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Assessing the System & Capacities in ‘innovation-driven entrepreneurial’ (IDE) Ecosystems

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'Innovation' and 'entrepreneurship' are now much sought after, but not always well-defined, and even less often well measured. This Working Paper draws upon our MIT approach to innovation, entrepreneurship and the powerful combination of 'innovation-driven entrepreneurship' to propose a method to capture a set of globally-available metrics to assess the geographically-bounded 'ecosystems' in which they flourish.

In this Working Paper, we focus on assessing 'innovation-driven entrepreneurship ecosystems' ('*iEcosystems*')[1] – geographically bounded places where innovation-driven enterprises (IDEs) flourish. We make our definition explicit because many stakeholders are assessing their ecosystems and using a variety of names to describe them. Though a broad range of labels is widely used (including by MIT) and should be respected, we are specifically interested in activities that contribute to IDEs.

In this Version Three (v3) of the Working paper, we have had the great assistance of a number of students taking our 'Regional Entrepreneurship Acceleration for Leaders' (REAL)[2] class to produce an update. This revision required not only checking the data sources (several of which had ended) since our original 2019 version, but also suggesting new ones, with a special focus on the two Capacities (of I-Cap and E-Cap). This v3 adds URL links directly to the key pages. (Researchers will now be able to click on the URLs in the 'Sources' columns, and get directly to the underlying data: in several cases, the host website of the data sources also provides ways to format that data.

As with the ecosystem construct itself, there are already many 'ecosystem' approaches, definitions and data sources that are relevant (and we review the most widely used and relevant of these here). Indeed, in recent years, a number of organizations have sought to create metrics and indices to rank locations on innovation and/or entrepreneurship dimensions, and in doing so have provided orderings of cities, regions or countries. This is, at one level, a welcome step forwards beyond just looking at say R&D as a proxy for 'innovation' or the number of new startup enterprises for 'entrepreneurship'.

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[1] MIT itself and its faculty are associated with a variety of such 'ecosystem' names: eg "**Entrepreneurial Ecosystems**" (https://portal.scotlandeuropa.com/event-listings/view/36); "**iEcosystems"** (https://innovation.mit.edu/event/mit-iecosystem-symposium/); "**Innovation ecosystems**"(https://executive.mit.edu/openenrollment/program/innovation-ecosystems-a-new-approach-to-accelerating-corporate-innovation-and-entrepreneurship/#.Wb1uFq3MxE4).

[2] The 'Innovation Ecosystems for Regional Entrpreneurship-Acceleration for Leaders' (iEco4REAL) class is at: https://reap.mit.edu/get-involved/students-real/

This explosion of information, however, has not always been accompanied by greater clarity, nor has it facilitated decision-making, because these approaches are often hard to decipher or are based on a collection of measures that are not clearly defined. Many do not have global coverage (but are limited to the EU or OECD), whereas others do not differentiate 'innovation' and 'entrepreneurship'. From our MIT perspective, they also often conflate the 'inputs' for innovation and entrepreneurship (and fail to specify what are intermediate 'outputs'), so do not provide a clear guide for decision-makers.

Our approach, as outlined in this Working Paper, is to develop a simple but much more comprehensive measurement approach, informed by our MIT theory of innovation-driven entrepreneurship and the ecosystems ('*iEcosystems*') in which it flourishes.

Where our approach adds value is providing a clear framework for analyzing such ecosystems – our 'theory' if you will – and then selecting measures accordingly. To that end, we focus on the two key Capacities at the heart of the System.

Our approach to assessing iEcosystems is guided by a few critical insights that derive from our research-informed framework and our experience of working with an ever larger number of decision-makers who seek comparable metrics that make sense and yet are not overly complex:

- Our metrics are designed to capture (but separate out) both innovation and entrepreneurship which we identify in successful regional ecosystems and highlight the special blend in 'innovation-driven entrepreneurship';

- In such ecosystems, there are four key elements in our framework to measure: foundational institutions, separate innovation and entrepreneurship capacities, comparative advantage, and impact;

- Starting with foundational institutions, we seek globally-available metrics that allow for maximum comparability, both over time as well as in comparison to other countries, with the caveat that these are typically available on a national but not a sub-national 'regional' level.

- Emphasizing metrics for both innovation and entrepreneurship capacities, we then focus on the key inputs into these two distinctive capacities – over five key areas: human capital, funding, infrastructure, demand and culture/incentives;

- Building on the separate inputs into innovation and entrepreneurship capacities, we then include metrics that capture intermediate outputs (that in turn can lead to longer term regional 'comparative advantage' and ultimately 'impact');

- Within our framework, it is the key differentiation between the ‘innovation’ and ‘entrepreneurship’ capacities, and between ‘inputs’ and ‘outputs’, that places this MIT approach apart from most other methods.

1. A Framework for analyzing ‘innovation Ecosystems’

To define the phenomena of what are commonly described as ‘innovation ecosystems’ or 'entrepreneurship ecosystems' (*iEcosystems*), we draw on our own analysis of 'innovation-driven entrepreneurship' and that of our MIT colleagues with whom we have collaborated on much of this material.[2] We are also guided by lessons learned from teaching this framework in a range of global settings and with decision-makers from different stakeholder groups, but especially from government and corporates.[3]

While not the place to explore all the intellectual foundations of the MIT iEcosystem framework, the approach here emphasizes a more comprehensive understanding of the ‘System’ that underpins innovation-driven entrepreneurship in these ecosystems. For simplicity, we break the ‘System’ down into four core elements (see Figure below). Taken together, these elements lead to ‘comparative advantage’ and ultimately (to a greater or lesser extent) ‘impact’ within an iEcosystem.

