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CYBERSECURITY, INNOVATION, AND REGIONAL ECOSYSTEMS:

A COMPARATIVE STUDY

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MIT MANAGEMENT SLOAN SCHOOL

Cybersecurity, Innovation and Regional Ecosystems: A comparative study

EXECUTIVE SUMMARY

This joint Working Paper by MIT (specifically its Innovation Initiative, MITii) and Global EPIC (GE) - a Global network of "Ecosystems in Partnership in Innovation and Cybersecurity" - brings together two important strands of work which we hope will continue to shine a light on the apparent paradox of the logic of 'innovation ecosystems' which are regional/local in nature, with that of innovation in cybersecurity which might be seen as global and digitally-connected.

The global transition to a digitally-based, innovation economy – accelerated during the current pandemic – has long promised to deliver major opportunities for economic prosperity and social progress. It has also brought with it, however, a wide-ranging set of problems including digital security - and with those challenges, a growing attention to the importance of cybersecurity to the global internet and 'world wide web.'

Though cybersecurity opportunities and problems may be globally distributed, it is clear, even at this early stage of our research, that many of the sources of solutions, and most especially the development of novel solutions to the problems posed by cybersecurity, are highly localized in specific regions, namely innovation ecosystems. These innovation ecosystems highlight the importance of 'cyber hubs', both for defensive security capabilities and also for capturing the benefits for economic development. This report highlights the examples of Beersheva in Israel and of Belfast in Northern Ireland as particularly interesting examples in this regard and also looks at Kenya as an emerging ecosystem worth watching.

Between our Cyber Innovation Ecosystem Workshop[2] and now this Working Paper's publication, the world has of course experienced both a planet-wide pandemic and numerous Covid-related lockdowns. These have forcefully demonstrated the extent to which people rely on such digital technologies, to collaborate in tackling the virus, but also to remain socially and economically engaged. It has also exposed organisations to greater cyber threats, as the fast rise in remote working has revealed vulnerabilities in their systems, technologies and policies.

As the world turns towards recovery, there are opportunities for those that recognize that cybersecurity and its related innovation are likely to continue developing according to a logic of localized, multi-stakeholder 'innovation ecosystems'. Even if these hubs may become better networked globally, most nations and regions within them are likely to wish to have such important cyber capabilities within their borders, and so may be interested in how best to encourage innovation ecosystems with a cybersecurity innovation focus.

[2] https://innovation.mit.edu/assets/Enhancing-Cybersecurity-The-Role-of-Innovation-Ecosystems.pdf

BACKGROUND

Both MITii, through its 2019 Cyber Innovation Ecosystem Workshop, and Global EPIC, with its long-term engagement with a range of cyber ecosystems around the world, are committed to understanding the ways in which cyber security – including the most leading-edge approaches to digital security – can serve as the foundations for significant regional economic growth in regions where this expertise becomes a source of comparative advantage. In addition, both groups are concerned with the ways in which such expertise serves as a foundation for wider digital security that will, by its very nature, be more widely used across regions and nations.

MITii Cyber Innovation Ecosystem Workshop (2019): partners and summary

In 2019, MIT's Innovation Initiative (MITii) co-hosted a workshop to explore whether the general phenomenon of such clustering (in multi-stakeholder ecosystems) also applied to cybersecurity. The seminar participants – including this report's authors – shared their approaches and realized by the workshop's end that, even in cybersecurity, the logic of localized 'innovation ecosystems' were playing a factor. The seminar summary records the conclusion: "Innovation ecosystems … provide an important lens to understand the specific case of innovation in cybersecurity."[3]

As a result, MIT has looked to partner with cybersecurity ecosystem experts and practitioners to apply its general 'innovation ecosystem' approach to that specific sector. This will help deepen our understanding of existing cyber ecosystems, but also allow us to identify the factors which help (or hinder) the development of such cyber-focused innovation ecosystems. To that end, MITii has been pleased to partner on this new Working Paper with Global EPIC (GE), a network of "Ecosystems in Partnership in Innovation and Cybersecurity" (https://globalEPIC.org).

Global EPIC (GE): cybersecurity organization model, and member partners

Global EPIC was created in 2017 to facilitate global collaboration among digital security and cyber ecosystems to create positive local economic development for all their economies. The organization, envisioned originally as a membership organization, was motivated by the success of CyberSpark in Israel, CSIT at Queen's University in Belfast (Northern Ireland), and Carleton University in Ottawa, Canada.

Early supporting locations also include Poland, The Netherlands, and Boston and Maryland in the US. The founding members were (and are) leaders in their own countries, building their own local cybersecurity ecosystems which includes strengthening their position in a global economy.

The Global EPIC founders agree on the core concept that cyber resilience can only be achieved by a comprehensive approach to digital security that includes economic development. Its founders believe that a "network of ecosystems" will create wider benefit to the global economy, while adding value to local/regional economies. Over the course of two years, the founding team has engaged more than 30 formal organizations world-wide.

[3] https://innovation.mit.edu/assets/Enhancing-Cybersecurity-The-Role-of-Innovation-Ecosystems.pdf

Specifically, Global EPIC was organized to:

- Provide leadership and resources to a global community of Digitization clusters (digitization goes beyond cybersecurity *per se*, e.g., to AI aspects);

- Assist countries, through partnerships with their state and regional organizations, with the process of developing their own digital economic ecosystems; and

- Develop and advance the methodologies associated with the growth of the cyber digital network of ecosystems.

To date, Global EPIC (GE) includes thirty members, representing different cities and/or regions in twenty-two (22) different countries around the world (see Appendix 1 for a table of members). The GE organization is not legally incorporated, rather it is an *ad hoc* organization that is self-managed by its members.

Global EPIC welcomes new members who demonstrate a willingness to contribute time and expertise and/or who need expertise in order to strengthen their own economy. More importantly, Global EPIC seeks members who have a stakeholder model that requires government, academia, and industry be included as core partners in the local ecosystem.

One: Introduction

Cybersecurity, and its Economic Development Opportunity

The global transition to a digitally-based innovation economy has long promised to deliver major opportunities for both economic prosperity and social progress. Covid-related lockdowns have demonstrated the extent to which people rely on such digital technologies, to collaborate in tackling the virus but also to remain socially and economically engaged. However, the success of our open digital realm relies on a certain level of trust among participants and connections across stakeholders.

Every country and economy, big or small, must enable a digital transformation that allows for such connectivity and must also demonstrate to the world that it is a trusted participant with clear rules and norms for the security of digital infrastructure as well as data. Security in the digital economy is not simply about being prepared with a good cyber-defense, and it is not a job to be done by one person in a given organization or government department. Rather, it is the role of various people, in various stakeholder groups, to be active participants in securing the digital economy.

This proposition means that digital security is at once a measure of economic development strength as well as of resilience and readiness. It means that a culture of processes and practices designed to protect data needs to be present to attract new investment and protect existing stakeholders and institutions. Each country, state, and city must therefore:

- Educate new talent and support human capital with expertise in digital security,
- Invest in and advance research and development (R&D) that will enable expertise of this complex system,
- Allocate government resources to the infrastructure needed to grow and secure a digitally-enabled economy, especially in the post-Covid recovery, and
- Collaborate with multi-national corporations as partners in the local ecosystems.

Beyond these basic elements that provide countries, states and cities with the much-needed system resources to build the foundations of digital security, there is also an opportunity to build specialized expertise in digital security, through investments in research and development (R&D) that can drive 'innovation capacity' in digital security, and through complementary investments in entrepreneurial start-ups and scale-ups that can provide much needed 'entrepreneurial capacity'. Together these two additional elements provide for potential comparative advantage in particular aspects of digital security, thus establishing security not simply as a "nice to have" requirement but as a source of comparative advantage and regional/national economic growth.

Such an agenda fits well with MIT's more general approach to 'innovation ecosystems', an approach that builds on perspectives on 'agglomeration' and its role in economic geography (as first put forth by Alfred Marshall in the 1880s, and later Michael Porter in his important 1990 work on *The Competitive Advantage of Nations*). In analyzing economic 'clusters' that are

grounded in advances in technology and rely upon innovation, in 2001 Porter adapted his approach, collaborating with MIT's Professor Scott Stern, to examine why location matters to innovation, and why all clusters were not dynamic in their growth and evolution.[4] Brookings built on this foundation to highlight the role of 'innovation districts' (such as Kendall Square) with a strong emphasis on micro-geography within wider industrial clusters noting that "clusters are geographic concentrations of interconnected businesses, suppliers, and associated institutions. They can contain anchor institutions, small firms, start-ups, business incubators, and accelerators."[5]

MIT's approach to 'innovation ecosystems' addresses why some 'districts' or 'hubs' do not end up accelerating innovation in the wider cluster, ecosystem or community, and why some do. Further, MIT's approach considers the potential for nationally and internationally connected innovation ecosystems to develop complementarity and further growth.

