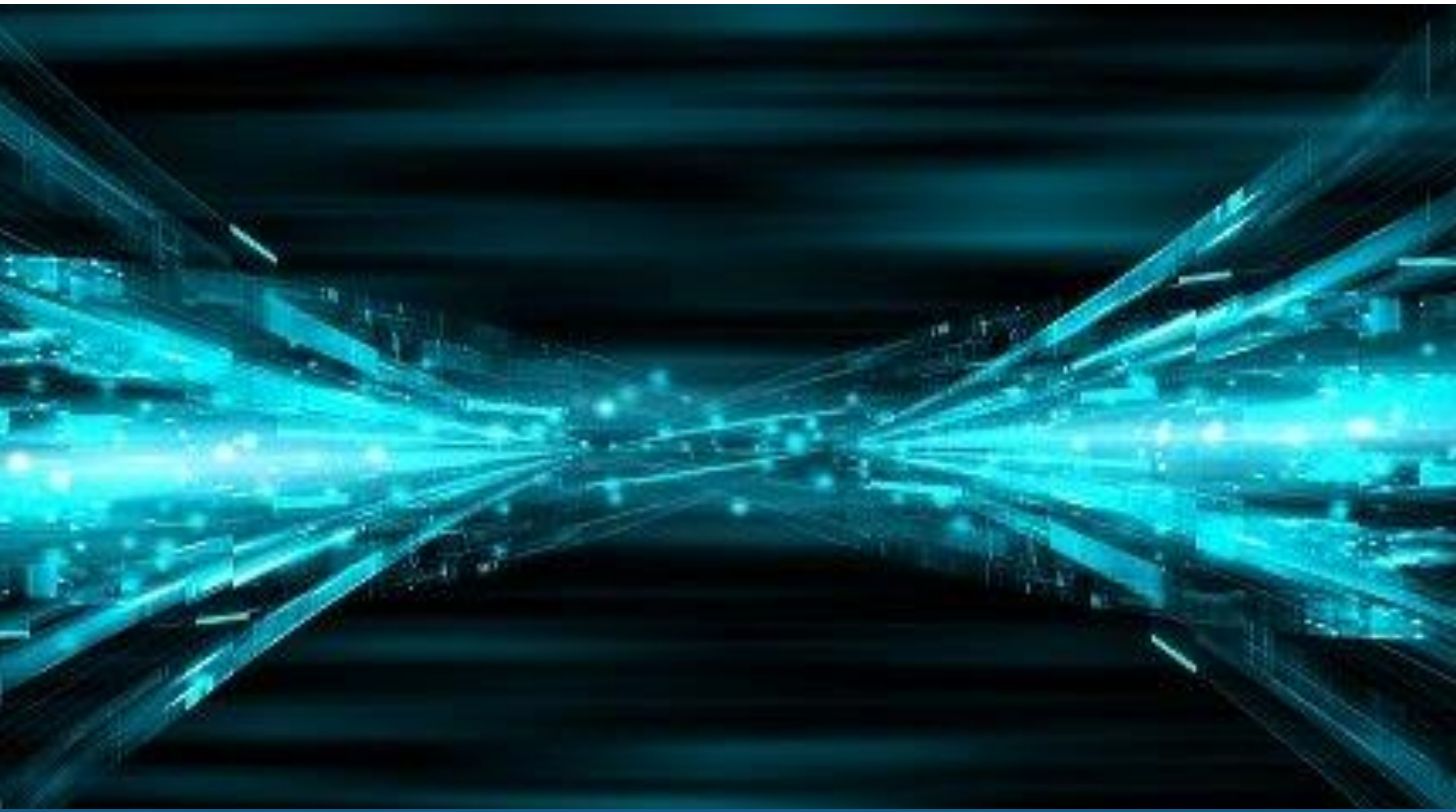


INNOVATION INTERMEDIARY INFRASTRUCTURE

Comparative Review of International Approaches

Dr Jessica Ocampos

Commissioned by IFI BIOTECNOLOGIA CORFO

Cambridge | February 2018

REPORT CITATION
Ocampos, J.A. (2018). Innovation Intermediary Infrastructure. Benchmark and Comparative Review of International Models. Cambridge (UK). 22 February 2018.©

CONTENTS

EXECUTIVE SUMMARY

In the context of the programme 'Biotechnology as an Enabling Platform for Productive Diversification and Sophistication, 15IFI – 48518', the Competitiveness Management Office of the Chilean CORFO Chilean Economic Development Agency (herein CORFO) commissioned a benchmarking and bibliographical review of three international innovation intermediary infrastructures or translational research centres.

The aim of the consultancy was to review key features underpinning international innovation intermediary infrastructures, selected by the consultant after a pre-filter process realised by CORFO. The key features were defined by CORFO as the following:

- origins and constitution;
- aims and objectives;
- governance structure;
- services provided;
- and minimum infrastructure.

The intermediary innovation infrastructure approaches revised were the Fraunhofer – Gesellschaft of Germany, adopted as a reference in several countries; the Catapult model of the UK; the Carnot network of France; and the Taiwan's ITRI. Catapult and Carnot models are recent attempts of their respective governments to effectively exploit and transfer the strong science base into the industrial sector based on the Fraunhofer model. Unlike the three formers, ITRI's Taiwan, founded in 1973 by the government, is still considered a model of intervention for developing countries, as example of a latecomer strategy - with relevance for the Chilean innovation landscape - with a transformative effect on Taiwan's industrial base, creating a whole new sector in the absence of significant infrastructure and competences.

The origins of each approach and their **key features are diverse and greatly dependent on the country's innovation landscape**, seen as a quadruple-helix model, which includes existing R&D strengths (HEI and basic research centres), the characteristics of their industrial and productivity sector (relevance of SMEs versus larger industry), historical and political context, and society and cultural aspect, such as the relationship among the public administration (government and regional level), public research institutions, and the local industry and wider society. **This makes difficult, if not inviable**, trying to replicate them into other scenarios (even within each country several differences can be observed in regional innovation landscape): the context in which intermediate organisations operate matters greatly, and they cannot be considered as the only responsible for successful cases.

Despite the differences, important aspects can be drawn from their trajectory and success cases, which are summarised below:

- All the models have the mandate to support small businesses, in recognition of their key role driving innovation, with emphasis on **high-value added by competing on export in identified**

global market opportunities, based on identified strengths on their country's research basis, which in the case of latecomers, complemented with a long-term capability development plan.
- The two international leading approaches, ITRI and Fraunhofer, have a long-standing trajectory of decades, (ITRI, 40 years and 69 years for Fraunhofer), with a **clear mission and government support**, reflecting a '**national consensus that public investments** must be made in research infrastructure that includes infrastructure for applied research with commercial relevance'.
- All of them receive **government funding (core funding)** that they use to equip, staff, and operate research facilities that provide services to industry. The level of core funding varies in time and within the different models.
- All the reviewed **approaches are not expected to be self-sustainable**. Government or regional funding is key to ensure their mission of social benefit and increase the country's competitiveness.
- All the organisations are non-for-profit. Fraunhofer, one of the world's reference and long-lasting organisations, is a **private non-for-profit** registered association.
- The main service provided is **contract research**, offer to industry and public organisations, by which they receive revenue from those organisations pursuant to research contracts. The revenue is calculated on the basis of the cost of each project.
- They do not disburse government funds to companies.
- Best practices of successful models involve **clear and sustained mission and vision** aligns with a strategy **that governs to all their centres** under the same umbrella, with independent governance from the public bodies but **with close and systematic evaluation and monitoring system**. Key role of the technical and industrial committees, with representatives - **in their individual capacity** - of the industry, the public administration, the civic society and international experts.
- Executive board with industrial professional experience.
- **Policy of incentives**: the Carnot model recognises and incentivises the institutes that have a clear research strategy, that verify what types of technology the French industry is seeking, that secure contracts to develop those technologies. The government rewards success in obtaining contracts with matching funding.
- Original infrastructures are based on existing infrastructure previously funded by either government or regional public or private funds.
- Substantial physical sites with the infrastructure necessary to conduct research and to create a manufacturing environment with onsite production lines and simulation platforms.
- The institutes are staffed by professionals with deep scientific and engineering competencies.
- **Role in training:** Lack of sufficient highly skilled engineers, scientists and technicians has determined an important role in capability building by the infrastructures. They provide training to young people in the practical application of science in an industrial setting. Also, by partnering with nearby universities, they provide part-time and sometimes full-time jobs at the research institutes for the university students.