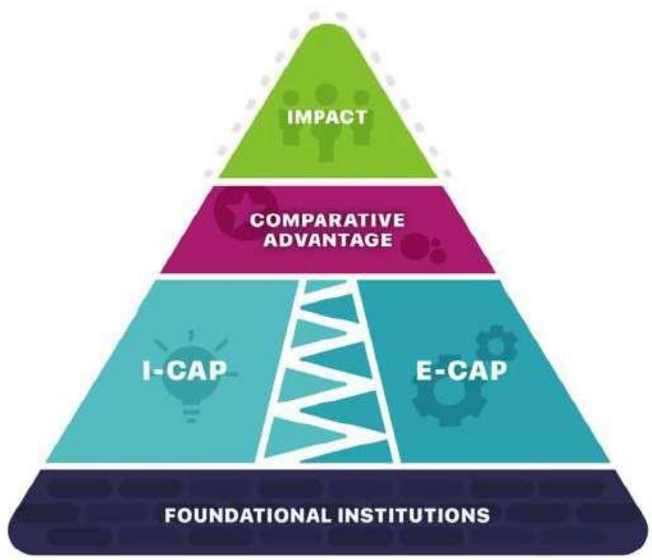

Figure 1: the 'System' for innovation-driven entrepreneurship

Working from the bottom of the System up, we explore each of these elements in turn.

[2] We particularly recognize the work that we have done in collaboration with our MIT colleagues – Professor Scott Stern and Professor of Practice Bill Aulet.

[3] Teaching has raised and refined this material in a number of settings, both in custom and Exec Ed settings, and also in formal courses: ‘Innovation-Driven Entrepreneurial Advantage’ (IDEA, 2011+), ‘Regional Entrepreneurship Acceleration Lab’ (REAL, 2012+), ‘Regional Entrepreneurship Acceleration Program’ (REAP, 2012+), ‘Innovation diplomats’ (2014+) and ‘Innovation Ecosystems’ (2016+).

<u>Foundational institutions</u> are those institutions, rules, practices and norms that are often taken for granted, but ensure that investments in a wide variety of capacities and assets can be effectively protected and leveraged to the benefit of the economy. At the core, they include rule of law (and conversely lack of corruption), protection of property rights (especially for intellectual property), financial institutions, freedom for new ideas (including scientific openness), and general ease of doing business.

The **two 'capacities'** are the twin engines of the 'system', resting on the foundational institutions and combining distinctive 'inputs' to ultimately drive impact, often in the form of 'innovation-driven enterprises' (IDEs), rather than standard 'small/medium-sized enterprises' (SMEs).[4] A key contribution from MIT's work on innovation, entrepreneurship and ecosystems is to separate out these two capacities:[5]

- **<u>Innovation Capacity (I-Cap)</u>** is, in our definition, the capacity of a place – a city, a region or a nation – to develop 'new-to-the-world' ideas and to take them from 'inception to impact' (whether this be to economic, social and/or environmental impact). In other words, innovation capacity covers not only the development of basic science and research but also the translation of their 'solutions' into useful products, technologies and/or services that truly solve problems.

- **<u>Entrepreneurship Capacity (E-Cap)</u>** emphasizes a subset of the more general entrepreneurial capability and conditions for forming enterprises: the latter supports all types of entrepreneurship (leading mostly to SMEs rather than 'IDEs').[6] The aspects of 'E-Cap' most interest to innovation are the ones supporting this 'innovation-driven' side of entrepreneurship capacity, tailored to support the growth of IDEs in a specific place – such as a city, region or nation.

Building on foundational institutions, it is the combination of (and linkages between) innovation and entrepreneurship capacities within a city, region or nation that drives impact. However, innovation- and entrepreneurial-capacity are not always general assets developed in a regional context: they are more likely to be specialized around areas of expertise, which we think of as a broader form of comparative advantage.

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[4] This distinction between SMEs and 'Innovation-Driven Enterprises' (IDEs) highlights the distinctive set of start-ups that are entrepreneurial but also have a source of advantage grounded in innovation (see Aulet & Murray 2012).

[5] For this key insight of separate capacities, we are grateful to Professor Scott Stern and Professor Fiona Murray: this builds on the ground-breaking work by Porter, Furman and Stern (1999) on 'innovative capacity'.

[6] See Budden and Murray "Differentiating Small Enterprises in the Innovation Economy" (2021) paper with its typology of "Start-ups, new SMEs & other Growth Ventures" https://innovation.mit.edu/assets/BuddenMurrayUkuku_SME-IDE_WorkingPaper__Jan2021.pdf

Comparative Advantage of any region's economy is based on specific areas of strength that differentiate it from others around it, increasingly globally.[7] For 'innovation-driven entrepreneurship ecosystems' (iEcosystems), such 'comparative advantage' is shaped by underlying strengths in both innovation and entrepreneurship capacities but is also distinctive. A region's comparative advantage will often find expression in geographical clusters or industrial sectors - as agglomeration and specialization remain factors even in this latest phase of the industrial revolution – whether they be clusters in the life sciences, IT services or education.

We have also found that comparative advantage can be usefully expressed not only in backward reflection upon existing, well-defined clusters, but in forward-leaning areas of expertise and specialization e.g. 'Oceans', Smart City Infrastructure, etc. In the case of a region like Greater Boston, for example, this 'comparative advantage' is in life sciences, and, recently, clean energy and hardware. For Pittsburgh, it is robotics: for Singapore, maybe 'smart city infrastructure'. In countries such as Chile and Morocco, potential sources of comparative advantage for the ecosystem are likely focused on mining - its safety, water and energy needs, and new uses for specific minerals.

The resulting **'impact'** comes from the combination of innovation- and entrepreneurial-capacities, when combined with core comparative advantage and often taking specific actions through 'program and policy interventions' (PPIs). Such PPIs can be measured in a variety of different ways, and such measurement is key to their evaluation. The key 'impact' metrics are, in part, a matter of choice and prioritisation on the part of the decision-makers and iEcosystem stakeholders. It should be recognized that even the most profound interventions in the system will only drive measurable changes in impact over the longer run.

At the highest level, impact can be captured in the form of economic or social progress indicators. For economic progress, the most commonly used metric is GDP per capita: this is not without its problems, but it is widely used. For social progress, indicators such as the Social Progress Index (SPI) or UN Sustainable Development Goals (SGDs) may be more appropriate.[8]

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[7] In his Wealth of Nations (1776), Adam Smith introduced the concept of "absolute advantage" which David Ricardo developed into what has since been known as "comparative advantage" from his Principles of Political economy and Taxation (1817). The regionalized geographical dimension was introduced by Alfred Marshall in his treatment of "industrial districts" in his Principles of Economics (1890), and developed by Michael Porter with 'clusters' in his Competitive Advantage of Nations (1990). Likewise, the notion of flexible specialization (Piore and Sabel) as well as the 'varieties of capitalism' literature also focused attention on particular regional expertise.