Across the world, digital security 'hubs' within wider economies are emerging at the core of important innovation ecosystems. Hubs in locations as different as Tallinn and Tokyo are concentrated in cities, predominantly in developed regions of the world. That said, the economic growth (and expertise) from these hubs often struggles to spillover into outlying, and less populated regions, or many parts of less developed countries. This is especially problematic because cybersecurity attacks generally do not respect geo-political boundaries. Attackers look for weaknesses in a variety of places which makes building the global landscape of cybersecurity hubs imperative, each with localized competitive advantages.

Moreover, these digital/cyber ecosystems, while growing in strength individually, are not generally connected in a way that motivates resource sharing and learning among them. Economic competition between countries and cities is commonplace, even while global digital transformation in a shared, international, secure environment benefits a competitive marketplace for new products and services.

Ultimately, cybersecurity as an economic competitiveness model is important to economic development, but it is also more than a cluster. Given its centrality to the digital economy (which is now most of the economy), cybersecurity is a foundational and "horizontal" element that must be supported and understood in order for any economy to be agile and ready to grow new economic tech clusters as they emerge.

MIT 's approach to 'innovation ecosystems'

Since the turn of the twenty-first century, the world has begun to view economic clusters more as innovation and entrepreneurship ecosystems with their implied dynamism and evolution, around hubs of existing, interconnected organizations and supply chains. MIT has studied 'innovation-driven entrepreneurship' and why it tends to cluster at high concentrations in certain places which are identifiable as 'innovation ecosystems' (iEcosystems).

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4 Michael Porter, The Competitive Advantage of Nations (1990). Porter and Scott Stern, "Innovation: Location Matters" in Sloan Review (2001) https://sloanreview.mit.edu/article/innovation-location-matters/

5 Martin Neil Baily and Nicholas Montalbano. "Clusters and Innovation Districts: Lessons from the United States Experience", The Brookings Institution, December, 2017, https://www.brookings.edu/wp-content/uploads/2017/12/es_20171208_bailyclustersandinnovation.pdf

This observation implies that the world of innovation (despite promises to the contrary) is not flat: even while talent is likely to be more evenly distributed, opportunities for engaging that talent in the innovation economy are not. Understanding why that is the case, and assessing the factors which drive the differing outcomes, drive MIT's research in this area.[6] The MIT aim is not just academic, but to be able to share useful best practice and guide strategy making and the creation of a common purpose for those building such ecosystems, including for cybersecurity.

At first sight, one might expect that cybersecurity – one of the most digitized areas of human activity – would avoid the logic of such physical agglomeration and clustering. Even a cursory glance at the location of key cyber 'hubs' and 'hotspots' suggests, however, that some forces of clustering are at work: as such, this sector seemed like a ripe area for further research. Given the underlying importance of information and communications technologies (ICTs) to the wider innovation economy in this digital age, the issue of cybersecurity is indeed fundamental (even if not always readily appreciated) to the wider health of these innovation ecosystems.

[6] https://innovation.mit.edu/assets/Assessing-iEcosystems-V2-Final.pdf

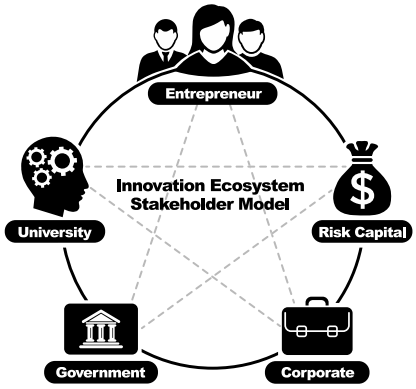
Two: Comparative Analysis Framework

MIT's analytical framework for the comparative analysis of innovation ecosystems

Building on its research into innovation ecosystems around the world, MIT has pioneered an analytical framework that separates out the factors which drive the differing outcomes, and allows a more nuanced assessment of those ecosystems. While there are many Indexes and rankings of 'innovation' and/or 'entrepreneurship' which list many different inputs (and some outputs), none adequately parse and define the phenomena in a way that fits with a research-based approach to 'innovation-driven entrepreneurship', making a comparative analysis based on those factors difficult.

In its research into innovation in ecosystems, MIT has taken a systems-level analytical approach, which has flagged two key aspects for assessing these ecosystems.[7] First is a 'System' approach to the production of innovation (as represented by the triangular graphic below), drawing on traditional approaches to 'foundational institutions' and 'comparative advantage'. Different in the MIT approach is a separation of two key Capacities at the heart of the 'System' that drives different outcomes – namely an 'innovation capacity' (I-Cap) and a separate 'entrepreneurship capacity' (E-Cap), which we discuss in more detail below.

Second, in each ecosystem, MIT identifies five distinct Stakeholders which are critical to the success of most efforts at innovation ecosystem creation, and the subsequent growth and acceleration of innovation-driven entrepreneurship in the ecosystem.[8] Debates used to focus just on the Government and Corporate (as in the 'state and industry' or 'public and private') interactions, before adding the 'entrepreneurial University' (a subset of the wider world of academia) to create the so-called 'triple helix.'

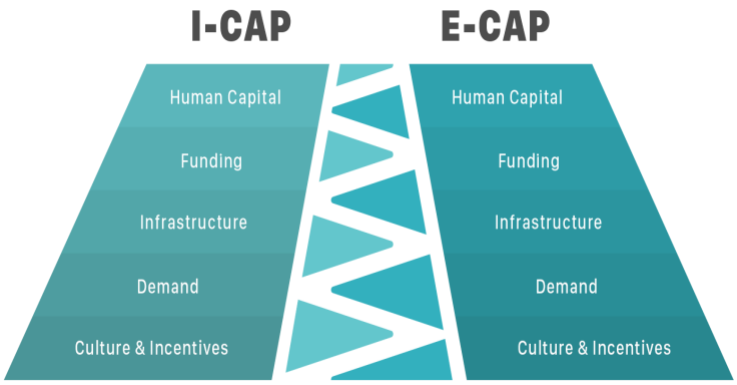


MIT's model goes beyond the 'triple helix' to reflect twenty-first century realities, by adding the Entrepreneur (and her/his start-up) and also the 'Risk Capital' providers (beyond just VC to a range of other providers, like business angels).

[7] https://innovation.mit.edu/assets/Assessing-iEcosystems-V2-Final.pdf.
[8] https://innovation.mit.edu/assets/MIT-Stakeholder-Framework_Innovation-Ecosystems.pdf

There are of course many other actors in any socio-economic/political system – ranging from trades unions to law firms, the general public to the media, NGOs to activists (many of which exist inside the 'pentacle', often funded by one of the five) – but, for the purpose of understanding the primary drivers of innovation-driven entrepreneurship ecosystems, the same five consistently show up around the world as the necessary stakeholders.

In the 'system' for such innovation-driven entrepreneurship, the two distinct Capacities are like the 'twin engines' of the ecosystem: thrust from both is required to drive innovation-driven entrepreneurship. Each of these Capacities can be broken down into the same five categories of inputs, as shown in the graphic below, namely: Human Capital, Funding, Infrastructure, Demand, and combined Culture & Incentives.



The inputs differ depending on which Capacity they serve. As an example, Funding appears in both Capacities, but the money is different if it is for I-Cap (eg R&D spend) than if it is for E-Cap (eg VC investment): the most effective 'innovation ecosystems' have a blend of both, realizing that neither by itself is going to lead to optimal outcomes.

MIT's framework is not itself an attempt to create a new MIT index or ranking to accompany all those that already exist, but should be read alongside them. Based on its research approach, it attempts to cast light on why outcomes differ, and what ecosystem players might do to build on their own ecosystems' strengths and to address its weaknesses. More sector-focused indexes and rankings – building on this general approach to innovation ecosystems – might be a more appropriate way forwards in some cases, revealing distinctions that are specific to certain sectors (such as cybersecurity).

What follows is a summary of the thirty Global EPIC cybersecurity ecosystems and an analysis of their appearance in several common indexes of 'innovation' as set out in MIT's Working Paper. This is followed by a more detailed MIT-style analysis of several GE members' hubs, using MIT's I-Cap and E-Cap characteristics that we could see across the network of 30 international hubs. In addition, eight non-GE countries have been added to the analysis: these countries exhibit the characteristics needed to grow a strong cybersecurity ecosystem and are potential future prospects for Global EPIC membership.

Insights from Global EPIC and its members:

A. Stakeholders and Champions

MIT places stakeholders at the center of its model of innovation ecosystems: individuals are critical in representing the different types organizations whose contributions to the innovation ecosystem, particular in the form of critical resources, and their role in resource exchange, are essential. Our experience working with over 50 regions worldwide though the MIT Regional Entrepreneurship Acceleration Program (MIT REAP: http://reap.mit.edu) emphasizes the need for regional 'champions' who, while coming from a variety of different stakeholder groups, share a distinctive and essential willingness to serve as ecosystem champions bringing together the wider stakeholder network: these Champions drive a shared understanding of the value of ecosystem-building and collective action.