As a comparative review, the following table point out the main features of each of the centres.

	Fraunhofer	Catapult	Carnot	ITRI
Year of implementation	1949 (foundation)	2011	2006	1973
Direct Supervisory Authority	None	Innovate UK (oversees without direct management)	National Agency for Research	Ministry of Economic Affairs
Form of Entity	Private non-for-profit	Non-for-profit company limited by guarantee	Public research institutions	Government-owned research institute
Annual "Core" Government Funding	€672m[1] [2]	£10m (to each centre)[3]	*£1,700m*[4]	USD$300m[5]
Geographical locations	Widely distributed across Germany and international presence	Distributed across the UK	Distributed across France	One main site in Hsichun, one beta site in Tainan
New or existing facilities	Existing and new facilities	Existing and new facilities	Existing research institutions	Existing and new facilities
Prototype Development for Companies	Yes	Depends on the catapult centre	Yes	Yes
Pilot Lines/ Simulation Platforms on Premises	Yes	Depends on the catapult centre	Yes	Yes
Number of Institutes	72 (Fraunhofer and research institutions)	10	38	1
Staff	24,458	Estimated 2,700 (with 2,114 at HVM)	30,000 (including 9,600 PhD)	6,074
Patents	6,762	No information	1,020 (per year)	26,509

Table 1 Comparison of the four innovation intermediate infrastructures reviewed in the project.

[1] Fraunhofer, Annual Report 2016.
[2] Within the research network, the proportion of each institute's income that is attributable to government expenditures varies from institute to institute (National Research Council, 2013).
[3] They have been traditionally funded with £50m per new Catapult across five years, with a 'flat' funding profile of £10m per annum (Ernst & Young, 2017).
[4] According to Hauser Report (2014), considering though not just core funding but competitive public funds (based on the formula that Carnot uses to reward the institutes). According to Philippe Larédo (Université Paris Est and University of Manchester, 2011) there is of €60M/year support grant independent of contract research formula to renew capabilities (http://ifris.org/wp-content/blogs.dir/1/files/2014/10/Vienna-PL-june-2011.pdf)
[5] 21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program, National Research Council, 2013.

BACKGROUND OF INTERMEDIARY INFRASTRUCTURE IN INNOVATION

Several studies and policy advisors have addressed the important issue of how to transfer university research into the industry, particularly, into SME technology, and the key role of intermediary infrastructures (Carayannis et al., 2000; Mina et al., 2009; Hauser, H., 2010; Betz, 2015). 'Antonie J. Jetter and Songphon Munkongsujarit have discussed the concept of an intermediary organization to facilitate the technology transfer from science and technology at a national level down into the technology acquisition and development at a firm level, operating as an 'innovation intermediary.' (Betz et al., 2016).

Intermediary infrastructures include organisations that are either internal or external to university environments. In the first group (internal intermediaries) are, for example, technology transfer offices. These have proliferated after the Bayh-Dole Act (1980) granted US universities the right to appropriate and commercially exploit knowledge generated by or jointly with academic departments. In the second group (external intermediaries) are intermediate research organisations that operate as bridges between universities and firms but are autonomous and independent and are funded through combinations of public and private resources. Alternative forms of knowledge exchange through intermediary organisations do not exclude other channels, but are in fact ways to incentivise, streamline and manage licensing, spin-off, dissemination, networking and labour-exchange activities (Mina et al, 2009).

External innovation intermediary infrastructures are referred in the literature by different names including 'technology & innovation centres' (TICs) by Hermann Hauser (Hauser, 2010), 'manufacturing extension partnership' (MEP) (National Research Council, 2013), 'government–university–industry strategic partnerships' (GUISPs) (Betz et al., 2015), and 'public research institutes' (PRIs) (Carayannis et al. 2000). The two latter specifically refer to the role of governmental support. In particular, many studies describe the roles of PRIs in supporting the process of catching-up, whose activities vary according to the development stages of the industries, as it is stated by Shiu et al. (2013): 'Chang et al. (1999) proposed stage approach for PRIs to facilitate the industry technology development, by first selecting what technology to be diffused, then select the way to acquire the technology (either local development or overseas transfer), and finally developing the technology to the level that the industries can assimilate. These studies elucidate how PRIs were used to transform the industrial structure that was once based on "captive" type of relationship into "mutual" type of learning relationship with the world frontiers. The strategic models of PRIs discussed in literature provide policy lessons for other developing economies aspiring to follow the path of technology upgrading.' (Shiu et al., 2013).

The activities of intermediary organisations from the perspective of the users (firms) can include the following (Mina et al., 2009):

- foresight and diagnostic analysis in particular sectors
- scanning and information processing
- gatekeeping and brokering of relationships,

- testing
- validation
- various kinds of accreditation,
- validation and regulation,
- activities connected more directly with the commercialisation process including intellectual property protection and appropriation methods, and finally the evaluation of outcomes

All these different approaches of intermediary infrastructure, which operate with an eye on international technology markets and global R&D, face some similar challenges, such as (Mina et al., 2009):

- problem of institutional renewal
- balance between short and long-term targets
- management of intellectual policy
- changing policy expectations
- evolving relationships with universities

The role of government grants and procurement policies also seems crucial in the early development of all these organisations (independent of their character of public or private), which would not have survived their first years of operation if they had not adopted the 50:50 or 60:40 ratios of public to private funding (Mina et al., 2009).

The Carnot (France) and Catapult (UK) initiatives both are recent attempts by European countries to ‘replicate’ what they see as the best features of Germany’s Fraunhofer-Gesellschaft to improve the transfer of technology from the national research base to private industry (National Research Council, 2013). In the case of Carnot, and in the beginning of the Catapults’ implementation (e.g. High Value Manufacturing), existing institutes / infrastructure of applied research or innovation are assigned a designation (“Carnot” in France and “Catapult” in Britain) with the hope that the designation will develop into a recognised symbol of excellence, as has been the case with the Fraunhofer name (National Research Council, 2013). The Carnot and Catapult institutes are also being provided with core funding from their respective governments, with the expectation that most of their revenue will be derived from contract research.

FRAUNHOFER-GESELLSCHAFT

The German model of intermediary infrastructure based on the Fraunhofer-Gesellschaft has been extensively studied by researchers of innovation policy (Beise et al., 1999; Harding, R., 2002; National Research Council, 2013; Robin et al., 2013; Betz et al., 2016,) and adopted as a reference in several countries including the UK with the Catapult model (Hauser, 2010; Hauser, 2014), the Carnot network ITRI of Taiwan and ETRI in South Korea (Mina et al., 2009; National Research Council, 2013), among others.

Germany has a rich ecology of research organisations. Among them, the Fraunhofer-Gesellschaft (or Fraunhofer Society in English) plays a distinctive and influential role. It is widely cited as an important component of the German innovation system and an important institutional channel for technology transfer in the country (Mina et al., 2009). A 69-year old institution this year (2018), with 72 Fraunhofer Institutes and Research Institutions across Germany, the Fraunhofer-Gesellschaft engages in applied research in a national context where the total R&D budget approximates 92.5 billion euros (2.94% GDP) according to the latest available figures by the European Commission[6].

Fraunhofer's research portfolio covers a broad spectrum of topical issues, which also feature in the German government's High-Tech Strategy, including resource-efficient manufacturing, transportation and mobility, energy and housing, information and communication technologies (ICT), protection and security, as well as healthcare, nutrition and the environment.[7]

While it has not given rise to entirely new industries, Fraunhofer has enabled Germany to retain a leading position in its traditional industries over the very long run.

