with the use of AI in software development. Respondent 5 found that gender is not an important issue for an entrepreneur in Estonia, though she has encountered a slightly different attitude in Western Europe, supporting the observation by Jonsson (2024) in the comparison of the Scandinavian and Anglo-Saxon contexts.

Respondent 4 pointed out, based on her international communication experience, that she has encountered gender-based unprofessional attitudes among investors, some of whom she characterized as "jerks" due to flirtatious behavior. She has experienced a similar attitude while working in IT but summarized: "In IT, many companies fight for talent. Become a talent worth fighting for, and they will not risk with jerk behavior". However, her opinion was very positive toward Estonian investors' professionalism.

Respondent 6, who studied gender topics in the startup ecosystem, found that female founders in Estonia are beginning to catch up with men, except in some substantial investments. However, she has experienced culture conflict between the entrepreneurs and software development teams. Respondent 9 agreed that women can be less risk-tolerant and have "feet on the ground". She mentioned the pressure to promote women's entrepreneurship and support women entrepreneurs (otherwise, there is a risk of discriminating against women by disregarding their ideas and implementations). Nevertheless, she noted that a good idea by a male entrepreneur can be undeservedly overlooked in such cases. From the investor's point of view, unconscious discrimination may occur (stereotype: a woman is not as competent or capable, etc.), but verbal and behavioral discrimination, as a rule, does not occur.

5.3. Gender distribution in Estonian Top 30 and sustainability startups

In order to find patterns of female entrepreneurship in the Estonian startup ecosystem, we compiled and analyzed the collected quantitative data in Tables 5, 6, and 7. The total number of ventures in the Sustainability Startups group is 171, of which 70 have reached one million euros or more in fundraising. When comparing the number of founders in top-invested and sustainability startups, it is notable that the representation of women in the top-invested group is nearly four times lower (Table 5: Subtotal).

Table 5. Founders' gender distribution within the Top 30 and sustainability ventures.

Founders' team by the group	Women (W)		Mixed W+M				Men (M)		Subtotal				Total	
	W	%	W	%	M	%	M	%	W	%	M	%	W+M	%
Top 30	2	3.1	2	3.1	5	7.7	56	86.2	4	6.2	61	93.8	65	100.0
Sustainability	33	9.3	49	13.8	59	16.7	213	60.2	82	23.2	272	76.8	354	100.0

Source: Authors.

Figure 2 reflects the dynamics of the number of founders in the Estonian startup ecosystem, showing that during the last five years, the number of female founders has remained stable between 10 and 13, making up 20%–46% of the annual figures. A growing trend in female founders in young startups is noticeable, although the database of 1–2-year-old ventures may not be complete. Entrepreneurs who have not yet obtained funding from investors may not register their ventures in the ecosystem database for various reasons. Therefore, we can expect the number of startup founders to increase in the next couple of years.

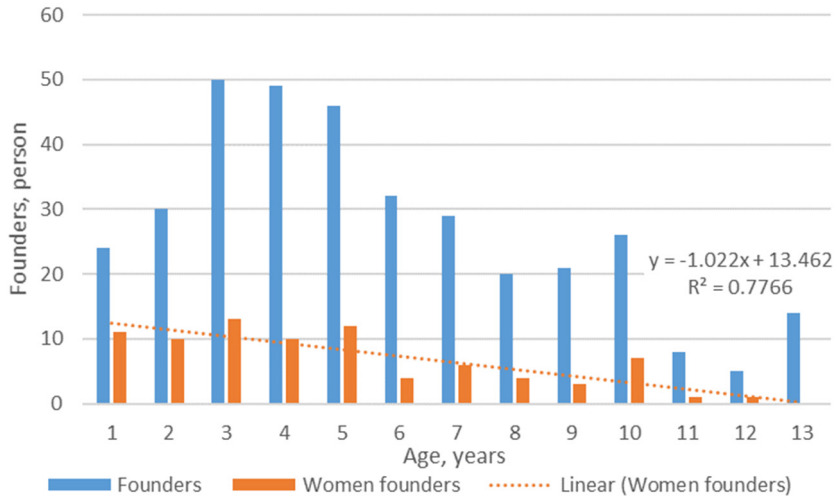

Figure 2. Total number of founders and women founders (y) within the Estonian startup ecosystem by age (x) of sustainability ventures, including 13+ years (R – correlation coefficient). Source: Authors.