[8] See the SPI (https://www.socialprogressindex.com) and UN SDGs (https://sustainabledevelopment.un.org).

Other decision-makers will define 'impact' differently – such as qualitative changes e.g. in local attitudes towards such entrepreneurship – and therefore measure it with different (often survey-based) metrics, tailored to the strategies and aspirations of key stakeholders.

At a more granular level, impact can be captured in terms of the types of start-ups that are being created and grow within the ecosystem – eg the level of job creation and levels of valuation. One novel metric of particular interest is the rise in the number and quality of 'innovation-driven enterprises' (IDEs) - enterprises that blend innovation and entrepreneurship, and in doing so have the potential for extraordinary job creation and the potential to develop solutions to important problems (at a scale that is more significant than traditional small/medium-sized enterprise (SME) start-ups).[9] In the even shorter run, it is possible to measure the impact of specific PPI interventions in an ecosystem that take place at the regional (or national) level, where 'impact' might be most easily targeted and evaluated.

[9] These IDEs are a subset of all start-ups, many of which will be on the trajectory of less exponential growth. As such, they are a critical vehicle for advancing new solutions to important problems, for long run job creation, and ultimately for economic growth and social progress. Approaches to measuring and mapping such IDEs along an "Entrepreneurial Quality Index" (EQI) – from high levels of potential based on innovation, to much lower levels, are under development by Professor Scott Stern and Jorge Guzman. See, for example, http://www.startupmaps.us/

2. Common Indices of Innovation, and Rankings for Entrepreneurship

In our experience, a challenge for most decision-makers, and for all those working within complex innovation ecosystems, is to develop a simple set of metrics to evaluate the current '*as-is'* state of their ecosystem, to assess its performance relative to other benchmark locations, to inform choices and then to track progress and evaluate impact.

These challenges arise for a number of different reasons:

- First, 'innovation' and 'entrepreneurship' are hard to assess, as is 'impact' resulting from choices: in cases where 'innovation-driven enterprises' are the sign of success, they can be complex to measure in and of themselves, especially as they take time to emerge, even after system-level changes and efforts (a topic we return to later in this paper).

- Second, 'impact' arises from a complex underlying 'system' so that there is no singular metric that can capture the state of that ecosystem, and so instead we need measures of various system elements.

- Third, I-Cap and E-Cap are the result of multiple inputs (as well as effective transformation of these into 'outputs' for 'comparative advantage' and 'impact') leading to the need for a basket of input measures for each.

- Fourth, there is widespread disagreement and lack on clarity in the sorts of measures that are useful, leading to a proliferation of rankings and indices, with various ones placing nations and regions in a pecking order without the underlying assumptions (and calculations) always being so clear.

The rise in popularity of innovation 'indices' and entrepreneurship 'rankings' means that decision-makers are presented with ever more information on which to base decisions, but with less guidance on how to assess these or determine the most appropriate measures for their ecosystem or program/policy interventions.

Before turning to our own proposed series of metrics, we review (and provide limited commentary on) a range of the most commonly used indices and rankings – and their baskets of measures – so as to be able to compare our approach to these existing ones. Below, we why we see the need to return to the underklying data sources, rather than add another ranking or index to this already crowded field!

What follows is a brief summary of the most widely-used rankings and indices, including the Global Innovation Index (GII), the Global Competitiveness Index (GCI, which is broader than innovation), the European Innovation Scorecard (EIS), the Global Entrepreneurship Monitor (GEM), the Global Entrepreneurship Index (GEI, created by GEDI) and the Global Startup Ecosystem Report.

The Global Innovation Index (GII) is an annual report which covers country ranking in terms of capacity, success & innovation.[3] The report was launched in 2007 by INSEAD, the World Business Magazine and World Intellectual Property Organization (WIPO) in partnership with Cornell University. Hosted today by the World Bank (with its added 'ProsperityData360' set), the GII index is a top choice, as it offers metrics that provide context for various elements of the MIT framework, in terms of both innovation and entrepreneurship elements. The re-designed web site also provides visualization tools that allow researchers to easily compare national economies of interest, and present the resulting exportable analyses.

The Global Competitiveness Index (GCI) was published annually by the World Economic Forum (WEF) from 2004 to 2020, so has some historical value. It assesses a country's productivity factors across 12 pillars, ranging from Institutions to Market Efficiency. Its Innovation Pillar aligned closely with the 'demand' component of the MIT Framework. While relevant for analyzing 'Foundations', the GCI's measures were less applicable to 'I-Cap' and 'E-Cap'. The GCI relied on the WEF's Executive Opinion Surveys to evaluate competitiveness across various dimensions. The report, produced annually for just 16 years, aimed to assess the ability of countries to provide high levels of prosperity to their citizens by measuring the set of institutions, policies, and factors that established sustainable current and medium-term levels of economic prosperity.

The European Innovation Scoreboard (EIS) is an annual publication for the European Commission (EC), prepared by Maastricht University. While limited in scope to members of the European Union (EU), and some other European countries and regional neighbors, the EIS provides comparative analysis of innovation performance across these countries. The earliest edition in a consolidated state is from 2010, although earlier editions (with a slightly different set of parameters) going back to 2007 are available. The Regional Innovation Scoreboard is a regional extension of the EIS, published every two years. The EIS collects a number of parameters that fit into the MIT framework, but its scope is limited to Europe and its surroundings.

[3] The Global Innovation Index (GII) is today at: https://prosperitydata360.worldbank.org/en/dataset/WIPO+GII. It is not to be confused with the 'GInI' (Global Innovation Institute), a certification and consultancy practice for those interested in the GII.

The Global Entrepreneurship Monitor (GEM) is developed by a consortium of corporations, universities, top research institutions and government laboratories that annually publishes studies on the state of entrepreneurship in over 70 countries. It conducts the research through a series of interviews and surveys: an annual survey and interviews of a representative sample of the population (the Adult Survey Population) and a survey of the experts in the country (the National Expert Survey). This GEM serves as a primary source for many other entrepreneurial indices. We will draw upon some of its measures of entrepreneurial culture/incentives as the best, and most comparative, measures of the underlying attitudes towards entrepreneurship.