Key Figures and Facts

- At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units.
- The majority of over 25,000 staff are qualified scientists and engineers.
- 2.3 billion euros annual research budget totalling. Of this sum, almost 2 billion euros is generated through contract research.
- Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects.
- Affiliated international research centres and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development.

Origins and Constitution

The Fraunhofer Society was founded in Bavaria in 1949. Its initial focus was geological research, but this soon expanded to cover a much broader spectrum of disciplines with the support of public

[6] http://ec.europa.eu/eurostat/documents/2995521/8493770/9-01122017-AP-EN.pdf/94cc03d5-693b-4c1d-b5ca-8d32703591e7

[7] https://www.fraunhofer.de/content/dam/zv/en/Publications/Annual-Report/fraunhofer-annual-report-2016.pdf

procurement policies (Beise and Stahl, 1999; Mina et al., 2009). The Society relied heavily, for example, on the Ministry of Defence as its main contractor until 1968, when it was formally incorporated in the Federal Government research budgets (Beise and Stahl, 1999). Over the 1970s the defence budget fell sharply while the Max Plank Society, born also in the Post War period from the pre-existing Kaiser-Wilhelm Society, reinforced its shift away from applied research and strengthened its focus on basic science in cutting-edge areas broadly complementary to research conducted in university departments (Mina, et al. 2009; National Research Council, 2013).

Fraunhofer-Gesellschaft was founded as an *eingetrager Verein* (*e.V.*) or registered association as translated in English (Fraunhofer, 2010). Under the German law *e.V.* are legal entities, separated from its members, and it is meant for non-business activities. The register involves association's Statutes and minimum number of members (German Civil Code). As decided in its foundation, "the founding of a Fraunhofer Gesellschaft as a registered association, should represent a community of interests in various research centres and therefore also the Economic Commission" (Trischler et al., 1999). The association is a private entity, which currently receives funding from public and private research contracts. Fraunhofer's statutes were revised in 2010 (Fraunhofer, 2010). Below are summarised the main features:

- The registered address of the Organisation is Munich.
- The Organisation is listed in the official register of non-profit organisations.
- The objectives pursued by the organisation are exclusively and directly classified as "non-profit" under the terms of the relevant German tax legislation. The Organisations' resources may not be used for any other purpose than that prescribed in the Statute. Members shall not receive any payments from the funds of the corporate body; this does not apply to the provisions of 24, section 8.
- The Organisation's activities are of a socially beneficial nature; its primary function is not that of earning profits for its own benefit.
- No individual shall receive preferential treatment in the form of expenditure of a nature that does not comply with the purpose of the Organisation, nor in the form of excessively high remuneration.
- The fiscal year is the calendar year.

Aims and Objectives

Mission (From Guiding Principles of the Fraunhofer-Gesellschaft)

"Applied research is the foundation of our organization. We partner with companies to transform original ideas into innovations that benefit society and strengthen both the German and the European economy."

"Our employees shape the future – in ambitious positions at Fraunhofer or in other areas of science and business. Fraunhofer therefore places great importance on their professional and personal development."

Vision (From Guiding Principles of the Fraunhofer-Gesellschaft)

Fraunhofer is the international leader of applied research. As an innovation driver, we lead strategic initiatives to master future challenges and thus achieve technological breakthroughs.

Governance Structure

Although in a strictly legal sense the Fraunhofer **is not answerable to the German government**, given its dependency on government core funding and contract research, it is not surprising that its policies and practices tend to align with the priorities of the German federal government and, to a lesser extent, the EU authorities.

From an organisational point of view, an Assembly of Members of the Society elects the Senate. This appoints an Executive Board, which forms the Presidential Council with the elected Group Spokesmen. The Senate has responsibilities of strategy. A separate organ, the Policy Committee, supervises financial matters. A Scientific and Technical Advisory Board assists the Executive Board in decision-making, while external Boards of Trustees advise the Institutes. Each Institute is led by a Director and a Steering Committee. Directors often have joint appointments at local Universities (Mina, et al., 2009).

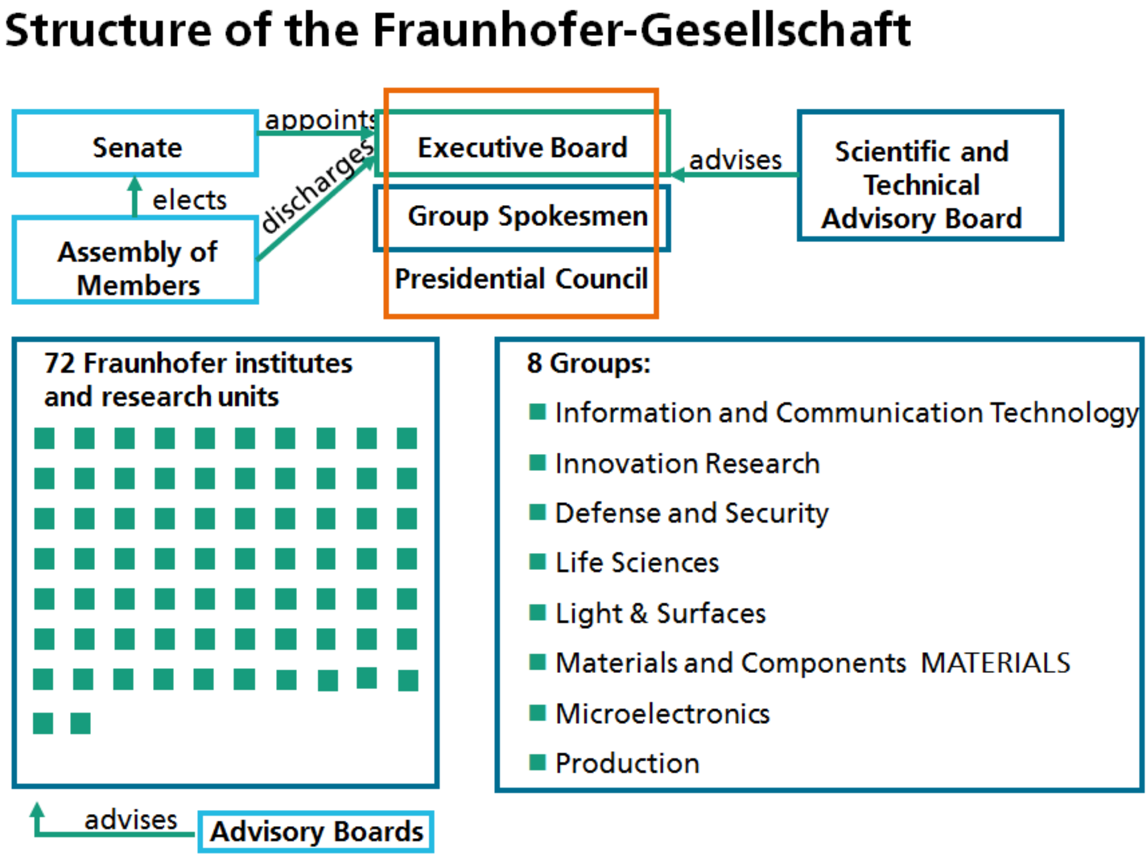


Figure 1 Fraunhofer-Gesellschaft Structure (Fraunhofer-Gesellschaft, https://www.fraunhofer.de/en/about-fraunhofer/profile-structure/structure-organization.html)

- The General Assembly
  - The General Assembly is made up of the member of the Organisation. Each member has one vote. Legal entities may exercise their membership rights through an elected representative with written power of attorney.
  - An Ordinary General Assembly shall be held at least once a year. An Extraordinary General Assembly may be convoked at the request of the Executive Board, the Senate, or by a vote carried by one fourth of the members.
  - The General Assembly is convoked and chaired by the President.
  - The General Assembly is deemed to be carried out regardless of the number of members present.
- The Senate (approx. 30 members)
  - up to 18 members elected from the fields of science, business and industry, and public life.
  - a total of seven members delegated by government institutions: four representing national government and three representing the Länder. The Länder are free to decide which three Länder shall each send a representative for a term of office likewise chosen by themselves.
  - Three members selected among the persons serving on the Scientific and Technical Council.