Experience from Global EPIC confirms the crucial role of stakeholders when it comes to the development and growth of cyber ecosystems. While there are thirty members of Global EPIC, it would be hard to argue that any two are alike. However, some common features exist, especially around leadership, that emerge as we look at the innovation and entrepreneurship characteristics that define the network. Such 'champions' not only take on a "Lead Organizer" role akin to the champion role in REAP teams. They often also serve as the "Primary Funding Source" for a range of activities that lie beyond the scope of any particular organization, as such funding the creation of public goods (including convening) that are essential to furthering cybersecurity capabilities.

National or Regional Hub?	Regional: 16	National: 14	
Lead Organizer? (government, academia, industry/NGO)	Government: 12	Academia: 7	Industry/NGO: 11
Entrepreneurship Start-up /Scale-up Program? (Yes/No)	Yes: 24	No: 6	
Year Organized (speaks to maturity of ecosystem)	2018-2020: 8	2016-2017: 10	2015 or earlier: 12
International Corporate Partners (# named)	0-5: 16 (9/15 reported 0)	6-10: 6	10+: 8
Primary Funding Source (financial sustainability)	Government: 16	Outside Grants: 9	Dues/Sponsors: 5
International Conferences (yes/no)	Yes: 17	No: 13	
International Alliances/ formal Government to Government Agreements	Yes: 9	None Reported: 21	

Just over half of the thirty ecosystems in Global EPIC are funded by government, but only 40% are led or organized by government. Indeed, government procurement laws can restrain the agility of economic growth strategies, so government becomes an important customer and a funder, but is limited as a lead organizer. In the hands of the private sector and academia, the E-Cap side builds on the I-Cap resources and germinates entrepreneurship. This trend can be noted in the number of start-up programs offered by Global EPIC members, the maturity of the organizations (older ecosystems have more developed I-Cap), and the number of international conferences offered (an indicator of the global impact of any given ecosystem).

Taken together these insights suggest the critical role of the major stakeholders of government, corporate and academia, but also the important ways in which start-up enterprises (and their investors) are essential to drive growth and deepen cyber security expertise.

B. System Resources:

MIT emphasizes the role of key system resources as critical inputs into successful innovation ecosystems. Our focus has been on separating out resources that strengthen innovation (I-Cap) from those that support the creation of new enterprises (E-Cap).

Historically, cybersecurity ecosystems formed organically from a number of factors including concentrated national military strategy, investment and expertise alongside the expansion of IT budgets into data security by multinational companies, particularly those in financial services. Since the 1980's, R&D funding for cybersecurity in universities has also accelerated. The lead organizer and the funding source, as a result, teaches us much about the role that cyber-security plays in the national or regional economy. Each of these conditions fortifies the I-Cap side of the ecosystem for cybersecurity.

In addition to these metrics, each Global EPIC member also reports on (A) the key performance indicators (KPI's) of its ecosystem, and (B) the 'technology thrust' areas that the ecosystem focuses on. These two sets of information allow Global EPIC members to have transparency into the opportunities for collaboration within the network of ecosystems and to more clearly understand that each hub is unique and has something to contribute as a partner.

C. Measuring System Strengths - Global EPIC Members' Key Performance Indicators (KPI's):

MIT's approach to metrics emphasizes the distinctive critical inputs into I-Cap and E-Cap, and highlights the importance to policy-makers of ensuring that investments in one without another rarely leads to highly productive outcomes. However, we also observe that in leading ecosystem change, building collective agreement on the nature and direction of additional resources is an essential part of leadership. Such agreement serves as the foundation for wider collective action among the five critical ecosystem stakeholders. As part of building collective action, a shared set of metrics is particularly important.

Global EPIC members each report on their Key Performance Indicators (KPIs). While GE does not itself track the annual data of each ecosystem, it does monitor what each member is tracking. The KPI's of a GE member's ecosystem provide an immediate way to determine what

the organizational mission is of the ecosystem and are also a window for other similar ecosystems to use for comparison. For Global EPIC, KPI's are usefully organized according to the primary funding source of ecosystem engagement; in other words, who pays those who keep the ecosystem operating:

Academia Funded	Government Funded	Industry Funded

• # Startups from University
• # Students enrolled in cyber degree programs
• # Graduates from cyber degree programs
• # Events
• $ Corporate/industry sponsorships for R&D
• $ Research dollars secured from all sources
	• # cyber jobs
	• Created
	• Retained
	• # Training partnerships
	• Startups
	  ○ Created
	  ○ Served
	  ○ $ raised
	• # Events
	• # Industry Partners
		• # members
		• $ Dues revenue
		• # Events
		• $ Research Grants
		• Partnership grants with academia, corporates or government (can include startup activities)

D. <u>Strategy: Specialization & Industry 'Thrust Areas'</u>

As might be expected given the imperative for building comparative advantage to enable the innovation economy and to drive agglomeration, MIT's work has confirmed the need to develop regional-level insights into such advantage, which GE members see built around constructs such as "super-clusters" or "thrusts". These are most successful when they are more broadly conceived of than single clusters (or sectors) but not so wide as to render decision-making and focus impossible. Many of the ecosystems that are part of Global EPIC and other locations worldwide have primary 'thrust areas' defined by particular technological capabilities or sector domains. This recognizes that cybersecurity is often a building block of a wider expertise in other technological or industrial areas but itself can also be sub-divided into different activities.

By sharing information on areas of focus across Global EPIC members, each one can create targeted partnerships with complementary expertise. Additionally, tracking these technology thrusts also allows the membership of this "network of ecosystems" to identify industry trends where cybersecurity is gaining traction and securing R&D funding. Ultimately, this information can lend itself to the financial sustainability of an ecosystem, allowing each one to stay on trend or ahead of it.

The summary of 'Industry Thrust Areas' below underscores the importance of building an ecosystem with at least academic, government, and industry partners. In order to best leverage the expertise in an area and translate that into economic value, it is critical that each sector be allowed to bring its own area of expertise and/or interest to the table. The strength of the ecosystem will ultimately be built upon the shared interests that arise when the collaboration is genuine among all three partners.

This summary of 'Industry Thrust Areas' is organized by funding partner.

Academia Funded	Government Funded	Industry Funded	
• Connected devices • Training • Threat sharing • Network security • Finance • Smart cities • Healthcare • Transportation • Data privacy • Cryptography • Industrial controls • Security intelligence • Secure mobility • Critical infrastructure • Public safety • Secure by design software/ Embedded security	• Public Safety • Training/Talent • Compliance/ Policy • Advanced manufacturing • Smart energy • Digital health • Food tech	• Financial Services • IoT - Connected Devices • Application Security • Embedded Security/ Secure design • Security Management • Enterprise Risk • Talent Development • Robotics • Microelectronics • Digital Security • AI/ Big Data • Smart mobility • Compliance and risk • Critical infrastructure • Smart home security	• Advanced manufacturing • Fintech • Public safety • Smart Cities • Forensics • National Security • Digital DNA • 5G • Public policy • Quantum technologies • AI • Cyber leadership • Maritime • Space, aerospace • Autism and security

Three. Systematic Comparison of Ecosystems

The data collected by each GE member in its own ecosystem vary widely as was demonstrated. The variety of these data makes a side-by-side comparison of the ecosystems difficult. Instead, for the purposes of this paper, we examined the innovation and entrepreneurship rankings of the indexes used by MIT to provide insight into the GE members through the measures of I-Cap and E-Cap. We added the Global Cybersecurity Index as we are focused on that particular sector. The indexes are:

I-Cap:

- World Economic Forum (WEF) Global Competitive Index (GCI)
- Bloomberg Innovation Index (BII)
- Global Innovation Index (GII)
- European Innovation Scoreboard (EIS)

E-Cap:

- Global Entrepreneurship Monitor (GEM)
- The Global Entrepreneurship and Development Index (GEDI)

Cybersecurity

- Global Cybersecurity Index[9]

We began the comparison with a broad look at the most complete *overall rankings* of these indexes (2018 is the most complete data set at the time of this research), and recorded how many times (eg '4x') a specific GE member was ranked in these indexes.

Global Epic members ranked in the top 5 in any of the 7 indexes	Global Epic members ranked in top 6-10 in any of the 7 indexes	Global Epic members ranked in top 11-20 in any of the 7 indexes	Global Epic members ranked overall higher than 20 in any of the 7 indexes (or not ranked)
Netherlands, 4x	Denmark, 3x	Australia	Costa Rica
US, 4x	Finland, 3x	Belgium	Kenya
UK, 3x	Ireland, 2x	Estonia	Nigeria
Denmark, 3x	Israel, 2x	Finland	
Canada, 1x	UK, 2x	France	
Estonia, 1x	US, 2x	Italy	
Finland, 1x	Australia, 1x	Israel	
France, 1x	Belgium, 1x	Japan	
	Canada, 1x	Poland	
	France, 1x	Spain	
	India, 1x	Taiwan	
	Japan, 1x	Turkey	
	Spain, 1X	UK	
	Taiwan, 1X		

[9] https://www.itu.int/en/ITU-D/Cybersecurity/Pages/global-cybersecurity-index.aspx

The Netherlands and the Unites States scored highest overall among Global Epic members with four citations each in a 'top 5' ranking, followed by the United Kingdom and Denmark each with 3 citations and then Canada, Estonia, Finland, and France with one each.