The Global Entrepreneurship Index (GEI) was created by the Global Entrepreneurship and Development Institute (GEDI), developed by Imperial College London's Business School, the London School of Economics, George Mason University and the Universities of Strathclyde, Aston and Pecs. GEI provides analysis of individual and institutional variables that impacts entrepreneurial development. The score of GEI provides a measure of the involved countries in terms of the quality of the entrepreneurship ecosystem using parameters like attitude, abilities, and aspirations of the entrepreneurs. GEI is impactful during the E-CAP benchmark comparisons.[4]

The Global Startup Ecosystem Report is a new study by Startup Genome (starting in 2017) that looks into a number of selected tech ecosystems. It looks in great detail at the demographics, performing, funding and infrastructure. A particular focus is on talent and other resource attraction for selected areas, however, this scope is also the limit of the study.

[4] This framework is extended to a Female Entrepreneurship Index, and Regional Entrepreneurship Index for the EU.

3. MIT's Approach to the two Capacities

Given the many indices and plethora of data outlined above, we have chosen an alternative approach that starts with our definition of the 'System', then breaks each part into a limited series of relevant metrics, especially for the Capacities.

In line with our MIT model of the 'System', we select metrics for the core components, guided by the following simple criteria:

1. Measures that are simple, self-explanatory and as close to the underlying phenomena as possible;

2. Measures that capture distinctive elements of the system with as little duplication or overlap as possible, so as to be parsimonious;

3. Measures that are widely available across countries around the world (not just the OECD, EU or US) while recognizing that these measures are not always available at the sub-national regional level;

4. Measures that might be replicated or measured with simplicity by countries who do not have existing coverage;

5. Measures that are objective given preference over those that are subjective, expect where those measures are not available;

6. Measures that are directly captured rather than those that contain multiple elements.

Measuring Innovation and Entrepreneurship Capacities

Together, I-Cap and E-Cap capture that a system is capable of two particular activities: innovation and entrepreneurship respectively. As a starting point, we usefully think of a 'capacity' as a sort of 'production function' - i.e. a way of relating a series of well-defined inputs to the outputs, in this case of entrepreneurial or innovative capacity outputs. Below we focus on the measurable 'inputs' into this function.

Through a decision-making lens, it is critical that the inputs into the production function be defined and then optimized for - or at least made as appropriate as possible for – innovation (moving ideas from inception e.g. in the lab through to impact in a variety of organizational settings not just in start-up enterprises) and entrepreneurship (the creation of start-ups and the scale-up of all new enterprises).

We consider five critical inputs into the I-Cap and E-Cap production functions, based on MIT research about the drivers of 'innovation-driven entrepreneurship' in a variety of locations – some within the United States but also from regions worldwide (including Singapore, Tokyo, Finland, Scotland, London, Israel, etc.).

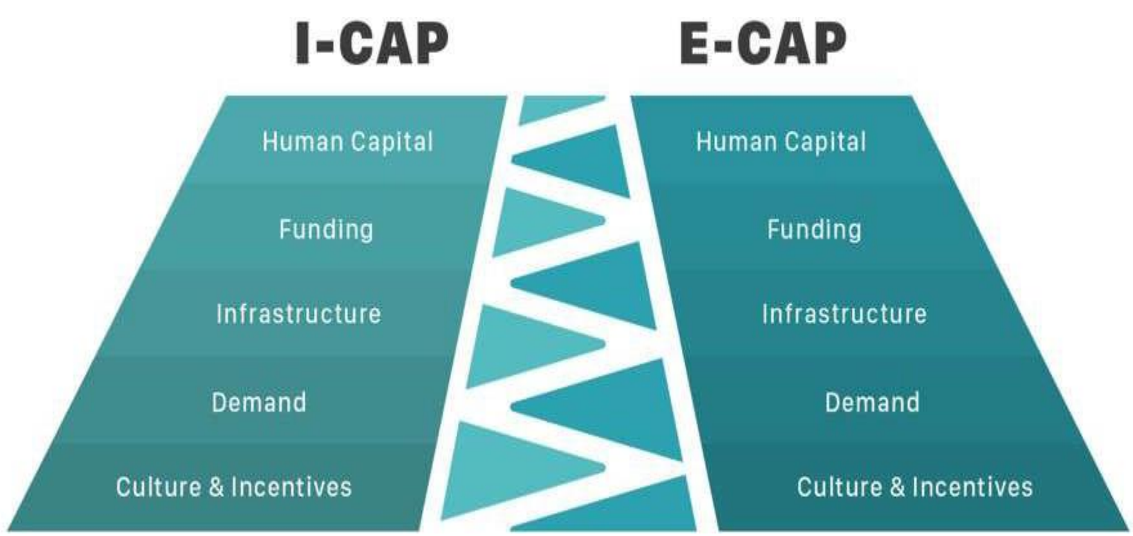

Figure 3: MIT I-Cap and E-Cap framework

This simplified framework allows decision-makers to determine their systems' greatest points of weakness and thus identify the points of leverage.

These five components, found in both capacities on either side of the ledger, are:

- **Human Capital** (people) – the appropriate human talent (from within a region, or attracted into a region) with relevant education, training and experience for either innovation or entrepreneurship (or both).

- **Funding** – a variety of types of capital (from the public and private sectors) that support innovation and entrepreneurship both at their origins but also throughout the journey from idea to impact, or start-up to scale-up.

- **Infrastructure** – the physical infrastructure that is necessary to support innovation and entrepreneurship at their different stages – including space as well as equipment required for discovery, production and supply chains, etc.

- **Demand** – the level and nature of specialized demand for the outputs of innovation and entrepreneurial capacities supplied by different organizations in the system.

- **Culture & incentives** – the nature of role models and individuals who are celebrated, the social norms ('culture') that shape acceptable career choices and the incentives that shape individual and team behaviors.

For each of the different inputs into I-Cap and E-Cap, we select a basket of measures that captures the strength of these specific elements (without being too repetitive and overlapping). Starting below we outline the inputs for each of these in turn.