  The Senate is responsible for decisions concerning:

  a) the basic scientific and research policy of the Organisation and the planning of its research activities and expansion;

  b) the establishment, the incorporation or devolution, the merger and dissolution of research entities belonging to the Organisation. The interests of public-sector sponsors shall be respected in any decisions related to the dissolution or merger of Organisation research entities.

  c) any amendments or revisions to the procedural guidelines as defined in §22, section 1 and to the voting procedures as defined in §24, section 4 of this Statute;

  d) any amendments or revisions to the general provisions of the Institutes' Statute as defined in §20, section 3 of this Statute;

  e) medium- and long-term financial plans and the establishment of the budget;

  f) the annual statement of accounts to be presented to the General Assembly;

  g) the acceptance of new members (§4, section 2) and the exclusion of existing members (§7, section 3).

- Executive Board
  - The Executive Board is composed of the President and up to four other full-time members. Two members of the executive board must be qualified scientists or engineers. One member must be experienced or well versed in business management

practices. One member must possess qualifications equivalent to those required for employment at a senior level in the civil service.

- As a general rule, the members of the Executive Board are appointed for a term of five years. Re-appointment is permissible.

Responsibilities of the Executive Board:

- Elaborate the basic premises of the Organisation's science and research policy and draw up its research, expansion and financial plans in collaboration with the Scientific and Technical Council and the Group Chairmen represented by the Presidential Council.
- The Executive Board shall set up governing boards for the Institutes and, where appropriate, for similar institutions. The governing boards shall be composed of representatives of science, industry, business and public life. They shall act as advisors to the Directors of the Institutes and the constituent bodies of the Organisation. Their more concrete functions shall be determined by the Institutes' Statute.

Infrastructure

Location, Facilities and Capability[8]

Fraunhofer is comprised of 72 institutes and research units distributed around the countries' geographic space. A number of individual institutes operate facilities in multiple locations. Example, the Fraunhofer for Material and Beam Technology IWS operates facilities at Dresden, Dortmund, Wroclaw in Poland and East Lansing and Plymouth in Michigan.

The Fraunhofer is responsible for establishing innovation clusters throughout Germany and is currently pursuing 19 cluster initiatives, each of which usually involves one or more Fraunhofer institutes, a local university, and an array of small, medium, and large industrial partners.

The Fraunhofer Institutes in German universities play an important role in connecting university research to industrial development. Each Fraunhofer is an applied research institute at a German university, directed by a chaired German professor, who also directs a basic research institute. The applied research institutes are funded by the Fraunhofer Society, and the basic research institutes are funded by the Max Planck Society. Both societies received funding by the German government.

Applied research focuses upon advancing technology, and basic research focuses upon advancing science. The Fraunhofer Society funds research projects in German universities to advance technology, and the Max Planck society funds research projects in German universities to advance science. Together, these agencies implement the science and technology policy of the German government. Each chaired German professor in engineering may direct two research institutes, applied and basic. The Fraunhofer Institute of a German professor is focused in advancing

[8] Data mainly collected from the Fraunhofer's Annual Report 2016 and Fraunhofer website https://www.fraunhofer.de

technology by connected the basic research of science to the applied research of technology (Betz et al., 2016).

Fraunhofer employs a range of instruments to develop new thematic areas from the basic research stage (Technology Readiness Level TRL 2) to pilot applications (TRL 8). They extend from support for high-risk ideas to the exploitation of intellectual property rights and the creation of new lines of business spanning several institutes. In this context, networking and cooperation among institutes plays an increasingly vital role. Fraunhofer is planning to set up what it calls Fraunhofer Research Clusters, in which several Fraunhofer Institutes work together according to a shared roadmap on a technology with disruptive potential. The Fraunhofer Research Clusters will provide structured interfaces for interdisciplinary collaboration and release synergy effects enabling system-related innovations to be developed efficiently.

Total expenditure went down from the year 2007 after rising significantly between 2006 and 2007 because of capacity expansion through new investments in infrastructure and staff. Significant investments were made in Dresden (Institute for Photonic Microsystems IPMS, €19m), Erlangen (Institute for Integrated Circuits, €17m) and in Leipzig (Institute for Cell Therapy and Immunology IZI, €10m).

The Fraunhofer-Gesellschaft's structural growth is based on the continuous expansion of the Fraunhofer Institutes, the integration of external research institutions and the creation of new project groups. As a rule, project groups are initially established for a duration of five years. At the end of this transitional period, their performance is evaluated to determine whether they are eligible for support according to the Fraunhofer funding model, which entitles them to base funding by the federal and state governments in a ratio of 90:10. A critical consideration in this evaluation is whether the entity's competency profile is a strategic fit with Fraunhofer's existing R&D portfolio. In addition, it must be ensured that adequate resources can be made available under the Fraunhofer model (including additional base funding) to cover the project group's medium-term funding requirements. Five new projects groups passed this evaluation test in 2016:

1. The Fraunhofer Project Group for Personalised Tumour Therapy, at Fraunhofer ITEM in Regensburg – The ATZ Development Centre.
2. Energy, resources, materials, at Fraunhofer UMSICHT in Sulzbach-Rosenberg.
3. The Project Group for Processing Technologies in Lightweight Construction, at Fraunhofer IPA in Stuttgart.
4. Integration of the former German Plastics Institute (DKI) as a new branch of Fraunhofer LBF in Darmstadt.
5. The Project Group for Components and Systems Design of Electrical Energy Storage Systems, at Fraunhofer IFAM in Oldenburg.

All five project groups are now eligible for base funding, split between the federal and state governments in a ratio of 90:10. Fraunhofer also established two new Fraunhofer Institutes and one new Fraunhofer Research Institution in 2016, all three of which were derived from positively evaluated project groups or institute departments.

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS based in Halle (Saale) became an independent entity on January 1, 2016, due to the successful results of the Halle branch of the Fraunhofer Institute for Mechanics of Materials IWM. The creation of Fraunhofer IMWS gives added strength to the Fraunhofer Group for Materials and Components – MATERIALS and the new institute has already joined numerous Fraunhofer Alliances.

The Cyber Security Learning Lab created in 2016 with BMBF support is a significant addition to Fraunhofer's research-based training activities in an area of technology of vital importance to the future of industry and society. It is operated by the Fraunhofer Academy in cooperation with selected universities of applied sciences and offers managers and other professionals practice-oriented training in IT security based on the latest research findings. This support enables companies and public bodies to embrace the opportunities offered by digitalisation without taking unnecessary risks. Training is provided in ultramodern laboratories equipped with the latest IT infrastructure, and comprises separate modules dealing with specific industries, security issues, and security functions.

The Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV was established in July 2016, with twin sites in Augsburg and Garching. Fraunhofer IGCV was formed by merging the Functional Lightweight Design (FIL) branch of the Fraunhofer Institute for Chemical Technology ICT, the Project Group for Resource-efficient Mechatronic Processing Machines (RMV), formerly a part of the Fraunhofer Institute for Machine Tools and Forming Technology IWU, and the Working Group on Metal Forming and Casting at the Technical University of Munich (TUM).

The Fraunhofer Institute for Mechatronic Systems Design IEM in Paderborn, founded on January 1, 2017, is a perfect example of the emergence of an institute from a project group. It started out in 2011 as a project group at the Fraunhofer Institute for Production Technology IPT and five years later obtained the status of a Fraunhofer Research Institution. Now, another year later, it has been recognised as a full-fledged Fraunhofer Institute.