Based on the comparative country-level data collected for the rankings under I-Cap, the United States, Netherlands, United Kingdom, Denmark, and Finland each received at least one top five ranking in each of the indexes. This group of GE members is followed closely by Israel, Ireland, Belgium, Japan, and France who each received top ten rankings and Australia, Estonia, Spain, and Italy which are each ranked in the top twenty. Two countries dominate the rankings overall, Switzerland and Sweden, neither of which are GE members.

*Global EPIC members are *italicized*

GCI	BII	GII	EIS
Singapore	Germany	Switzerland	Sweden
US	South Korea	Sweden	*Finland*
Hong Kong	Singapore	*US*	*Denmark*
Netherlands	Switzerland	*Netherlands*	*Netherlands*
Switzerland	Sweden	*UK*	Luxembourg
Japan	*Israel*	*Finland*	*Belgium*
Germany	*Finland*	*Denmark*	*UK*
Sweden	*Denmark*	Singapore	Germany
UK	*US*	Germany	Austria
Denmark	*France*	*Israel*	*Ireland*
Finland	Austria	Korea	*France*
Taiwan	*Japan*	*Ireland*	*Estonia*
R. of Korea	*Netherlands*	Hong Kong	Portugal
Canada	*Belgium*	China	Czechia
France	China	*Japan*	Slovenia
Australia	Ireland	*France*	Cyprus
Norway	Norway	*Canada*	Malta
Luxembourg	*UK*	Luxembourg	*Italy*
New Zealand	*Italy*	Norway	*Spain*
Israel	*Australia*	Iceland	Greece

Because of its relationship with China, Taiwan is rarely ranked autonomously in any global index. However, it is likely that Taiwan, which is a GE member, would rank highly if it was consistently ranked. The Industrial Technology Research Institute (ITRI) is the parent organization for Taiwan's cyber cluster, called the 'Art of Cyber War Taiwan', was organized in the 1970's and is a very advanced applied technology R&D center.

From rankings under E-Cap, comparisons can be drawn from the GEM and GEDI data. For these two indexes, The Netherlands, United States, Canada, Denmark, and United Kingdom each received a top five ranking. India, Taiwan, Australia, and Ireland each received top ten rankings, and Israel, Spain, Finland, France, and Belgium are in the top twenty.

GEM	GEDI
Switzerland	*US*
Netherlands	Switzerland
Qatar	*Canada*
China	*Denmark*
Arab Emirates	*UK*
India	*Australia*
Taiwan	Iceland
Indonesia	*Netherlands*
Norway	*Ireland*
US	Sweden
Jordan	*Finland*
Spain	*Israel*
Luxembourg	Hong Kong
Canada	*France*
Korea	Germany
Germany	Austria
Saudi Arabia	*Belgium*
Thailand	*Taiwan*
Sweden	Chile
Latvia	Luxembourg

Finally, we added the Global Cybersecurity Index (GCI) as a way to overlay the I-Cap and E-Cap rankings with a country's cybersecurity strength.

GE members the United Kingdom, United States, France, and Estonia receive overall top five rankings in this index. Estonia is notable in that it is a widely recognized powerhouse in cybersecurity, but it ranks lower in innovation and entrepreneurship. For GE, this is a comparison that allows the leaders to focus the community's resources in a way that offers Estonia tools for improving their I-Cap and E-Cap strengths.[10]

[10] This review of indexes revealed eight (8) additional countries that Global EPIC should consider building a relationship with based on their rankings and expertise in technology, innovation and entrepreneurship. They are the Republic of Korea, Singapore, Norway, Luxembourg, Germany, Switzerland, Sweden and Austria. These eight countries will continue to be mentioned throughout the remainder of the report as a comparison.

Global Cybersecurity Index
UK
US
France
Lithuania
Estonia
Singapore
Spain
Malaysia
Canada
Norway
Australia
Luxembourg
Netherlands
Saudi Arabia
Japan
Mauritius
S. Korea
Oman
Qatar
Georgia

Also notable in this comparison overall is Israel, a country that is often synonymous with innovation, entrepreneurship and cybersecurity. While Israel outperforms most countries marked by consistent top twenty rankings, anyone who follows the international competitiveness of these indicators would expect Israel to be ranked higher. This apparent discrepancy is a reminder that the data is country level data. A country with strong "hubs" (even if they are some of the strongest in the world) may not carry the data for the entire country which may in turn dilute the appearance of success of an ecosystem. Furthermore, these rankings are overall rankings and do not tell the story of specific metrics where a country like Israel ranks first among peers.

Following this overall ranking using indexes, we can consider an MIT-style analysis of several GE members' national data, with the I-Cap and E-Cap characteristics, using the next level indicators that serve as the building blocks of the indexes in the categories above. This approach draws on MIT's "system" analysis (from above), especially the two Capacities – for Innovation (I-Cap) and Entrepreneurship (E-Cap).[11] Each is divided into five input categories, based on twenty separate elements (drawing on a variety of commonly available data at the national level). The full detail of the MIT analytical approach is set out in the Annex that follows this Paper, for reference.

[11] https://innovation.mit.edu/assets/Assessing-iEcosystems-V2-Final.pdf

I-Cap Analysis

The I-Cap profile of the GE members begins with a look at human capital. The GCI ranks Singapore first for quality of STEM education with GE member Finland following in second. The Netherlands, Belgium, Estonia, and United States round out the top ten.[12] The next indicator, Tertiary STEM Graduates per Capita, indicates Germany holds a top position with GE member India ranking second. This is one of the few places where India places in the top 5 for any of the I-CAP indexes and is worth noting. Finally, we look at new PhD graduates per capita measured by the European Innovation Scoreboard (EIS). Spain ranks first for this indicator, the only place across all metrics where this occurs. One country receives a top ten place in all three of these metrics- Finland.

The next set of indicators reveals how the workforce reflects a readiness and availability to grow the STEM related fields of a country. The first indicator is the availability of scientists and engineers as reported by WEF GCI.[13] Finland continues to shine as a first-place holder for this metric followed closely by the US (2nd), Canada (4th) and Israel (6th). The next metric reported is the percentage of Researchers/Professionals engaged in R&D per million population. Israel ranks first for this indicator, followed by Denmark (2nd) and Finland (6th). These two metrics begin to put Israel on the competitive landscape in a way that the overall rankings did not and begin to tell the story of Israel's robust R&D ecosystem.

Next, we look at the money being spent on R&D in each country as a percentage of GDP. These metrics look at gross domestic expenditure on R&D as a percentage of GDP, the percentage of R&D in a country that is financed by "the rest of the world", financed by the host country government, and financed by private industry.[14]

Israel ranks first for gross domestic expenditure on R&D with an upward trend and is joined by four GE members in the top ten, each also indicating an upward trend in this metric (Japan, Denmark, US, Belgium). The nuanced analysis of this expenditure further puts the success of Israel into perspective. Israel ranks first for R&D financed by "the rest of the world" meaning it has excellent bilateral agreements in place for R&D. It is followed by Ireland, which reports half as much percentage in this category showing that Israel far outweighs any other country in this metric. India ranks first for R&D financed by government at 63.2% and is followed closely by Costa Rica at 53.6%.

This metric shows what could be seen as an over-reliance on government or a robust effort by government to get the R&D economy moving in a positive direction. The US and the UK are at 23% and 26% respectively with both indicating a downward trend as does Israel at 10.64%. R&D funded by private industry is the final metric in this set. Republic of Korea ranks first in this category at 76.23% followed by Switzerland, Germany and Belgium (only Belgium is a GE member). Israel ranks the lowest among Global Epic members at 35.77%.

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[12] WEF Global Competitiveness Index 2017-18: indicator 5.04: Quality of STEM education: http://www3.weforum.org/. OECD STEM tertiary grads per capita: https://read.oecd.org/. (https://ec.europa.eu/).
[13] WEF Global Competitiveness Index 2017-18:12.06: Availability of Scientists and Engineers, http://www3.weforum.org/. (Global Innovation Index 2019 Report: https://www.globalinnovationindex.org/).
[14] UNESCO: http://data.uis.unesco.org

A comparison of human capital and R&D investment is made more meaningful for an innovative cybersecurity economy once the measure of a country's accessibility, deployment, and usage of the internet and overall technology infrastructure are better understood.

A 2016 OECD report on the *Economic and Social Benefits of Internet Openness,* summarizes the critical nature of this relationship: "Internet openness benefits innovation and entrepreneurship by cementing the Internet as a venue for creativity. It does this in a number of ways – by boosting knowledge flows that support innovation, by underpinning the Internet as a platform on which entrepreneurs can construct new businesses and commercialise their ideas, and by enabling new avenues for businesses to obtain inputs, thereby lowering entry barriers and freeing up resources for innovative activity.