If the share of women among the founders of sustainability startups averages over 23%, this indicator drops to only 2.2% when it comes to capturing investments (Table 6: Women + Mixed). Startups with women's participation have secured 3.6% of the top 30 investments (Table 6). Bolt's share in all startup investments is nearly 40%, significantly affecting the *sustainability* group, reaching €2805 million (62.9% of total ecosystem fundraising) and, without Bolt, €1032 million (23.1%). These figures, in euros, are listed without Bolt on a separate line.

Table 6. Investments' gender distribution within the Top 30 and sustainability ventures.

Data by the venture	Women		Mixed W+M		Men		Total	
group	m€	%	m€	%	m€	%	m€	%
Top 30	78	2.0	62	1.6	3829	96.5	3969	100.0
Sustainability startups	18	0.6	45	1.6	2742	97.8	2805	100.0
-ICT-based	15	0.8	32	1.6	1930	97.6	1977	70.5*
-other tech	3	0.4	13	1.6	812	98.1	828	29.5*
-without Bolt	18	1.7	45	4.4	969	93.9	1032	36.8*

Source: Authors; *comparing *Sustainability* group.

Given the recent growth trend in female founders, we examined investments in startups with female participation (Figure 3).

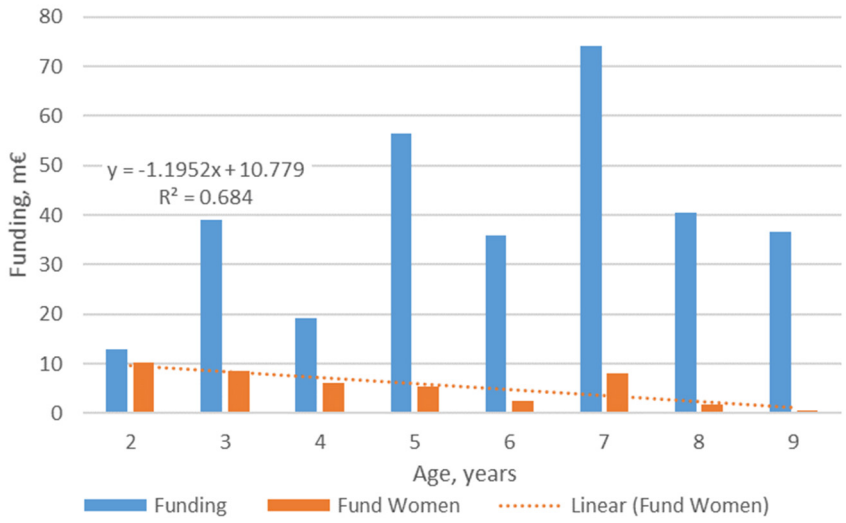

Figure 3. Total fundraising and women founders–related fundraising (y) in sustainability startups within the Estonian startup ecosystem, by the age (x) of ventures, in million euros. Source: Authors.

The share of fundraising by startups with women and mixed teams has risen, reaching 24% of total funding in the last five years and even 80% for two-year ventures. This last figure may not be sustainable as these ventures are still at the early stage. Startups up to one year old are not considered here, as the investments of this group have not yet developed (less than 2% compared to two year olds) and do not characterize the trend.

All-women teams have founded nine ICT-based sustainability startups (Table 7), which make up one-tenth of the total, roughly equivalent to the representation of all-women teams in the overall group (12.3%). The representation of mixed teams is somewhat higher in the ICT group. Overall, the level of investment in ICT-based startups with female participation is approximately twice the group average. This suggests that despite the greater number of technologies in the group of sustainability startups, ICT ventures prevail, as seen from startup investments per venture as a whole (Table 7).

Table 7. Gender-based pattern of investments and technology distribution of ventures.

Data by the venture group	Women		Mixed W+M		Men		Total	
	data	%	data	%	data	%	data	%
Top 30 startups	2	6.67	2	6.67	26	86.67	30	100.0
Invest. per Top 30, m€	39.1		30.8		147.3		132.3	
Sustainability startups	21	12.3	41	24.0	109	63.7	171	100.0
-of them in ICT	9	5.3	24	14.0	58	33.9	91	53.2*
-other tech	12	7.0	17	9.9	51	29.8	80	46.8*
Invest. per startup, m€	0.86		1.10		25.2		16.40	
-per ICT startup	1.67		1.33		33.28		21.7	
-per other techs	0.25		0.76		15.9		10.4	

Source: Authors; * comparing Sustainability group.

The predominance of investments in ICT-based ventures is especially noticeable in the group of all-women startups—more than six times higher than of other tech. In other sustainability startups, the difference is roughly two-fold in favor of ICT. This allows us to generalize that the sustainability startup ecosystem is primarily ICT-based, although this does not mean that competencies from other fields are not utilized. For example, a startup may combine ICT with knowledge in agriculture, earth scanning, the forest industry, material circular processing, health platforms, and more.