Funding

The Fraunhofer Model

The Fraunhofer-Gesellschaft funding is based on a three-pillar model. A base funding is provided by the German federal and state governments, usually contributing approximately a third part of the total; a second pillar is based on public competitive funds; and a third is contributed by the private sector. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Under this model, the German government co-funds the Fraunhofer Institutes as a permanent programme, so Fraunhofer-Gesellschaft is not intended to be self-sustainable after initial government-level support.

The annual research budget for 2016 totalled 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. During 2016 the base governmental funding increased in €67 million, restoring the 70:30 balance prescribed by the Fraunhofer model.

Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

Customers and contractual partners are:

- Industry
- Service sector
- Public administration

Key financial figures:

- 2.3 billion euros annual research budget totalling. Of this sum, almost 2 billion euros is generated through contract research (Figure 2

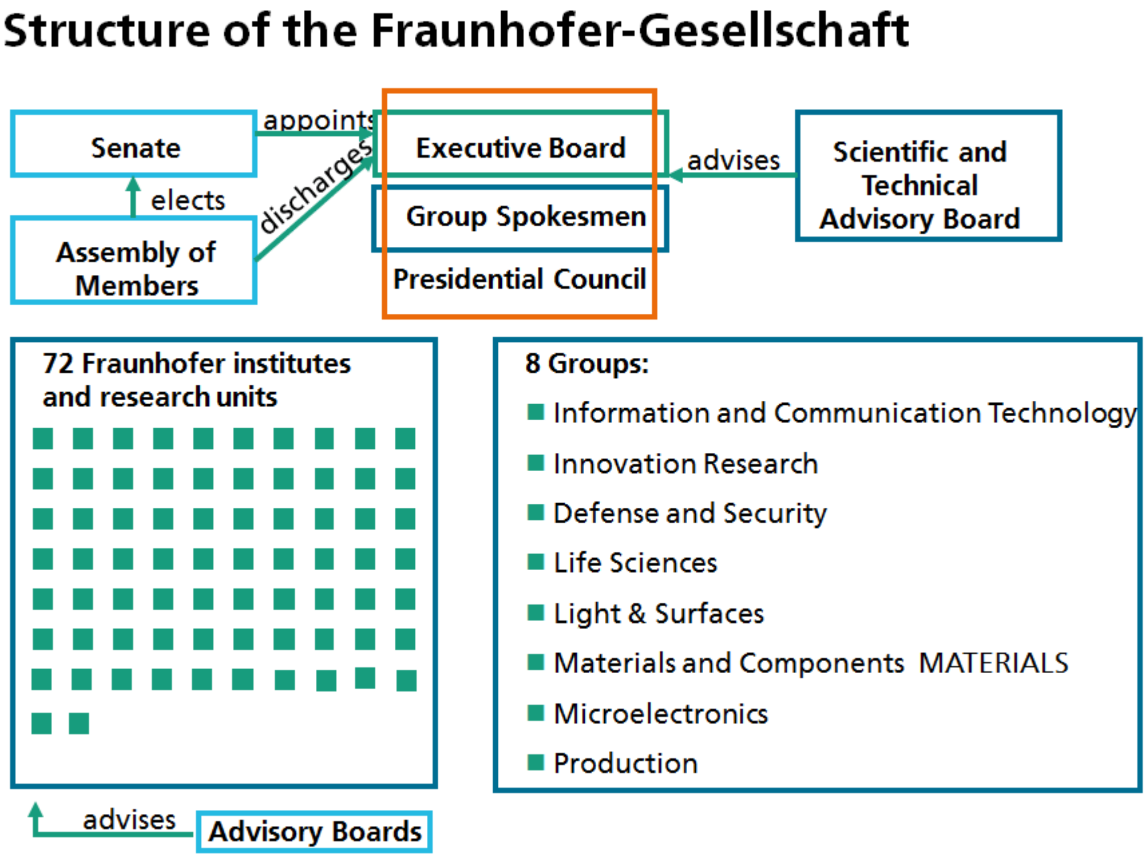
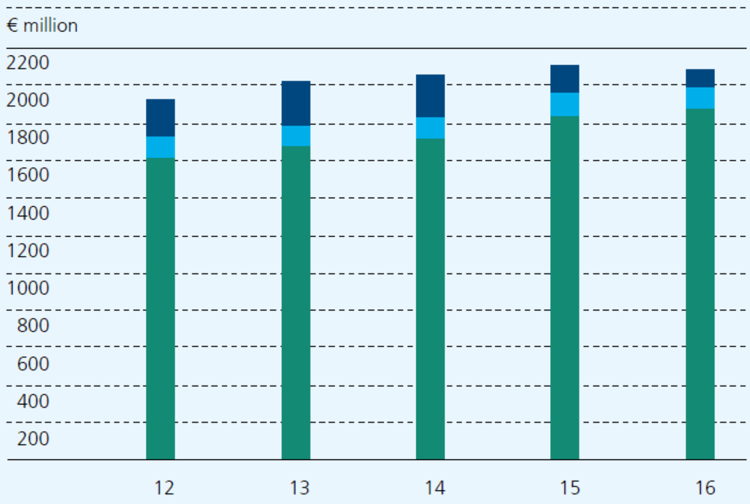


Figure 1).

- Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects (Figure 3).
- Affiliated international research centres and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development (Figure 4).

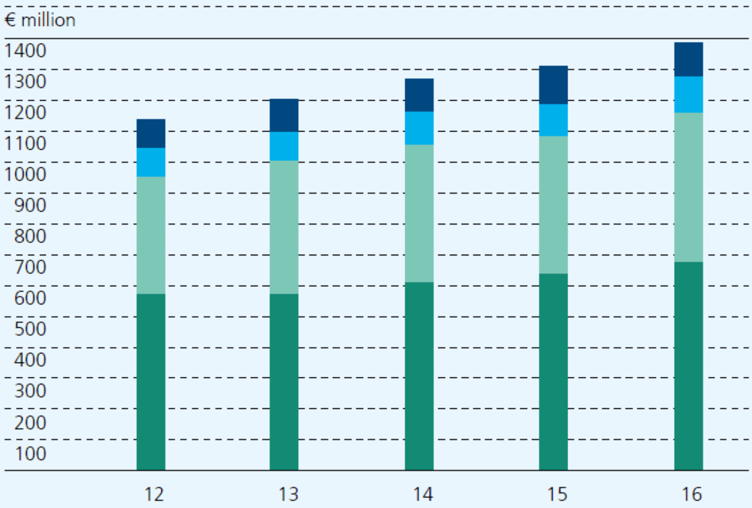
The Fraunhofer-Gesellschaft's total business volume 2012–2016



	2012	2013	2014	2015	2016
Major infrastructure capital expenditure	199	235	226	153	88
Defense research	113	114	118	127	114
Contract research	1614	1661	1716	1835	1879
= **Total business volume in € million**	**1926**	**2010**	**2060**	**2115**	**2081**

Figure 2 The Fraunhofer-Gesellschaft's total business volume during the period 2012 -2016. (https://www.fraunhofer.de/en/about-fraunhofer/profile-structure/facts-and-figures/finances/total-business-volume.html)