People can share, access and co-ordinate knowledge in ways that were previously not possible, with benefits for collaborative research, public service delivery and business activities. The Internet's end-to-end design principle makes it open to new applications and, combined with a competitive market and an absence of gatekeeping, means lawful new services can bubble up. This dynamism makes the Internet a crucible for innovation, which is nourished by the availability of finance, business services and marketplaces online.[15]

Through this lens, we can observe the current digital infrastructure supporting innovation in a country as well as predict where opportunity may be the strongest for new cybersecurity hubs to emerge. The first indicator examined, presented by the 'Global Innovation Index' (GII), is the ICT Access Composite Score[16] which represents the composite score of five indicators (see previous chart) in equal amounts. This dataset ranks Luxembourg as first, followed by Iceland, UK, Hong Kong, and Malta. Of those five countries, only the UK is a Global Epic member.

Luxembourg also leads the rankings for the next metric, Internet Bandwidth, as reported by the GCI (9.06, 2017-18 report). Luxembourg ranks first followed by Hong Kong, Malta, Iceland, and Singapore. A further look at Luxembourg's success is described by the European Commission, "The national broadband plan [of Luxembourg] aims for networks with ultra-high-speed rates of 1 Gbps download and 500 Mbps upload for 100% of the population in 2020. A 5G taskforce and strategy was established to keep Luxembourg at the forefront of connectivity".[17] This initiative by Luxembourg focuses on both bandwidth (the amount of data that can be transferred) and the speed or transfer rate of data. While internet speed is included in the first GII metric, if it is extracted as a stand-alone data point, the latest 2020 figures generally rank Singapore, R. of Korea, and Taiwan as the counties with the fastest internet speeds (lowest latency) with Luxembourg consistently in the top ten.[18]

Digital infrastructure goes beyond the internet. Automation and a suite of digital tools have modernized the workplace, streamlining processes beyond the dull, dirty and dangerous work of previous generations. The GCI measures this modernization through a survey response tool reported in the annual Global Competitiveness Report (11.07, 2017-18). Topping the list are Switzerland, Japan, Norway, Netherlands, and Sweden. GE members Finland, Belgium, and the

[15] https://www.oecd-ilibrary.org/docserver
[16] https://www.globalinnovationindex.org/gii-2019-report
[17] https://ec.europa.eu/digital-single-market/en/country-information-luxembourg
[18] https://worldpopulationreview.com/country-rankings/internet-speeds-by-country

US are in the top 10. It's notable that GE member Costa Rica is 37th, advancing past many other more developed countries. Conversely, Estonia, which is a cybersecurity leader, is ranked 52nd.

This metric is complemented by another GCI metric, Availability of Latest Technology (9.01, 2017-18). Finland tops this ranking accompanied by GE member Israel in 4th. GE members US, The Netherlands, and the UK round out the top nine with Luxembourg landing in 10th. Interestingly, Estonia moves to 25th for this metric and Costa Rica drops to 46th.

Overall for innovation infrastructure, Luxembourg emerges as a country that GE should be working with as there is a commitment to a digital economy and an adoption rate of latest technology that makes them perhaps an ideal location for closely examining their cybersecurity ecosystem.

The next set of indicators is specific to demand in a particular country for innovative products and services. In order to spur innovation and entrepreneurship in any economy, there must be some level of local demand to create a customer base for new products. A 2007 JRC European Commission report, *Public Procurement for the Promotion of R&D and Innovation in ICT* states: "The public sector has the potential to positively influence innovation and R&D through public procurement. It can provide a sufficient and stable demand for innovative products, thereby reducing the risks associated with innovation for suppliers. It may also act as the main or first user of new products or services. Thus, public procurement can be most influential in the early stages of the lifecycle of a product, promoting emerging industries."[19]

The GCI (12.05) ranks countries by the amount of spend by a national government on emerging technologies. This indicator offers the UAE, US, Qatar, Malaysia, and Singapore as the top five countries in that order. GE members India (8th) and Israel (11th) are accompanied by Germany, Rwanda, Luxembourg, and China in the top ten. The ranking by India is consistent with their high ranking in government funded R&D and the second place ranking by the US reflects a long history of government funded advanced technology through procurement by the military most notably.

Demand is also measured by University/Industry Research Collaborations, measured by the GII (2019). This research is funded by industry most often to co-create intellectual property with academia in order to advance new innovations to the market. This is particularly important to those GE members who have research institutions as their primary ecosystem organizer. The US (1st) and Israel (2nd) lead this category and coincidentally, their respective GE members are led generally by academia. The Netherlands, Finland, and the UK are also in the top ten, with GE members Ireland (11th) and Belgium (12th) rounding out the top twelve and Luxembourg ranking thirteenth (13th). In each of these countries we can expect to see a robust demand cycle driven by these university/industry partnerships.

Finally, we measure demand by a look at trade, competition and market scale. The GII (2019) defines this metric as a composite score of three factors: applied tariff rate (weighted mean), intensity of local competition, and domestic market scale. The US leads this category, followed by GE members Japan (3rd), the UK (5th), France (6th), India (9th), and Australia (10th). Across all

[19] https://www.researchgate.net/publication/237386665_Public_Procurement_for_the_Promotion_of_RD_and_Innovation_in_ICT

three categories, only the US consistently ranks in a top position. Germany, a non-GE member, is the only other country that ranks in the top ten across all three Demand indicators.

The final set of I-Cap indicators is in the category of "Culture and Incentives". This category is measured by two indicators: Quality of Scientific Research Institutions (GCI, 2017-18) and the number of Tertiary Graduates in Science and Engineering as a percent of the entire population of tertiary graduates (GII, 2019). For the first indicator, GE members occupy all of the top ten positions, except for Switzerland which ranks 1st. The UK, Israel, The Netherlands, US, Belgium, France, Finland, Canada, and Australia round out the top ten in that order. However, for the next indicator which measures the percentage of graduates from universities in science and engineering, the numbers are quite different. The top five counties: Oman, Tunisia, Iran, Germany, and Singapore (ranked in that order), are not GE members nor do they appear in the rankings for the previous indicator. Only GE member India, ranked 7th, appears in the top 10.

E-Cap Analysis

The E-Cap profile of GE members offers a deeper look at the entrepreneurial capacity of a country. The five categories of input indicators are the same as I-Cap: human capital, funding, infrastructure, demand, and culture and incentives. However, the indicators used to measure the potential for creating an economy steeped in entrepreneurship are focused more on markets, business climate, and individual attitudes.

The first set of measurements, Human Capital, provides a characterization of entrepreneurship potential within the general population. The percentage of people enrolled in tertiary education within a corresponding age cohort presents the backdrop of higher education in a population. According to the GII,[20] Greece ranks first, followed by GE members Australia (2) and Turkey (3). Spain, US, and Finland each rank in the top ten, establishing themselves as prepared to present a well-educated cadre of entrepreneurs who can potentially draw upon research to build entrepreneurially focused use cases and market strategies. But how focused are these people on starting a business?

The next indicator is offered by the Global Entrepreneurship Monitor (GEM). GEM is published annually by a consortium of researchers as a measure of entrepreneurship potential across the globe. Founded in 1998 by Babson College in the US and The London School of Business in the UK, the GEM offers an annual index based on survey data collected in various countries. The data collected is volunteered by the country itself, leaving the index to include only those countries that wish to participate.

For this report, we look at the 2019 GEM rankings by country indicating the share of population who, based on survey data, believe they have the required skills to start a business. India ranks first, followed by the US in 16th place, Canada in 28th and Australia in 30th. Not included in the survey are GE members France, Belgium, Estonia, Finland, Turkey, Costa Rica, Kenya, and Nigeria. Singapore, which is a potential GE member, is also not included.

[20] https://www.globalinnovationindex.org/gii-2019-report

The next set of indicators is Funding and begins with a GCI ranking on how easy it is for a business to secure a bank loan (indicator 8.04).[21] This ranking reflects a population-based survey response that reports New Zealand at 1st, followed by the US, Singapore, Finland, Taiwan and Japan. Australia, Canada, Israel. Belgium, and Estonia all land in the top 30 followed by India in 35th and Kenya in 58th. Kenya's ranking is notable here as it offers a competitiveness that exceeds many more developed economies. Ease of Credit is the next indicator (GII, 4.1.1). This GII indicator groups several countries together for a ranking that presents New Zealand as 1st, followed by US, Rwanda, Zambia, and Columbia together as 2nd place. GE members Australia and Kenya are ranked 3rd, followed by Costa Rica, Nigeria, and Canada ranked 4th. India (5th) and UK (6th) round out the top rankings of GE members.