3a. Measuring Innovation Capacity (I-Cap) Inputs

Human Capital: The number and quality of innovations that move from idea to impact are critically dependent on who is trained in the various skills that are essential to the innovation process and the availability of such high-quality human talent in the region of study. Human capital depends on the quality of education, the level of educational attainment and employment in their fields. We include five elements in measuring human capital as an input into I-Cap.

Funding: Research and Development (R&D) as well as the later stages of innovation is an expensive and risky process that requires a lot of financial support. Countries vary in the degree they provide for R&D, with some dedicating a larger portion of public funding, others leaving it to the business sectors. We include four elements representing funding as an input into I-Cap.

Infrastructure: Infrastructure to support I-Cap spans the range from highly specialized technological support to information access support e.g. the availability of good telephony and Internet connections. Infrastructure to support the later stages of innovation also comes through sophisticated production processes that can serve to produce innovations at a large scale. We include four elements in measuring both hard and soft infrastructure as an input into I-Cap.

Demand: Demand for innovation can be intrinsic and/or extrinsic. Here we study the interaction among innovators in different sectors, as well as buyers and their willingness to adopt new innovations. We use three elements to measure demand.

Culture & Incentives: Culture and Incentives to pursue innovation are an important factor in how much I-Cap a country has. Is there cultural support for the pursuit of technological innovations? How popular is science and engineering as a course of study in your young population and how do they view innovation? While hard to evaluate, for now, we include two elements in measuring culture and incentives as inputs into I-Cap.

Table 1 - Innovation Capacity (I-Cap) Inputs

HUMAN CAPITAL		**Source**
Researchers in R&D (per million people)	This indicator measures the number of scientists and engineers available.	UIS
Quality of STEM education	Survey response to the question 'How do you assess the quality of math and science education? '	GCI (2017 and prior only)
STEM Graduates per capita	This indicator measures the number of graduates by the field of education, i.e. sciences, mathematics and statistics, engineering, manufacturing and processing.	OECD
New PhD graduates	This indicator measures the number of new doctorate graduates.	OECD
New Masters graduates	This indicator measures the number of new Masters graduates.	OECD
Government researchers	Government researchers are professionals working for government institutions engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned. This indicator is measured in per 1000 people employed and in number of researchers; the data are available as a total and broken down by gender.	OECD
Availability of Scientists & Engineers	Survey response to the question 'To what extent are scientists and engineers available?'	GCI (2017 and prior only)
FUNDING		
R&D expenditure as a % GDP	This indicator is measured by the total expenditure on R&D performed during a specific reference period as a percentage of GDP.	UIS
% of Expenditure in R&D (GERD) funded from Abroad	This indicator measures external funding on R&D.	UIS (2015 and prior only)
% of Expenditure in R&D (GERD) funded by Government sector	This indicator measures Government funding on R&D.	UIS (2015 and prior only)
R&D expenditure in '000 current PPP$	This indicator measures total expenditure on R&D performed during a specific reference period.	OECD
Business Expenditure as % of total R&D expenditure	This indicator measures the share of R&D expenditure by business sector (i.e. private and public enterprises, corporations etc.) during a specific reference period.	OECD
Public R&D Expenditure as % of total R&D expenditure	Share of R&D expenditure in the public sector (government and higher education).	OECD
INFRASTRUCTURE		
ICT access	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.	GII

Internet Bandwidth	This indicator measures total used capacity of international Internet bandwidth per Internet user.	ITU
Production Process Sophistication	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?'	GCI (2017 and prior only)
Availability of latest technologies	Survey response to the question 'In your country, to what extent are the latest technologies available?'	GCI (2017 and prior only)
Most Technologically Advanced Countries In The World 2023	Based on a set of indicators from various data sources.	GF (Report)
DEMAND		
Government procurement of advanced technology	Survey response to the question 'In your country, to what extent do government purchasing decisions foster innovation?'	GCI (2017 and prior only)
University-industry research collaborations	Survey response to the question 'In your country, to what extent do people collaborate and share ideas between companies and universities/research institutions?'	GII
Trade, Competition & Market scale	A score Composed of three factors: 1. Applied tariff rate, weighted mean, 2. Intensity of local competition; 3. Domestic market scale	GII
CULTURE & INCENTIVES		
Quality of scientific research institutions	Survey response to the question 'In your country, how do you assess the quality of scientific research institutions?'	GCI
Graduates in science & engineering (%)	The share of all tertiary graduates in science, manufacturing, engineering, and construction over all tertiary graduates.	GII
Triadic patent families	A triadic patent family is defined as a set of patents registered in various countries (i.e. patent offices) to protect the same invention. Triadic patent families are a set of patents filed at three of these major patent offices: the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO). Triadic patent family counts are attributed to the country of residence of the inventor and to the date when the patent was first registered. This indicator is measured as a number.	OECD
National strategy on innovative technologies	Does government have a national strategy on disruptive / innovative technologies?	GTMI

3b. Measuring Entrepreneurship Capacity (E-Cap) Inputs

Human Capital: Human Capital for E-Cap is more complex to measure but conceptually it refers to the number of people in a region/nation with the relevant skills and knowledge to build an enterprise from start-up through to growth and scale. It may be derived from relevant education, training, and experience. Given that it challenging to capture human capital for entrepreneurship, we include two elements in measuring human capital as an input into E-Cap.

Funding: A new enterprise often requires investment in the form of external 'risk capital', ranging from angel equity funding or then Venture Capital (VC), through to debt finance and credit arrangements. (As such 'risk capital' is defined as funding for seed and start-up finance as well as later rounds requiring the capital for expansion and replacement. In our analysis of inputs into E-Cap, we attempt to capture how accessible such funding is. The guiding questions are how transparent and efficient is the credit system and how available and common is the VC funding. We therefore include five elements in measuring funding as an input into E-Cap.

Infrastructure: Infrastructure for E-Cap is more basic than that which might be relevant for I-Cap, however it includes a number of different elements. We look at the infrastructure for telecommunications and for goods transfer, which could be crucial for the life expectancy of a start-up, the number of Internet users (as a measure of access to on-line products and services), and logistics so as to explore the delivery of products from suppliers and to customers. We include three elements to measure infrastructure.