Revenue and expenditure in the contract research segment 2012–2016

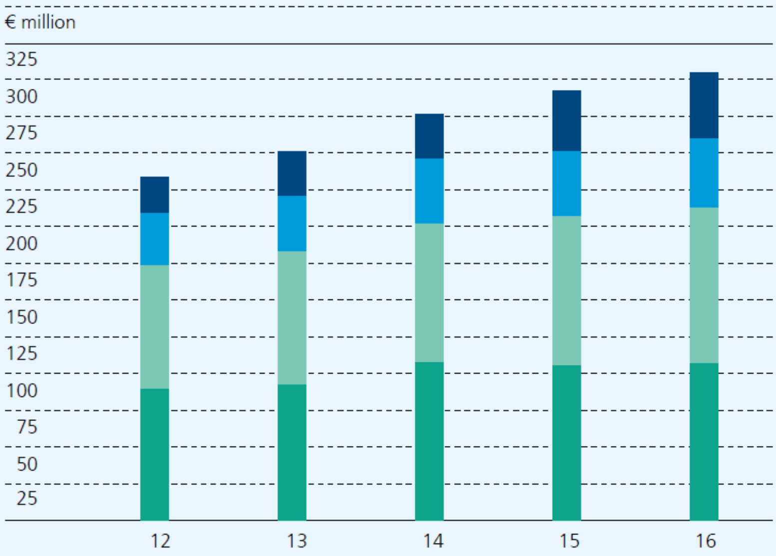


	2012	2013	2014	2015	2016
Project revenue	**1137**	**1200**	**1272**	**1305**	**1386**
■ Other revenue	97	99	103	118	111
■ EU revenue (European Commission)	88	92	106	105	106
■ Public-sector revenue (German federal and state governments)	382	431	445	441	487
■ Industrial revenue	570	578	618	641	682
Funding requirements[1]	**477**	**461**	**444**	**530**	**493**
= **Total revenue in € million**	**1614**	**1661**	**1716**	**1835**	**1879**
Personnel expenses	868	945	1021	1066	1118
Non-personnel expenses	543	549	556	580	591
Change in special reserve for license-fee revenue and allocation to foundation capital	52	0	–15	29	41
Capital expenditure	151	167	154	160	129
= **Total expenditure in million**	**1614**	**1661**	**1716**	**1835**	**1879**

1 In 2012 and 2013, this item included the transfer of funds from Fraunhofer reserves.

Figure 3 Fraunhofer-Gesellschaft's contract research segment: revenue and expenditure period 2012 to 2016 (https://www.fraunhofer.de/en/about-fraunhofer/profile-structure/facts-and-figures/finances/contract-research-revenue.html)

Revenue from work with international customers and partners 2012–2016



	2012	2013	2014	2015	2016
Asia	24	29	30	40	44
North and South America	35	38	44	44	47
European countries	84	90	94	101	106
EU revenue (European Commission)	88	92	106	105	106
Other countries	2	1	2	1	1
= **Total international revenue[1] in € million**	**233**	**250**	**276**	**291**	**304**

1 Includes revenue generated by international subsidiaries with third parties, which amounted to €29 million in 2016.

Figure 4 Fraunhofer-Gesellschaft's revenue from international customers during the period 2012 - 2016 (https://www.fraunhofer.de/en/about-fraunhofer/profile-structure/facts-and-figures/finances/international-revenue.html)

Risk Management in Access to Public and Private Funding

Public Fund Access

It is important to emphasise that Fraunhofer is constituted as a society, independent from public administration and, as a not-for-profit organisation and beneficiary of public funds, Fraunhofer keeps a close eye on changes in legislation and taxation that might affect its access to financial support and continuously evaluates these changes with respect to their possible impact on the financing of its activities. Fraunhofer maintains an ongoing dialog with the funding agencies at federal, state and EU level and, if necessary, makes the appropriate amendments to its funding model to ensure that it remains in conformity with current funding legislation.

Base funding by the German federal and state governments is one of the three main pillars of the organisation's financial security. To counter the risk of a possible decline in the proportion of base funding relative to total spending requirements, Fraunhofer applies a strategy of forward-looking growth management combined with lobbying to maintain its institutional funding at a level in keeping with its mission and in proportion to its performance.

Fraunhofer's access to public-sector project funding is affected by changes in the supported thematic areas of research and the available funding instruments, for instance in the case of the European Framework Programme. A loss of income can also result from changes in funding regulations or a disadvantageous interpretation of such regulations. By carrying out frequent audits and continuously improving its cost management processes, the Fraunhofer-Gesellschaft ensures that it meets the requirements for the reimbursement of incurred expenses and negotiates with the relevant European and national bodies to obtain their approval of the costing models Fraunhofer applies.

Private Fund Access

Fraunhofer counters the risk of a possible decline in its project revenue from industrial research contracts by developing new areas of research and collaboration models geared to market requirements and through the strategic expansion of its customer acquisition and loyalty activities, especially at a cross-institute level.

Systematic checks by the central controlling department are used to keep track of the spending and earnings of individual institutes. Regular comparisons of each institute's results with respect to its annual targets permit the identification of downward trends, enabling the necessary countermeasures to be developed and implemented in good time.

Intellectual Property Rights (IPR) and Related Activities

IPR

The Fraunhofer appropriates new knowledge via patenting whenever the process of contract research generates results which not only solve a technical problem on the basis of existing know-how but have been produced with a substantial contribution by Fraunhofer staff and are deemed to have potential commercial value in their own right (Fraunhofer, 2016). An industry partner may receive an exclusive license from the institute, but only for the particular application that was the target of the research (NAP).

Co-operative agreements include non-exclusive rights and royalty-free use of know-how by clients, which become royalty-bearing when key patents underpin commercial developments, for both foreground and background IP.

Intellectual Property (IP) Activities

- More than three invention disclosures per working day
- More than two patent applications every working day
- Fraunhofer among the Top 100 Global Innovators
- Fraunhofer employees submitted 798 invention disclosure reports in 2016. Of these, 608 were filed with the relevant patent offices as patent applications claiming rights of priority, which corresponds to a rate of more than two patents filed per working day.
- Fraunhofer's portfolio of active patents and utility models and pending patent applications rose again in 2016 to 6762 patent families.

- The total number of newly registered German patents granted to Fraunhofer increased to 3114.
- Fraunhofer signed 401 new licensing agreements in 2016, raising the total number of active licensing agreements to 3210.
- License-fee revenue increased in 2016 by 4 percent compared with the previous year, to €143 million.

IP Portfolio Exploitation Process

To guarantee a continuous flow of revenue from the exploitation of intellectual property rights, patents owned by different institutes are increasingly being grouped together in application-specific portfolios to create offers for selected companies. This approach creates new opportunities for generating income from licensing agreements and R&D projects. The process was preceded by an evaluation of the earnings potential of the technologies concerned and the possible volume of contracts.

Services Provided

Contract research for industry and government

- Contract research is the most important business field of the Fraunhofer-Gesellschaft. Its range of services focuses on the needs of industry (any sizes) as well as of government and society.
- The Fraunhofer-Gesellschaft develops solutions of direct practicable value to technical and organisational problems and contributes to the wide-scale implementation of new technologies.
- The Fraunhofer-Gesellschaft represents an important source of innovative know-how for small and medium-sized companies that do not maintain their own R&D departments. For industrial customers Fraunhofer develops and optimises technologies, processes and products right up to the production of prototypes and small batch series.

Studies / analyses

Fraunhofer advises contractual partners, prior to research cooperation, through:

- Custom-designed studies
- Feasibility and acceptance studies
- Market observations
- Trend analyses
- Life-cycle analyses
- Profitability calculations
- Authorisation studies and clinical test patterns
- Examination and evaluation of chemicals
- Innovative screening methods

Advice / support

Fraunhofer supports its customers in introducing new organisational forms and technologies into their business. This includes:

- Testing in demonstration centres with the most up-to-date instrumentation
- Training of participating employees on site
- Services during and after the introduction of new processes and products
- Usability services, e.g. evaluation of software and web applications, online services, eCommerce or eCRM and hardware; usability engineering; consulting and planning of user orientated development processes.

Inspection / certification

As part of Research and development services customers can also access the services of accredited test laboratories and receive verification for adherence to obligatory standards.

External Reviews: Challenges and/or Recommendations

Despite its established role in the German innovation system the Fraunhofer model has had its problems and its critics.

- A model of research based on contract tends to be responsive to existing market needs and is more suited to react to technology trends than to anticipate them. This implies a focus on sectors that have traditionally been strong in the German economy to the possible detriment of emerging sectors (see Harding, 2002).
- Interestingly, the Fraunhofer has not figured prominently in biotechnology research, an opportunity that has arguably been better exploited by the Max Planck, at least until the recent cross-organisational alliances between the two institutions in this area.
- In terms of new products and new process technologies, the Fraunhofer model has often been said to privilege incremental innovation over radical breakthroughs.