While bank loans and credit are one form of business finance, startup funds often begin with investment from venture capital. The GCI (indicator 8.05) asked survey respondents to gauge how easy it is for startup entrepreneurs with innovative but risky ventures, to obtain equity funding. The results rank US as 1st followed by GE members Israel (2nd), and Finland (3rd) in the top five and UK (12th), India (13th), Estonia (24th), Ireland (54th), and Kenya (59th) in the top 60. GE members Nigeria and Italy rank around 130th.[22] Nigeria has a burgeoning startup community focused on cybersecurity and the digital economy driven by a partnership with Deloitte which may over time drive this number up.[23]

E-CAP is also characterized by the European Innovation Scoreboard (EIS). The EIS offers a ranking of venture capital (VC) investment in countries within the EU and including the UK. Switzerland ranks first, followed by GE members UK (3rd), France (4th), Netherlands (7th), Ireland (10th), Denmark (11th), and Belgium (12th). Potential GE member Luxembourg, described previously, is ranked 6th while leading entrepreneurial GE countries Israel, US, Japan, India and Kenya are not included.[24]

Finally, the GII ranks countries based on an index of venture capital deals (4.2.3) compiled using "Thomson Reuters data on private equity deals, per deal, with information on the location of investment, investment company, investor firms, and funds, among other details.[25]" The US and Canada are tied for 1st followed by Israel, UK, and France in the top five. GE potential members Singapore and Luxembourg are ranked 7th and 8th respectively and GE members Finland (11th), Denmark (12th), Ireland (14th), The Netherlands (15th), and Estonia (16th) round out the top twenty. It's worth noting that Kenya ranks 23rd and India ranks 30th, just after Spain (29th). GE member Turkey is ranked last at 78th.

Infrastructure plays a critical role in I-Cap, but it also is a required element for E-Cap strength. The quality of a country's electricity supply is a core element of a thriving digital economy. The GCI (indicator 2.07) surveys this infrastructure measurement and ranks Norway, Switzerland, and Singapore as the top three accordingly. GE member country Denmark ranks 5th followed by The Netherlands (6th), France (7th), Luxembourg (8th), Finland (9th), and Japan (10th). India, Turkey and Kenya, each GE members, are ranked 80th, 88th, and 94th respectively.

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[21] http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017–2018.pdf)

[22] (http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017–2018.pdf

[23] (https://www2.deloitte.com/content/dam/Deloitte/ng/Documents/risk/ng-cyber-security-outlook-2020.pdf).

[24]https://ec.europa.eu/docsroom/documents/41941/attachments/1/translations/en/renditions/nativeEuropean Innovation Scoreboard2020VCInvestment/ranking

[25] https://www.globalinnovationindex.org/analysis-indicator

The number of internet users is also a critical indicator for entrepreneurship in a digital economy, especially for cybersecurity considerations. The UN, through its International Telecommunication Union (ITU), publishes an annual report that ranks the telecommunications development sector by country.[26] The only country to report 100% internet usage over 12 months among all internet users is Kuwait. Luxembourg, which has an ambitious internet usage plan, ranks 1st among countries followed in this report as both GE members and potential GE members. Among GE members, Denmark leads followed by Republic of Korea, UK, The Netherlands, Taiwan, and Canada each have a greater than 90% usage rate. The GE members between 80% and 89% are US, Australia, Spain, Japan, Ireland, Belgium, Estonia, Finland, Israel, and France. While Kenya is increasing in percentage year over year, it remains very low in its percentage of 17%.

Finally, the last indicator for Infrastructure under the E-CAP ranking is Logistics Performance as reported by the World Bank and is specific to the movement of goods based on six (6) indicators, combined to deliver a single weighted average score.[27]

Germany and Sweden, both potential GE members, rank 1st and 2nd respectively. GE member Belgium ranks 3rd followed by Japan (5th), The Netherlands (6th), Denmark (8th), UK (9th), and Finland (10th). The US ranks 14th and Israel ranks 37th. The relevance to cybersecurity could be drawn by interpreting vulnerabilities in the supply chain that could make a country more susceptible to hacking, specifically the ability to track and trace shipments. Cybersecurity entrepreneurs could benefit from studying the world class systems of Germany, Sweden or Belgium to better understand how security impacts the larger movement of goods in and between countries.

Demand is the next E-Cap set of indicators and is measured by two indexes, the GCI and the GII. The GCI (indicator 6.16) measures "Buyer Sophistication" based on a survey response to the question, "in your country, on what basis do buyers make purchasing decisions, low price or high performance?" and higher scores trend towards higher quality preferences over low price. The US ranks 1st for this indicator followed by potential GE members Republic of Korea, (2nd), Switzerland (3rd), and Luxembourg (5th). GE member Japan is 7th followed by UK (9th), Taiwan (10th), and India (15th).[28]

The GII indicator (4.3.3) measures and ranks domestic market size, as measured by GDP.[29] China ranks 1st followed by US (2nd), India (3rd), Japan (4th), and Germany (5th). The UK and France are 9th and 10th respectively. Many of the GE countries are very small and cannot compete in pure numbers but may rank higher in a per capita comparison (not provided). The top ten do reflect the markets where we see entrepreneurs setting up operations to be close to the massive market size these countries represent, especially as it relates to cybersecurity.

The final E-Cap measurement is Culture and Incentives. Four out of the five indicators for this section are taken from the GEM. For GE countries, this complicates a fair comparison because so

[26] https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2019/Individuals_Internet_2000-2018_Dec2019.xls
[27] https://lpi.worldbank.org/international/global2018LogisticsPerformanceIndex/ranking
[28] http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017–2018.pdf
[29] https://www.globalinnovationindex.org/analysis-indicator

many GE members are not GEM participants. However, it is worth noting the profile India develops through this selection. India ranks 1st for Fear of Failure, but it also ranks 1st for perceived skills to start a business (previously noted in Human Capital), ranks entrepreneurship as 2nd as a "Good Career Choice", ranks 3rd as a country that perceives high status associated with successful entrepreneurs, and ranks 3rd for Domestic Market size (previously noted).

Other notable rankings from the GEM among GE members that are measured are Israel is 3rd for Fear of Failure (meaning it's high) followed by Republic of Korea with the lowest fear of failure (50th). Among GE members that are ranked for "Entrepreneurship as a Good Career Choice", Poland ranks 1st, followed by India and Sweden. The US is 11th, Canada is 12th, and Israel is 35th. Taiwan and Japan rank at 40th and 50th respectively. The last GEM indicator measures the survey response to the status that successful entrepreneurs receive in a country. Interestingly, Italy, which has been fairly quiet in the overall rankings, ranks 1st. India, as noted, is 3rd and Israel and the US are 10th and 14th respectively.

The final indicator for Culture and Incentives comes from the Heritage Foundation's annual ranking of "Business Freedom" (https://www.heritage.org/index/ranking) which is a composite score indicating an individual's ability to establish and run an enterprise without undue interference from the State, i.e., the complexity of the process. Singapore has ranked 1st two years in a row followed by Hong Kong (2nd), New Zealand (3rd), Australia (4th), and Switzerland, (5th). GE members Ireland (6th), UK (7th), Denmark (8th), Canada (9th), and Estonia (10th) round out the top ten. The US and Israel are ranked 17th and 26th respectively and GE members Nigeria (116th), India (120th), and Kenya (132nd) complete the list.

Four: Conclusions

First, it is clear that we can usefully apply the eco-system and capacity approach used by MIT – alongside international indices – to examine the comparative characteristics of cyber ecosystems, in this case individual Global EPIC members. By doing this, we can get a high-level understanding of where each ecosystem's host country compares to other countries, according to select inputs and indices.

When taken together, the profile of I-Cap and E-Cap indicators for GE countries provides strong validation of the current membership. It is worth noting those countries that score high in both I-Cap and E-Cap (i.e. multiple top ten rankings on both capacities): the US, UK, The Netherlands, France, Israel, Denmark, Australia, India, Belgium, and Finland. These countries represent a variety of sizes, demonstrating that even a smaller country can compete on a global scale. For consistency, most of these numbers were taken from 2017-2019 data sets.

Since Global EPIC was formed, many of these countries and their corresponding ecosystems, have expanded in capacity and funding. Poland, Costa Rica, Turkey, Kenya, and Nigeria are all growing start-up ecosystems, some through new bilateral relationships. While we watch their E-Cap side grow in these countries, it will be important to also watch the I-Cap side of the data. Indicators for innovation moving in a positive direction will ensure that this new growth is sustainable and continues to evolve with an ever-changing digital economy.

These rankings, however, measure just the aggregate strength of a country which shortchanges the I-Cap and E-Cap story of an individual city or region. Greater Boston (Massachusetts) in the US is a global tech hub cluster and one of many in the US. However, there are many more regions of the US that struggle to define a digital economy as a growth strategy and even some regions that lack broadband internet access altogether.

For those countries that are larger in size, a deep dive into their key regions must be considered. To this end, this Working Paper includes three 'case studies' of GE-member cyber organisations in their local ecosystems (see Annex 2 Below), as a model for how such regions and their stake-holders might benchmark themselves. Some organizations like Startup Genome do rank cities and regions annually based on the maturity of their entrepreneurship ecosystems. Within the US or the UK, similar rankings exist allowing a comparison of regions and a competitive ranking.