Demand: Demand for new products and services could be predicted, to a certain extent, by the size of the domestic market (at least as a starting point). Is the domestic market attractive enough for the products/services of a new enterprise? The demand could also be affected by the sensitivity of customer to price or quality of the product. What is the share of men declaring that they would rather take a risk and start a new business than work for someone else? We include two elements to capture demand.

Culture & Incentives: Culture is widely regarded as an important factor that may support or inhibit the success of any entrepreneurial. In our index we wish to explore how culturally accepted entrepreneurship is: Are the winners celebrated sufficiently and if a business is a failure, how accepting is the society? Do the surrounding policies make it easier or harder? Furthermore, what are the positive or negative incentives in your area? If the business was a failure, does it affect one's chances for starting a new enterprise? We therefore include a total of eight elements in measuring culture and incentives as an input into E-Cap!

Table 2 - Entrepreneurial Capacity (E-Cap) Inputs

HUMAN CAPITAL		Source
% school grads in tertiary education	The ratio of total tertiary enrolment to the population of the age group that officially corresponds to the tertiary level of education.	World Bank
Entrepreneurship perceived capabilities	Share of the population who, in response to a survey, believe they have the required skills and knowledge to start a business	GEM
ICT Skills	The proportion of youth and adults with ICT skills, by type of skills	ITU
Entrepreneurship by Gender	The differences between levels of entrepreneurship among males and females in different economies.	GEM
New business density	Number of new businesses formed in a year per 1000 persons aged 15-64	World Bank
FUNDING		
Easy Access to Loans	Survey response to the question, in your country, how easy is it for businesses to obtain a bank loan?	IMD
Ease of Credit	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)	GII
Venture capital (VC) availability	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?	GCI CB Insights Report
VC investment	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 purchases of quoted shares are excluded.	EIS OECD
VC deals	Index of venture capital per investment location	GII

INFRASTRUCTURE		
Electricity & telephony infrastructure	A score measuring a survey of the quality of electricity supply?, fixed telephone lines, and mobile telephone subscriptions per 100 population	World Bank ITU
Number of internet users	Internet users are individuals who have used the Internet (from any location) in the last 12 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.	ITU
Logistics performance	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 the destination	World Bank
DEMAND		
Buyer sophistication	Survey response to 'In your country, on what basis do buyers make purchasing decisions, low price or high performance?'	Atlas of Economic Complexity
Domestic Market Scale (GII)	Domestic market size as measured by GDP bn PPP$	IMF
Trade Exports	Size of Export Market per country	World Bank; Atlas of Economic Complexity
CULTURE & INCENTIVES		
Entrepreneurial intention	Share of the population (individuals involved in any stage of entrepreneurial activity excluded) who are latent entrepreneurs and who intend to start a business within three years	GEM
Fear of failure	Share of the population perceiving good opportunities to start a business indicating that fear of failure would prevent them from setting up a business	GEM
Entrepreneurship as a Good Career Choice	Share of the adult population who agree with the statement that in their country, most people consider starting a business as a desirable career choice	GEM

High Status to Successful Entrepreneurs	Share of the population who agree with the statement that in their country, successful entrepreneurs receive high status	GEM
Entrepreneurial Potential across countries	How entrepreneurs view their business from different perspectives and resource access	World Bank
Business Freedom	A composite score measuring an individual's ability to establish and run an enterprise without undue interference from the state, i.e. the ease of starting, operating, and closing a business, measuring how long and how costly these processes are.	Heritage Foundation

4. Measuring other elements of the 'System'

While the chapter above focuses on the two Capacities, and especially their Inputs, this one looks to the other elements of the 'System' as set out below:

i. Innovation-driven entrepreneurship 'impact'
ii. Comparative Advantage of regions
iii. Innovation and Entrepreneurship Capacities
iv. Foundational Institutions

Figure 2: metrics for the 'System' for innovation-driven entrepreneurship

We start by setting out metrics for the top of the ecosystem pyramid – its 'innovation-driven entrepreneurial impact' – which is informed by the 'comparative advantage' (including regional clusters). This is in turn shaped by these two capacities (as set out in detail above), which are core to this Working Paper, namely the small basket of metrics which are the critical 'inputs' into both the innovation and entrepreneurship capacities. These in turn rest on the Foundational Institutions, at the base of the pyramid.

i. Innovation-driven entrepreneurship 'impact'

Though 'impact' is at the top of the pyramid – and often the primary focus of those trying to boost 'innovation-driven entrepreneurial' (IDE) outcomes in an ecosystem – it is important to recognize that the potential or expected 'impact' is shaped and informed by the undergirding elements of the whole 'System' pyramid.

In this sense, it is important to start from the 'bottom up' in terms of analyzing the data and actual potential of the ecosystem, rather than simply dictating a 'top down' impact (in terms of the number of jobs created, or IDE start-ups). The latter might not be a realistic outcome from sober assessment of the elements underpinning the 'System'.

As such, it is hard to specify the precise measures for any given region's ecosystem effort which can be frustrating for those seeking a simple 'GDP enhancement. Further work is required to examine and discuss a range of different approaches to capturing the 'impact' desired for specific ecosystems.

ii. Measuring the 'Comparative Advantage' of regions

As we noted in our introduction, the 'comparative advantage' of a region is based on specific areas of strength that differentiate it from others around it – locally or globally. In some instances, such advantage arises within a country having that region be the most successful in the nation. For example, Bangalore is India's most successful region for information technology, Cambridge is such a region for life sciences in the United Kingdom, and Berlin for creative media in Germany.

On the other hand, some regions have comparative advantage that is global in stature – in other words, the region is unique on the global stage. Silicon Valley is the most obvious example, having global comparative advantage in a range of sectors including B2C and B2B software and some hardware. Similarly, Boston's Kendall Square has emerged as the leading global location with a comparative advantage in the life science.

Comparative advantage can most easily be measured through an assessment of the existing economic 'clusters' in a given region – which identifies the relative strengths in that place. The relative national or international standing are often more difficult to measure, although this can be done at a national scale. Such 'cluster' analysis has been undertaken for the United States, Europe and other selected nations.[5] As such, it can provide a useful starting point for regions that are so covered to investigate their 'as is' competitive state. Some regions find themselves seeking competitive advantage in a 'cluster' that is not part of the traditional list, such as 'oceans' for several bordering the north Atlantic which have recently identified it as their cluster focus of choice.