6. Discussion

The Estonian startup ecosystem presents several key biases, particularly toward (1) male entrepreneurs, (2) the influence of Bolt, and (3) the sustainability startup sector. Analyzing the top 30 startups that attracted significant investments reveals that only about 6% of the founders are women. This starkly contrasts with the general entrepreneurial activity indicators, where women constitute nearly 40% of the country's total level of entrepreneurial activity (Table 1).

Bolt' stands out significantly with €1.78 billion in funding, which is nearly 40% of the total startup ecosystem funding and surpasses the next largest funded startup, Wise, by approximately 5.3 times. This heavy weighting of Bolt's contribution skews the overall perception of the ecosystem. For instance, the sustainability startup sector appears to receive an extremely high 62.9% of ecosystem financing, but when excluding Bolt, this figure drops to 23.1%, offering a more moderate perspective.

Interestingly, the percentage of female founders in sustainability-oriented startups is significantly higher than in the top 30 funded startups, standing slightly over 23%. This supports the notion that women are more inclined toward ventures addressing environmental sustainability and social issues. However, the capital these women-involved sustainability startups raised is nearly ten times lower than their male counterparts, making approximately 2.5% of the total funding, with the share for only female teams even lower (about a quarter of that figure). When excluding Bolt's contribution, the investment figures for female-participated startups would quadruple, yet still remain modest compared to the 26.1% share of US VC in female-participated ventures (Davis, 2024).

Despite the relatively high proportion of women in the ICT workforce (23%) and sustainability startup founders, this fact is not reflected in sustainability startup accumulated fundraising in Estonia. Compared to the trend in the USA and Germany, Estonia appears to lag. However, Estonia's success

rate for startups on an international scale may offset this discrepancy, suggesting that the average fundraising figure for women might not be as dire as it seems.

To contextualize Estonia's position, consider the per capita startup investment. From 2018 to 2022, Germany, with a population of 84.1 million, had an annual average startup investment per inhabitant of 103 euros (Statista, 2023). With its 1.3 million inhabitants, in Estonia, this per capita indicator is five times higher. Adjusting for GDP per capita, which is 1.35–1.64 times higher in Germany and the USA compared to Estonia (World Bank), Estonian startup investment per capita significantly narrows the gap with these countries. This adjustment paints a better picture of the contributions of Estonian female startup founders in an international context, though domestic disparities remain evident.

Positive trends emerge when examining the role of female founders in newer startups (up to five years old). In the past five years, the share of female founders in these 93 new sustainability startups has increased to 28%, with their share of fundraising to 24%. These trends indicate that male dominance in this crucial ecosystem sector is vanishing, suggesting the potential for a significant breakthrough in long-term fundraising for women-led startups in the near future.

In examining the share of investments in ICT-based women's new ventures, Estonia aligns with broader European indicators (EC, 2019) until an expected significant breakthrough is achieved. Notably, ICT sustainability startups with female participation receive more funding than those in other technology sectors (Table 7). However, they still receive significantly less funding compared to all-male teams.

The promising indicators of the increased female participation in recent years (Figures 2 and 3) are overshadowed by the considerably higher funding levels achieved by older startups in 2020–2023 (Figure 1). In the top 30 startups, there has been a modest increase in funding for deep tech companies from 7% in 2016 to 10.3%. Given the rising focus on deep tech, this sector's overall share might grow. However, the dominance of individual ventures like Bolt, Skeleton, and Elcogen heavily influences the overall investment landscape.

Excluding Bolt's massive €1.78 billion fundraising, Skeleton and Elcogen together account for nearly 40% of sustainability venture funding, and with Bolt included, this share rises to nearly 78%. This concentration suggests that a few ventures significantly impact the investment volume in Estonia's small startup ecosystem. These ventures serve as crucial role models for emerging entrepreneurs, demonstrating the potential for significant investment success. However, role models for female entrepreneurs with similar impact do not emerge from the sustainability startups but rather from the top 30 group.

7. Conclusions and future research

In studying the startup ecosystem, we aimed to uncover gender patterns that describe sustainability venturing in Estonia, a rapidly developing entrepreneurial post-transition country in East Europe. The press dubs Estonia a "startup paradise" (Stefanuk, 2020). Unfortunately, this characterization does not encompass all aspects of new venture creation. In summary, while Estonia's ICT-based women's sustainability startups reflect broader European trends, significant funding disparities persist. The ecosystem is heavily influenced by a few standout ventures, which, while being positive role models, highlight the need for greater diversity and support for female-led initiatives, particularly in sustainability entrepreneurship. This will help create a more balanced and equitable startup environment in Estonia.