Although sometimes criticised for being too bureaucratic, the Fraunhofer lets its institutes establish their own research strategies, build relationships with industry, and spend their money with little interference from headquarters. Beside the dominant mode of funding (contract) other co-determinants might include some degree of organisational rigidity, the stronger emphasis of top-down over bottom-up approaches and the fundamental not-for-profit status of the Society. Margins do exist to allow for – arguably slow – evolutionary change within the organisation and new institutes can be founded while other decay or merge with others. Moreover, new channels have been introduced to favour bottom-up approaches to the exploitation of research and commercialisation opportunities.

THE UK CATAPULTS MODEL

Britain's Catapult initiative, launched in 2011, seeks to capitalise on the country's superb capabilities in basic science. The concept underlying Catapult is that the initiative will pick a few thematic areas where British science is strong and where an industrial capability exists in Britain to commercialise the fruits of that science. The effort will be limited to sectors where major and rapidly growing global markets are expected to exist in the future. The role of the Catapult centres will be to serve as an intermediary between Britain's science base and British companies. Like Germany's Fraunhofer and Taiwan's ITRI, the Catapults will perform contract research for companies to turn scientific ideas into products and industrial processes.

From the Hauser's report 2010:

> ***'…It calls for the UK to make choices and focus its attention on developing such a capability for platform technologies only where:***
>
> - ***there are large global markets worth billions of pounds per annum; /with a national strategy***
> - ***the UK has technical leadership;***
> - ***there is a defensible technology position;***
> - ***and, there is capacity to anchor a significant part of the value chain, from research to manufacturing, in the UK…'***
>
> **'The Current and Future Role of Technology and Innovation Centres in the UK', H. Hauser (2010)**

Key Figures and Facts

- At present there are 10 Catapult centres distributed across the UK.
- The Catapults receive funding from Government, as 'core' funding, through Innovate UK to develop and maintain their internal capability and infrastructure.
- They have been traditionally funded with £50m per new Catapult across five years, with a 'flat' funding profile of £10m per annum.
- After five years, the Catapult must apply for its grant to be renewed subject to approval of a business plan for the subsequent five years (Ernst & Young, 2017).
- Catapults operate facilities worth £850m (Catapult, 2017).
- According to the annual report 2017 (Catapults, 2017), Catapults have delivered 636 academic collaborations, supported 2,851 SMEs and created 2,473 industry collaborations.

Origins and Constitution

The perceived failure of the UK to exploit effectively its science and technology base has been the subject of hand-wringing by politicians and policy specialists for nearly a century and government efforts to remedy this have been redoubled over the last fifteen years. A key feature of recent policies has been the creation of a third mission for universities alongside research and teaching, and increasing pressure on them and the research councils that fund them, to direct more research towards societal and industrial needs and to collaborate more closely with business (Mina et al., 2009).

In 2010, the Department of Business, Innovation and Skills (BIS) commissioned to Dr Hermann Hauser, a successful serial entrepreneur and investor of the Cambridge cluster, a review of the role of technology and innovation centres in the effective translation process of research to industrial application (Hauser, 2010).

Hauser proposed the creation of a network of Technology and Innovation Centres or TICs, based on the evidence of international translational infrastructure. Along with this proposal, Hauser included a series of recommendation urged to be implemented by the UK Government.

As a result of Hauser's report, in 2010 the Government decided to establish the network of TICs called 'Catapults' to commercialise new and emerging technologies in areas where there are large global market opportunities and a critical mass of UK capability. To-date 10 Catapults have been established, each one specialist in a different area of technology, being the first the High Value Manufacturing (HVM) Catapult (launched in 2011).

Each Catapult centre is a company limited by guarantee (CLG), a separate legal entity from Innovate UK, the UK's governmental innovation agency, sponsored by the Department of Business, Energy and Industrial Strategy (BEIS). They are a not-for-profit research organisation and act as a neutral, trusted entry point to an entire network of UK expertise in applications development across government, academia and industry. The Catapults operate as private sector organisations at arm's-length from IUK, though established and overseen by Innovate UK. This was configured to ensure that the Catapults respond to the needs of UK businesses and address the challenges and opportunities facing the sectors in which they operate (Ernst & Young, 2017).

Aims and Objectives

Agreeing with the findings of Ernst & Young (Ernst & Young, 2017) it is not easy to clearly identify the aims and objectives of the Catapult network as a whole. By revising several governmental documents and the websites of the catapults, it is possible to extract that:

- The Catapult centres were established to commercialise new and emerging technologies in areas where there are large global market opportunities and a critical mass of UK capability[9].

- They are expected to transform the UK's capability for innovation in specific areas and help drive future economic growth.

9

- They were expected to provide access to infrastructure, expertise and capabilities that are generally not available in the market and bring together business, academia, research and Government to transform innovative ideas into new products and services to generate economic growth in the UK.

- Connecting business and research: Catapults are not-for-profit, independent physical centres which connect businesses with the UK's research and academic communities. Each Catapult centre specialises in a different area of technology, but all offer a space with the facilities and expertise to enable businesses and researchers to collaboratively solve key problems and develop new products and services on a commercial scale.

Mission and Vision

There is not found a clear general mission and vision statements that applied to all the Catapults network as a whole. A vision statement is only found in the TBS report 'Catapult Network Launching your ideas with the UK's new centres for innovation' (TBS, 2013):

'The Catapult vision is to bridge the gap between these ambitious businesses and the expertise of the UK's world-class research communities.'

Revising each Catapult centre, they defined their own mission and vision. Also, in some cases, statements include their services provided, or how the proposed to achieve both, mission and vision. Some examples as follow:

HVM: "The HVM Catapult is the catalyst for the future growth and success of manufacturing in the UK. We help accelerate new concepts to commercial reality and thereby create a sustainable high value manufacturing future for this country."

Satellite: "To innovate for a better world, empowered by satellites"

CGTC: "Our mission is to grow the industry in the UK to substantial and sustainable levels by:

- taking products into clinical trial, de-risking them for further investment;
- providing clinical expertise and access to NHS clinical partners;
- providing technical expertise and infrastructure to ensure products can be made to GMP and delivered cost effectively;
- providing regulatory expertise to ensure that products can get to the clinic safely, in the shortest amount of time;
- providing opportunities for collaboration, both nationally and globally; and
- providing access to business expertise, grants and investment finance so that commercially viable products are progressed and investable propositions are generated."

Governance Structure

Governance

The Catapults were set up as independent research and technology organisations, established and overseen by Innovate UK, though structured to operate as private sector organisations at arm's-length from Innovate UK.

As a private sector classification was designed to enable the Catapults to:

- Maintain a neutral status across industry
- Act in an agile, responsive and flexible way, driven by a commercial mind-set
- Attract talented leadership and highly qualified expert staff to support industry
- Be trusted with IP and commercially sensitive information
- Avoid the constraints and administrative costs faced by public organisations

This private classification means that:

- Innovate UK is unable to take up formal representation on Catapult boards and is restricted to having only an observer type role.
- Innovate UK is unable to be prescriptive about Catapult board appointments.
- As pointed out in the EY report (EY, 2017) this classification can also create some tensions between the private and public-sector culture, e.g., when Catapults are asked to deliver for Government, report on performance or comply with government accounting rules.

Each Catapult centre are controlled by their own Boards with an Executive Management team responsible for the day-to-day management of each Catapult[10]. Some examples are summarised below.

Case of Satellite Catapult

- The company is controlled by an independent Board comprising the Chair, Chief Executive Officer, Chief Financial and Operating Officer, and six Non-Executive Directors (NEDs).
- The UK Space Agency and Innovate UK have representatives on the Board.
- The Board is responsible for devising the company's strategy, approving the annual budget, signing off the financial statements, making significant investment decisions, and setting the limits and delegated authorities for expenditure.
- There are two sub-committees to support the Board: a remuneration committee and an audit committee. These are made up of NEDs who meet regularly during the year and make recommendations to the Board.
- In addition, there is an Advisory Group whose purpose is to bring together industrial, public and academic representatives to interact with the Board.
- An Executive Management Team consisting of the CEO and other senior personnel (CFO/COO, Chief Technical Officer, and Chief Innovation Officer) is responsible for the day-to-day management of the Catapult.