As well as exploring strong clusters, it is also useful to find measures that capture the collection of specialized assets, critical talent and unique challenges that might be crafted into 'comparative advantage' in a more forward-looking fashion.

For example, in Chile, the obvious strengths in the mining cluster are being fused with challenges in mining-related health, environment and energy so as to provide a platform for a new generation of innovation-driven entrepreneurial startups. London's emergence as a "TechCity" built on creative talent in media and arts, from software talent unleashed from the financial sector in 2008, and the presence of many multi-national headquarters in the city.

[5] The most fully developed measures of economic clusters have been developed by Delgado, Porter and Stern as part of the US Cluster Mapping Project. And by the European Cluster observatory.

Of course, measuring such comparative advantage or even the foundations of advantage is not simple. And it is not likely to be suitable for the development and application of standard metrics in the vein of other elements of our framework. We therefore recommend that regions work with their stakeholders to explore different perspectives and opinions on the current sources of comparative advantage e.g. existing strong sectors, and future sources of comparative advantage such as potentially powerful future opportunities based on key assets, talent and challenges.

In all this work, it is critical to consider the degree to which any cluster, asset or talent is national, continental, or global. This often requires an honest and clear-eyed assessment: as an example, at one period in time, over 40 of the states in the US claimed to be 'in the top three' life science clusters. On the other hand, a region such as south Wales (in the UK) had noted its national comparative advantage in compound semi-conductors, while in fact it was actually global in its degree of advantage. The validity of claims to 'global advantage' is likely to be rare because, given the natural nature of agglomeration, only a small number of regions will rise to truly global significance in any given economic arena.

From a measurement perspective, we would therefore advise developing a simple collection of measures and metrics (Table below)

Table 4, collection of measures and metrics

Leading current economic clusters	Ranking the three to four strongest economic sectors or clusters in the region, with additional ranking information on the degree of competitiveness of those sectors/clusters at the international level.
Leading assets	Ranking of the three most important assets in the region e.g. physical assets.
Leading areas of expertise and talent	Ranking of the three most important areas of expertise and talent in the region e.g. AI, creative arts etc. with ranking information on the degree of competitiveness at the international level.
Critical problems/ challenges	Ranking of the three most critical challenges for the region e.g. water shortages, defense security, that might be of broader relevance to other markets.

iii. Measuring Innovation and Entrepreneurship Capacities' Outputs

While the innovation and entrepreneurship capacities can be seen as having a range of inputs (in five distinctive categories), there are easy-to-measure (though incomplete) intermediate 'outputs' that can be a useful stepping stone towards assessing Comparatve Advantage (as the next step up in the pyramid).

These simple outputs are not adequate to capture the (ever-changing) impact of an 'innovation-driven entrepreneurship' ecosystem. They are still useful, however, as intermediate outputs with which to evaluate the effectiveness of the twin engines of the innovation and entrepreneurship capacities:

- Innovation Capacity (I-Cap) Outputs include, at the simplest level, the number of research publications produced each year by a country, and (though an incomplete way of measuring innovation) the number of patent applications filed and/or granted each year. Obviously, all the usual caveats about the limitations of using publications and patents as measures of innovation apply, but they remain useful output (rather than impact) measures, especially when considered over time or against other nations.

- Entrepreneurial Capacity (E-Cap) Outputs include, in the most simplistic fashion, the number of new start-up enterprises established each year. This is a good measure of basic entrepreneurship capacity output that can be further refined when we consider 'impact' measures to consider the entrepreneurial quality (or potential) of these start-ups, and their outcomes eg. venture fund raising, job creation, public listing, etc.

By establishing some simple benchmarks for the effectiveness of the engines of I-Cap and E-Capacity, it is possible to develop an understanding of where a country of interest lies within one of the four I-Cap/E-Cap quadrants:

- high I-Cap/high E-Cap (for example Israel and parts of the United States),
- high I-Cap/low E-Cap (for example countries such as South Korea);
- low I-Cap/high E-Cap (for example Thailand, Nigeria etc.); and finally
- low I-Cap/low E-Cap (though this is rarer, suggesting much change is needed).

All of these measures can be considered in terms of population and GDP. These two different denominators allow the outputs of I-Cap and E-Cap to be compared more globally against a baseline of either population or economic scale.

iv. Measuring 'Foundational Institutions'

Many organizations and scholars have explored the importance of foundational institutions that serve to support broader economic development in a nation, which has an obvious read-across to the establishment of a vibrant innovation ecosystem within it. Below we have selected a short list of metrics from these rankings that capture some of the key foundational institutions. Of course, these indices provide much greater depth which may be relevant for some decision-makers versus others and in some specific contexts. For our 'innovation' purposes, we consider a handful of measures that capture our conception of foundational institutions (and the strength of these), including rule of law, property rights, ease of doing business, and levels of corruption.

From the World Bank's (WB) Doing Business (DB)[11] site, we look at headline 'Ease of doing business' (DB) rankings but also to a number of its constituent innovation-related metrics (eg 'Topics' like starting a business, resolving insolvency, etc) and their 'Distance to frontier' (DF). From the Heritage Foundation's Index of Economic Freedom[12] (IEF), we look below the headline 'overall score' and within its four key categories for particular areas of institutional concern (eg property rights). Finally, from Transparency International (TI), the headline figures from its Corruption Perceptions Index provide a useful benchmark for countries (by perception) and the overall trends.

Table 1: Overview of metrics for 'Foundational Institutions'

Ease of doing business (WB)	Composite country ranking from the World Bank across 10 topics relevant to ease of operating private-sector firms.
Starting a business (WB)	Ranking of the simplicity of starting a new business for entrepreneurs incorporating and registering a new firm.
Paying taxes (WB)	Ranking level of tax rates and administrative burden in tax payment for typical medium-size firms.
Resolving Insolvency (WB)	Ranking level of weaknesses in insolvency law and main bottlenecks in the process.
Enforcing contracts (WB)	Ranking level of time/cost for resolving a commercial dispute including degree of good practices in the court system.
Property Rights (IEF)	Score across the strength of laws allowing individuals to accumulate five types of property rights (including IPRs).
Government Integrity (IEF)	Score capturing levels of trust, transparency and absence of corruption.
Labor Freedom (IEF)	Score capturing flexibility and efficiency of a country's labor market including hindrance to hiring etc.
Trade freedom (IEF)	Score capturing tariff and non-tariff barriers to imports and exports.
Corruption Perceptions Index (TI)	Overall ranking of countries in their composite level of perceived corruption (high ranking implies high corruption).