Our study revealed that the share of females among founders and in fundraising for sustainability startups in Estonia is particularly disproportionate. Participants in the startup ecosystem do not see a direct reason for this, and it remains unclear why the share of women at the top of fundraising and in sustainability (technology) startup funding is so low. This disparity exists despite the fact that women's education levels in Estonia are significantly higher than men's. From this, we can conclude that the international success of Estonian male startup companies has somewhat overshadowed Estonian women sustainability entrepreneurs who may be at the best European (international) level. However, this does not mean that Estonian women should be content with their current position and contribution to the Estonian startup ecosystem. A closer examination of how women become technology entrepreneurs could provide answers to this question.

At the same time, it can be assumed that Estonian society is overcoming the gender gap in technology-related sustainability entrepreneurship, as evidenced by the micro-analysis of new ventures in the startup ecosystem. Additional prerequisites for women's technology entrepreneurship have been created by initiatives like the HK Unicorn Squad, founded by successful Estonian IT entrepreneurs. Launched in 2018, this program provides technology education as a hobby specifically for girls (https://unicornsquad.ee/?lang=en), fostering "a true interest in engineering, robotics, and natural sciences among girls aged 8–14 through practical and exciting assignments". The European Social Fund co-financed the project, and its results are expected to manifest in the coming years. To date, nearly 4000 girls have participated. They could be part of a sample for deeper research into positive trends in female sustainability startups. There is no reason to believe that the recent growth in women's roles is solely due to girls' tech circles from five years ago, but programs like the HK Unicorn Squad, which target young girls and encourage interest in STEM and entrepreneurship, are crucial. Expanding such initiatives could positively affect gender distribution in technology entrepreneurship. Consequently, future studies must encompass the broader education system and societal context.

In investigating these dynamics, it is crucial to understand the multifaceted nature of entrepreneurship, especially within the Estonian context. Estonia's rapid transformation into a tech-savvy nation and its emphasis on digital advancement provide a unique backdrop for examining gender disparities in startup ecosystems. However, addressing these disparities requires a comprehensive approach.

To this end, several national policy recommendations have emerged from our analysis:

1. Strategic monitoring and financing: The state should not depend solely on EU measures for funding new developments. Instead, it should establish a strategic, systematic monitoring and financing scheme. This would ensure the continuous development of the startup ecosystem, entrepreneurship, and technology education, with particular attention to gender differences.

2. Competence center for research and applications: Given Estonia's advancements in ICT and entrepreneurship, a dedicated competence center is needed. This center would combine strategic research with practical applications, moving beyond basic statistics to delve into the nuances of career choices in STEM and technology entrepreneurship. This includes comparing educational and cultural factors as well as personal and psychological influences on success.

3. Enhanced strategy for Startup Estonia: Building on the above recommendations, Startup Estonia's strategy should be further developed. This would involve implementing policies that address the specific needs and challenges faced by female entrepreneurs in the tech and sustainability sectors.

These steps highlight the necessity of studying these trends not only within Estonia but also in an international context. Questions remain about whether the lack of fundraising stems from the low potential of women's ideas, biases among funding decision-makers, or cultural stereotypes affecting female entrepreneurs locally and globally. The insights gained from other ecosystems, such as those presented by Welsh et al. (2023) or Kanze et al. (2018), may not be directly applicable to Estonian female startups.

Thus, a broader approach is needed, one that encompasses social values, the education system, and the personal capabilities and resources required for entrepreneurship. By exploring these dimensions, we can better understand the factors contributing to the gender gap in technology-related sustainability entrepreneurship and develop more effective strategies to support female entrepreneurs in Estonia and beyond.

In conclusion, the potential for female entrepreneurs in Estonia, particularly in technology-based sustainability ventures, is significant. However, realizing this potential requires addressing systemic biases and providing targeted support through education, policy, and research initiatives. By doing so, Estonia can continue to evolve as a leader in innovation while fostering a more inclusive and equitable entrepreneurial ecosystem.

Author contributions

Conceptualization, TM and PVL; methodology, TM and PVL; software, TM; validation, TM and PVL; formal analysis, TM and PVL; investigation, TM and PVL; data collection and curation, TM and PVL; writing—original draft preparation, TM and PVL; writing—review and editing, TM and PVL; visualization, TM; supervision, TM; project administration, TM. Both authors have read and agreed to the published version of the manuscript.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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