Global EPIC was established by 30 regional and local ecosystem leaders in twenty-two countries. While each leader is responsible for a set of Key Performance Indicators locally, perhaps this review of national data can demonstrate the importance of relationships among ecosystems within one country, as competition among ecosystems inside a single country is often a race to the bottom. The national collection of strong and collaborating ecosystems is stronger than each individual unit.

At the time of this report, some of the Global EPIC members are waning in their participation as new organizations pick up the investments in cybersecurity innovation and entrepreneurship within a region or country. Further, some organizations that were started with term-limited government funding (generally five years) are transitioning to self-sustaining membership or becoming grant-funded R&D organizations such as the hub in Poland. National trade offices play a role (Finland, Northern Ireland), venture capital companies drive new regional

investments (Estonia, Costa Rica, Nigeria), and large multinational companies commit to huge economic investments (Israel, India, and Ireland, to name a few).

Through all of these changes, Global EPIC remains a community of collaborating colleagues who transcend their organizational evolutions and continue to assist each other with growth, resource identification, best practice advice, and their own personal professional journeys while at the same time acting as the keepers of a critical, yet boutique, industry of cybersecurity driven economic development.

APPENDIX 1: Global EPIC's current 30 members are set out below:

Global EPIC Member	Country
Beersheva	Israel
Belfast	NI, UK
The Hague	The Netherlands
Ankara	Turkey
Maryland	USA
Ottawa	Canada
Dublin	Ireland
Lagos	Nigeria
Bengaluru	India
Boston, MA	USA
New Brunswick	Canada
Brussels	Belgium
Krakow	Poland
London	UK
Tallinn	Estonia
Surrey	Canada
Torino	Italy
Bilbao	Spain
Wales	UK
Helsinki	Finland
San Jose	Costa RIca
Tokyo	Japan
San Diego	USA
Copenhagen	Denmark
NYC, NY	USA
The Alps	France
Nairobi	Kenya
Taipei	Taiwan
Indiana	USA
Canberra	Australia

APPENDIX 2

GE Member Profile: CyberSpark, Beersheva, Israel

When studying the success of Israel's cybersecurity hub, there are some widely acknowledged factors that make the country's success fairly unique. Israel invested in cybersecurity decades before other countries as its leaders predicted a fast approaching future where digital warfare and its related national defense would be critical. They were right. This prediction was made not only from necessity and heightened awareness of the perils Israel faces, but also a deep culture of respect for STEM as a pathway to success.

A 2013 report by Hebrew University, commissioned by Australia's Council of Learned Academies, cites a 2006 public opinion survey which reports, "Israelis listed science and technology as the top source of national pride (78% of Israelis) and the category of academia and higher education was ranked 3rd (74%; Yaar 2006:8). Israelis also consider science and technology as essential for Israel's future: 90% of Israelis agree that science is essential for Israel's security, 94% note it as essential for Israel's economic success, and 89% - as essential for wellbeing" (Drori, Netivi; 2013).

This deep reference point was established very early on as the country was faced with creating value and productivity in a highly resource constrained environment. One pivotal moment was the creation of the "Office of the Chief Scientist" in 1968. This is "responsible for providing financial aid to worthy R&D projects, as well as guidance and training to new enterprises and funding for industrial and technological incubators. The chief scientist promotes cooperation with foreign countries to advance binational activities and tries to generate risk capital in Israel and abroad for the development of innovative technology".[30]

Also noteworthy is the establishment of the National Cyber Bureau in 2011 which we know today as the Israel National Cyber Directorate (INCD). This organization, and its previous incarnation, focuses on both the cyber threat to Israel and the economy of cybersecurity as a competitive cluster strategy. Its most recent investment in Israel's competitive position, building on the previous success in R&D, is CyberSpark.

Established in 2014 at Ben-Gurion University of the Negev in Beersheva, CyberSpark is "a non-profit organization, designed to be the central coordinating body for joint cyber industry activities with all stakeholders, to leverage the region and maximize its potential as a global cyber center, to encourage joint academia industry partnerships and to support the plans to draw other companies, whether international or Israeli, to establish projects or base themselves in the region".[31]

Fast forward to 2021, Israel now has one of the most respected and highly ranked tech economies in the world, defined by both applied R&D and entrepreneurship. In order to tell this story by the numbers, there are a few international reference points to consider. First, both the Global Innovation Index (GII) (https://www.globalinnovationindex.org/gii-2019-report) published by Cornell University and the World Intellectual Property Organization (WIPO), and

[30] https://www.jewishvirtuallibrary.org/history-and-overview-of-science-and-technology-in-israel
[31] http://cyberspark.org.il

UNESCO Institute for Statistics (http://uis.unesco.org/apps/visualisations/research-and-development-spending/) rank Israel as 1st in the world for the number of residents per capita engaged in R&D as a profession. The second datapoint to examine is the Stockholm International Peace Research Institute (SIPRI) national rankings on military spending as a percent (%) of GDP (https://www.sipri.org/databases). This data (2019) reveals that Israel is ranked 5th in the world for percentage military spend, well ahead of the US (10th) and first among the Global EPIC network.

In any other report on innovation and entrepreneurship, this might not matter. However, cybersecurity is often funded through military budgets and in the case of Israel, it drove the powerful R&D and talent pipeline the world has come to admire. The 2013 report by Drori and Netivi (2013) further describes this relationship, "Israeli Defense Forces (IDF) serve three functions in Israel's STEM pipeline: by training recruits in many technical fields, by providing work habits and team building skills that translate nicely into the work culture of start-ups, and by being a large client for local R&D". Notable is that the IDF is training its recruits to be both defenders of Israel and to be high-quality R&D professionals, and at the same time, serving as a customer for its alumnus who go on to start companies or work in the field of scientific R&D.

These datapoints can be paired with a 1st place ranking in Gross Domestic Expenditure on R&D (GERD) as a % of GDP and a 1st place ranking for % of GERD paid for by "Rest of the World (abroad)" (UNESCO). For the first datapoint, Israel is at 4.95% for GERD as a % of GDP, with a trend upward. For the second datapoint, Israel also leads the cohort with 52.55% of GERD funded by sources abroad. Israel is followed by Ireland, which is at 23.6 (2016 latest dataset), almost half. This datapoint is exceptional and reflects a long tradition of partnering with international entities through bilateral R&D agreements. The majority of the cohort (21/30) is trending downward for GERD as a % of government spending. Notable is that Israel, which follows this trend as well, is also one if the lowest percentages in this category. Finally, Israel, like the US and a few other countries are seeing stagnation in the percentage of GERD paid for by domestic private industry.

It should also be noted that Israel scores in the top five among this cohort for 1) availability of latest technology for R&D (WEF GCI); 2) University/Industry research collaborations (GII); and 3) quality of scientific research institutions (WEF GCI). The payoff, and the lesson to be learned is that this intensity of R&D investment leads to commercialization opportunities that are also world leading. Known as "Startup Nation", data on the "e-Cap" side of the equation shows world leading numbers for "VC capital availability" (WEF GCI) and VC deals ranking (GII), ranked 2 and 3 accordingly (US ranks 1st in both).The GCI (WEF) also ranks Israel 1st in Overall Entrepreneurial Culture, punctuated by a lead raking in Attitudes Towards Entrepreneurial Risk (indicator 11.05), Growth of Innovative Companies (indicator 11.07), Companies Embracing Disruptive Ideas (indicator 11.08), and Multi-stakeholder Collaboration (indicator 12.04).

This story of extremes indicates an R&D environment that is complicated and difficult to replicate. Regardless, Israel remains the model that so many other countries and ecosystems attempt to mimic. If there is something to replicate, it's a very strong economic development framework for R&D that addresses both the investment side and the talent side with a culmination in a very strong position for investment in startups and scaleups. Another point to mirror may be the investment in high tech and advanced skilled human capital paid for through military budgets.

GE Member Profile: e.Kraal, Kenya

Kenya is one of the newest Global Epic members and one of the most active, represented by the organization e.Kraal Innovation Hub. The Global Cybersecurity Index (GCI) presented by the ITU reports that within the African region, Mauritius, Kenya, and Rwanda score the highest composite scores. Kenya scored second overall and leads the pack in the "Legal Measures" category and in "Cooperation". Also noteworthy is that Kenya scored 44th overall globally out of 175 countries (up from 45th in 2017).

"Kenya ranks second [in the African region] with a high score in the legal pillar and in the cooperation pillar. Kenya has a multi-stakeholder local collaboration between the government, the different CIRTs and other key stakeholders including financial institutions, telecommunication operators, academia, critical information infrastructure providers, public utility service providers, content service providers, domain name registry service providers, etc.," (2018 ITU GCI Index Report).

Leading the evolution of the cybersecurity "culture" in Kenya is e.Kraal Innovation Hub. Formed in 2018, e.Kraal is Kenya's first innovation hub dedicated to cybersecurity and is focused on "securing the future of cybersecurity in Kenya by accelerating innovation and creativity in the cyberspace ecosystem."[32] The organization focuses its work on developing subject matter experts in the cybersecurity field through training (it hosts the first African cybersecurity Cisco Academy) and mentoring, and then supports those individuals as professionals and new company founders.