[11] http://www.doingbusiness.org

[12] http://www.heritage.org/index/

5. Conclusions

Our approach to measuring ‘innovation-driven entrepreneurship’ in an ecosystem is grounded in a clear framework for understanding this as a ‘system’ in which a range of inputs are combined, on the (more or less strong) bedrock of institutional foundations.

As the foundations for the whole System, the underlying ‘institutions’ are important, even though they might not be amenable to major change in the short term. Despite this, it is important to be honest and clear-eyed about them, but then turn to how to proceed in the circumstances, given the challenges – or opportunities – they provide.

For both analytical and decision-making purposes, the innovation capacity (I-Cap) and entrepreneurship capacity (E-Cap) can be usefully separated into the 'twin engines' of the system, each with a separate series of inputs to fuel them. Either or both of these engines can be stronger or weaker in any given country, contributing to an ecosystem, and this assessment can be captured in a series of simple output metrics.

These then feed into 'comparative advantage' at the regional level (including clusters), which is a useful intermediate prism through which to consider the outputs of both entrepreneurship and innovation capacities.

Beyond that, the health of innovation-driven entrepreneurship in an ecosystem – as a snapshot in time, or over time - must be captured through a series of higher-level impact measures that are appropriate for the particular circumstances.

As a starting point, we have provided decision-makers with a framework to understand the innovation-driven entrepreneurship in their iEcosystem and some simple measures that capture the institutional foundations, and both innovation and entrepreneurship capacities. While not as satisfying as a singular index, we find this approach to be more intellectually robust and more useful in terms of guiding subsequent actions of decision-makers – be they within government, corporations, universities or other stakeholders.

In future work, we will expand upon our discussion of 'impact' with a variety of measures from high-level national ones (such as GDP, SPI or the UN’s SDGs) through more regional ones (such as EQI for the ‘IDEs’) to more targeted evaluations of region-specific ‘policy and program interventions’ (PPIs).

In the meantime, we present this Working Paper to capture what we have learned so far, and to seek further feedback from researchers, practitioners and decision-makers.

Appendix A: Data Sources for Rankings & Indices

Taken together, our data is drawn from a range of sources. (Most of the innovation indices and entrepreneurship rankings are drawing on the same coresources, but then packagae and wight them in ways that are not as conducive to separating out the I-Cap and E-Cap elements, or focusing on the primary inputs).

Below we present each of these data sources in turn.

United Nations (UN)

The United Nations (UN) is a global organization and its Statistics Division (UNSD) is the central body within the UN system for the collection, analysis, dissemination, and standardization of statistical information on a global scale. UNSD covers a range of statistical areas, including demographics, social development, economic activity, environment, and gender statistics.

UNESCO Institute for Statistics (UIS)

The United Nations' Educational, Scientific and Cultural Organization (UNESCO) hosts the UN's Institute for Statistics (UIS) which is the statistical office of UNESCO and the United Nations depository for cross-nationally comparable statistics on education, science and technology, culture, and communication. UIS data provides crucial indicators used in the MIT REAP Innovation Capacity (I-Cap) framework within Human Capital and Funding. The data collected by UIS covers a wide range of indicators, including the number of researchers in R&D, quality of STEM education, R&D expenditure as a percentage of GDP, and government funding for research. These indicators are vital to understanding the nation's current landscape for innovation capacity.

To track progress on its Sustainable Development Goals (SDGs), the UN uses the UIS, especially for Target 9.5 which encourages countries to "Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending." Its more recent innovation data collection emphasizes the types and origins of innovation (e.g. product, process, organizational or market) as well as where innovation takes place (in universities, contractors, firms etc). It provides new insights into innovation capacity beyond R&D spending, and will plan to evolve its data sources for the post-2030 period.

International Telecommunication Union (ITU)

The International Telecommunication Union (ITU) is a specialized UN agency that focuses on information and communication technologies (ICT). ITU provides crucial data for understanding ICT development and its impact on innovation and entrepreneurship, making it a valuable resource for the MIT REAP Innovation Capacity (I-Cap) and Entrepreneurial Capacity (E-Cap) framework within Infrastructure and Human Capital. ITU provides key indicators for countries such as their internet bandwidth, proportion of the population with ICT access, and number of internet users. These indicators offer valuable insights into the nation's digital infrastructure and readiness for innovation and entrepreneurship.

GovTech Maturity Index (GTMI)

The GovTech Maturity Index (GTMI) is a tool developed by the World Bank to assess the digital transformation progress of governments in the public sector. It focuses on how effectively a country utilizes technology to improve service delivery, government operations, and citizen engagement. GTMI data provides a crucial indicator used in the MIT REAP Innovation Capacity (I-Cap) framework within Culture and Incentives on whether the government has a national strategy on innovative technologies.

Global Finance

Global Finance (GF) is a monthly English-language publication focused on the international finance industry and caters to an audience of high-level financial professionals. Based on a set of indicators from various data sources, GF ranks the most technologically advanced countries in the world. This ranking provides a crucial indicator in the MIT REAP Innovation Capacity (I-Cap) framework within Infrastructure.

Organisation for Economic Co-operation and Development (OECD)

The Organisation for Economic Co-operation and Development (OECD) is an international organization that provides a forum for its 38 member countries to collaborate and discuss policy solutions for pressing global issues. OECD is also a major source of high-quality, internationally comparable data across various domains, including education, science, and innovation. OECD data provides crucial indicators used in the MIT REAP Innovation Capacity (I-Cap) framework within Human Capital and Funding. The data collected by OECD covers a range of indicators, including the number of STEM graduates per capita, new PhD and Masters graduates, number of government researchers, number of triadic patent families, and total R&D expenditure. These indicators are vital for understanding the innovation capacity landscape of its member countries and beyond.