A further exploration into the I-Cap and E-Cap datapoints reflects this growth. While the numbers are not globally leading in the top 20, Kenya does show impressive trends in a positive direction. The World Economic Forum's annual Global Competitive Index (WEF GCI) reports a positive trend for Kenya overall since 2013(2019), noting a slight one-year dip due to the more rapid rise of other countries. Positive trends are reported for Quality of STEM education (indicator 5.04: 2017-18 WEF GCI), availability of scientists and engineers (indicator 12.06: 2017-18 WEF GCI), and government procurement of advanced technologies (indicator 12.05: 2017-18 WEF GCI). Another international index reporting Kenya's increasing strength is the Global Innovation Index (GII) published by Cornell University and the World Intellectual Property Organization (WIPO). The GII reports an overall climb in rankings with a reported ranking strength (29th) and upward trend in University/Industry Partnerships (indicator 5.2.1) and 7th place ranking and upward trend in Ease of Getting Credit (indicator 4.1.1).

These positive trends indicate a dedication to growing a modern, digital economy and investing the resources in talent and new company growth that are needed to continue a positive trend. Kenya's participation in Global Epic reflects this dedication. Upon its formation, leaders of e.Kraal traveled internationally, networking with leaders in the top 20 countries to build partnerships. The combined positive indicators in cybersecurity and clear leadership that leverages P3 opportunities and entrepreneurship, put Kenya on solid footing for continued growth.

[32] https://e-kraal.com

GE Member Profile: Center for Secure Information Technologies (CSIT), Northern Ireland, UK

In contrast to the profiles of countries summarized in this report, one specific economic region is important to note. Belfast, Northern Ireland is the largest cybersecurity cluster in the UK and the leading destination for foreign direct investment in cybersecurity by US companies (Invest Northern Ireland: https://www.investni.com/). Like the Boston cluster with which it has close ties, the Belfast cyber cluster received a massive infusion of I-CAP resources from academia via government funding.

Validation of Belfast's growing IT sector was secured in 2008 when it was designated the "UK's 'Innovation and Knowledge Centre' (IKC) for cyber security, and the UK's largest cybersecurity-focused university technology research, development and innovation centre" through the establishment of the Center for Secure Information Technologies (CSIT) at Queen's University Belfast (QUB). CSIT is a division of a larger research center at QUB named the Institute of Electronics, Communications, and Information Technologies (ECIT) which is one of the UK's seven Innovation and Knowledge Centers.[33]

Investment in talent in the IT sector in Belfast has paid dividends. More than 70% of the working population in Northern Ireland hold degrees in IT, either from QUB, the University of Ulster, and several other local colleges. Companies based in the US, noting a close proximity for travel and a low (but high quality) cost of living, began hiring at scale in Belfast. Rapid 7, Black Duck, Liberty Mutual, Microsoft and many more have scaled IT operations in Belfast. CSIT has also remained a valuable partner to these companies not only for talent generation, but also for R&D partnerships and start-ups. CSIT is located adjacent to the shipyard that built the Titanic and stands as a symbol of the industrial legacy on which Belfast was built. The transition from an engineering workforce to one steeped in IT, combined with a steadfast work ethic, sets the stage for a tech-based economy that is sure to continue to be a draw for multinational companies for years to come.

The success of Belfast's cybersecurity cluster is a strong example of a large country (UK) which has several scattered cybersecurity clusters that provide an overall ranking of country strength, but not one that accurately depicts the well-recognized global strength of Belfast and its CSIT. Dr. Godfrey Gaston, Executive Director of ECIT at QUB, is one of the founders of Global EPIC, along with Roni Zehavi, founder of Cyber Spark in Israel. It is no wonder that these two leaders, who had frequent meetings with burgeoning cyber clusters all over the world, formed a consolidated community on the topic.

Each year, CSIT convenes an invitation-only summit of cybersecurity R&D leaders from around the world. At this summit, trending policy areas such as Secure Design of IOT, International Supply Chain Standards, International Opportunities for Talent Development, and new sector collaborations in insurance technology, life sciences, robotics and more, are all previewed and discussed. Just as the UK led the world with GDPR standards, this gathering foreshadows where the industry is heading and where talent, R&D funding, and policy analysis need to be directed.

[33] https://www.qub.ac.uk/ecit/CSIT/

Annex 3: MIT's two Capacities, and their Inputs

Innovation Capacity (I-Cap) Inputs

HUMAN CAPITAL

Quality of STEM education (GCI)	Survey response to the question 'How do you assess the quality of math and science education? '
STEM Graduates per capita (OECD)	Number of graduates by the field of education, i.e. sciences, mathematics and statistics, engineering, manufacturing and processing
New PhD graduates per capita (EIS)	New doctorate graduates per capita aged 25-34
Availability of Scientists & Engineers (GCI)	Survey response to the question 'To what extent are scientists and engineers available?'
Researchers/Professionals engaged in R&D per million population (GII)	Researchers (FTE) engaged in R&D (conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned). Postgraduate PhD students are also included.

FUNDING

R&D expenditure as a % GDP (UNESCO)	Total intramural expenditure on R&D performed during a specific reference period as a percentage of GDP
R&D expenditure in '000 current PPP$ (UNESCO)	Total intramural expenditure on R&D performed during a specific reference period
Public R&D Expenditure as % of total R&D expenditure (UNESCO)	Share of R&D expenditure in the public sector (government and higher education).
Business Expenditure as % of total R&D expenditure (UNESCO)	Share of R&D expenditure by business sector (i.e. private and public enterprises, corporations etc.) during a specific reference period.

INFRASTRUCTURE

ICT access (GII)	A composite score of five ICT indicators (20% each): (1) Fixed telephone subscriptions per 100 inhabitants; (2) mobile cellular telephone subscriptions per 100 inhabitants; (3) Internet bandwidth (bit/s) per Internet user; (4) Percentage of households with a computer; and (5) Percentage of households with Internet
Internet Bandwidth (GCI)	The total used capacity of international Internet bandwidth, in bits per second per Internet user.
Production Process Sophistication (GCI)	Survey response to the question 'Is in your country work mostly done requiring labor-intensive methods, or previous generations of process technology or is the leading and most efficient processing technology more available in the region?'
Availability of latest technologies (GCI)	Survey response to the question 'In your country, to what extent are the latest technologies available?'

DEMAND

Government procurement of advanced technology (GCI)	Survey response to the question 'In your country, to what extent do government purchasing decisions foster innovation?'
University-industry research collaborations (GII)	Survey response to the question 'In your country, to what extent do people collaborate and share ideas in between companies and universities/research institutions?'
Trade, Competition & Market scale (GII)	A score Composed of three factors: 1. Applied tariff rate, weighted mean, 2. Intensity of local competition; 3. Domestic market scale

CULTURE & INCENTIVES

Quality of scientific research institutions (GCI)	Survey response to the question 'In your country, how do you assess the quality of scientific research institutions?'
Graduates in science & engineering (%) (GII)	The share of all tertiary graduates in science, manufacturing, engineering, and construction over all tertiary graduates.

Entrepreneurial Capacity (E-Cap) Inputs

HUMAN CAPITAL

% school grads in tertiary education (GII)	The ratio of total tertiary enrolment to the population of the age group that officially corresponds to the tertiary level of education.
Entrepreneurship perceived capabilities (GEM)	Share of population who, in response to a survey, believe they have the required skills and knowledge to start a business

FUNDING

Easy Access to Loans (GCI)	Survey response to the question, in your country, how easy is it for businesses to obtain a bank loan?
Ease of Credit (GII)	The ranking of economies on the ease of getting credit is determined by sorting their distance to frontier scores for getting credit (i.e., the strength of legal rights and the depth of credit information)
Venture capital (VC) availability (GCI)	Survey response to the question, in your country, how easy is it for start-up entrepreneurs with innovative but risky projects to obtain equity funding?
VC investment (EIS)	Venture capital investment is defined as private equity being raised for investment in companies. Venture capital includes early stage (seed + start-up) and expansion and replacement capital. Management buy-outs, management buy-ins, and venture purchase of quoted shares are excluded.
VC deals (GII)	Index of venture capital per investment location

INFRASTRUCTURE

Electricity & telephony infrastructure (GCI)	A score measuring a survey of the quality of electricity supply?, fixed telephone lines and mobile telephone subscriptions per 100 population
Number of internet users (UN)	Internet users are individuals who have used the Internet (from any location) in the last 12 months. Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.
Logistics performance (World Bank)	Weighted average score of 1) Efficiency of the clearance process by border control agencies, including customs; 2) Quality of trade and transport related infrastructure; 3) Ease of arranging competitively priced shipments; 4) Competence and quality of logistics services; 5) Ability to track and trace consignments; 6) Timeliness of shipments in reaching destination

DEMAND

Buyer sophistication (GCI)	Survey response to 'In your country, on what basis do buyers make purchasing decisions, low price or high performance?'
Domestic Market Scale (GII)	Domestic market size as measured by GDP bn PPP$