Case of Centre for Process Innovation[11] (one of the seven centres that conform HVM Catapult)

Centre for Process Innovation (CPI) is driven by an independent, business-led Board and which includes representatives from academia. The Board and the CPI Executive management team are assisted by a company technology advisory committee (TAC) and each technology area is advised by specific technology and innovation advisory groups (TIAGs). The TAC and the TIAGs are independent

[10] https://catapult.org.uk/about-us/funding/

[11] As it will be described later, CPI is one of the seven that conformed HVM Catapult, and one of the first to be included in the Catapult network implementation plan.

advisory groups comprising recognised expert representatives from industry, academia and the public sector. This approach ensures CPI is being advised by the best.

CPI creates partnerships between public organisations, academia and private industry to deliver capability not available to any individual organisation. This is delivered by a team of 120 highly qualified scientists, engineers and other staff, who have extensive management, project management and commercial experience.

Infrastructure

Location, Facilities and Capacity

Catapults centres are a series of physical centres where the very best of the UK's businesses, scientists and engineers work side by side on late-stage research and development – transforming high potential ideas into new products and services to generate economic growth. Each Catapult centre specialises in a different area of technology, but all offer a space with the facilities and expertise to enable businesses and researchers to collaboratively solve key problems and develop new products and services on a commercial scale.

The Catapult network is comprised of a number of centres that are distributed around the respective countries' geographic space. A number of such institutes operate facilities in multiple locations. Such is the case of the UK's High Value Manufacturing Catapult, which operates sites at Bristol, Manchester, Sheffield, Coventry, and Glasgow.

The Centres' facilities are made up either of existing facilities or new physical infrastructure as part of the Catapults implementation plan. Examples of existing facility are the five founding centres of HMV, each linked with a university and serving local industrial customers (NAP), such as the Centre for Process Innovation (CPI). CPI was founded in 2004 as part of a regional funding and regional innovation plan of North East England (Goddard, et al, 2012). Established to support the UK process manufacturing industry, CPI collaborates with universities, SMEs and large corporates to help overcome innovation challenges and develop next generation products and processes. CPI supports a sector which currently exports almost £50bn a year with a contribution of over £15b a year to the UK's Gross Domestic Product[12]. CPI business model has already delivered substantial benefit because it links the needs of business to CPI assets and technology expertise. The demonstrated success of CPI and its important expertise and role in the regional economy, determined its involvement in the Catapult network, as one of the centres of HVM.

As stated in the last Catapult report of 2017 (Catapult, 2017), Catapults operate facilities worth £850m providing open access to state of the art resource and expert support beyond the means of all but the biggest companies. Some also help apprentices get 'hands on' with the latest technologies, anchoring key skills here.

There are 10 Catapult Centres:

[12] UK Chemical and Pharmaceutical Industry Facts and Figures, Chemical Industries Association, 2015.

- Cell and Gene Therapy (CGTC): Based in Guy's Hospital in central London, the Cell and Gene Therapy Catapult has over 120 cell and gene therapy experts with state-of-the-art development and viral vector laboratories. According to EY report (Ernst & Young, 2017) CGTC is one of the only two centres (together with HVM) to demonstrate a positive economic impact.
- Compound semiconductor Applications: Based in South Wales, The Compound Semiconductor Applications Catapult is a world-class, open access research and development facility to help businesses exploit advances in compound semiconductor technologies across key application areas such as healthcare, the digital economy, energy, transport, defence and security, and space.
- Digital: The Digital Catapult is based on Euston Road, London and has centres in Sunderland, Northern Ireland, Brighton and Yorkshire. The Catapult currently focuses on two sectors, digital manufacturing and creative industries, alongside exploring opportunities in digital health and care. The Catapult works across a range of technology layers including data driven, connectivity, artificial intelligence and immersive interfaces.
- Energy Systems: Based in Birmingham, Energy Systems aims to build a consensus on the transition pathways to a future energy system and develop a vision for a clean, intelligent, energy system that works for people, communities and businesses.
- Future Cities: The Future Cities focuses on advancing urban innovation to make cities better. Based in London at their Urban Innovation Centre, the Catapult helps innovators turn ideas into working prototypes that can be tested in real urban settings. In addition, the Cities Lab provides data analysis, modelling and visualisation capabilities to understand city problems. The Catapult focuses on three core themes: integrated urban infrastructure, healthy cities and urban mobility.
- High Value Manufacturing: Consisting of seven centres across the United Kingdom, including a significant presence in the Midlands and North of England, HVM focuses on being a catalyst for future growth and success of manufacturing in the UK. The seven centres combine to create a sustainable high value manufacturing future for the United Kingdom. According to EY report, HVM is one of the only two centres to demonstrate a positive economic impact.
- Medicines Discovery: Housing 10,000 square feet of laboratory and collaboration facilities at their Alderley Park Headquarters in Cheshire, the Medicines Discovery Catapult works to develop approaches for the discovery and early development of new medicines.
- Offshore Renewable Energy: Based across three sites in Glasgow, Blyth and Levenmouth respectively, The Offshore Renewable Energy Catapult has a flagship technology and research centre for advancing wind, wave and tidal energy.
- Satellite Applications: Based in Harwell, near Didcot, the Satellite Applications Catapult helps organisations make use and benefit from pioneering satellite technologies and seeks to help fulfil the UK's ambition to increase its share of the global space market to 10%. The Catapult's mission is to place the UK at the heart of the ongoing revolution in satellite services.
- Transport Systems: Working from a headquarters in Milton Keynes, the Transport Systems Catapult seeks to enhance the use of Intelligent Mobility, using emerging technologies to enable smarter, greener and more efficient movement of people and good. The Catapult

aims to tackle wider societal challenges such as a growing and ageing population, climate change, depletion of traditional energy resources, and increasing urbanisation. Transport Systems was responsible for the first demonstration of an autonomous driving vehicle in the United Kingdom in October 2016.

Funding Model

The centres gain their funds from a mix of competitively earned commercial funding and core Innovate UK investment. The funding model will vary through the life of the technology and innovation centre, and can be expressed in simplified terms as following the one-third, one-third, one-third model. Under this model, centres are required (when fully established) to generate their funding broadly equally from three sources: business-funded R&D contracts, won competitively collaborative applied R&D projects, funded jointly by the public and private sectors, also won competitively core public funding for long-term investment in infrastructure, expertise and skills development (https://catapult.org.uk/about-us/funding/).

Figure 5 Catapult Funding Model (https://catapult.org.uk/about-us/funding/)

1. 33% Core public funding from UK Government, through Innovate UK, the Government's Innovation Agency
2. 33% Business Funded R&D Contracts
3. 33% Competitively won Collaborative R&D (CR&D)Projects, which tend to be funded from a mix of public and private sources

The funding is used to resource their business offer in terms of:

4. Maintaining world-class manufacturing capability both in terms of hardware and human capital
5. Undertaking specific feasibility studies to explore technology innovation opportunities
6. Developing and delivering Collaborative R&D project proposals

Catapults do not provide grants or loans[13].

The Catapults receive funding from Government ('core' funding) through Innovate UK to develop and maintain their internal capability and infrastructure. They have been traditionally funded with

[13] https://hvm.catapult.org.uk/about-us/what-is-a-catapult/funding/

£50mn per new Catapult across five years, with a 'flat' funding profile of £10mn per annum. After five years, the Catapult must apply for its grant to be renewed subject to approval of a business plan for the subsequent five years. Currently, seven Catapults are in the renewal stage, following completion of their first five years of operation:

Longer established Catapults	Date operational
High Value Manufacturing (HVMC) (seven centres)	October 2011
Cell and Gene Therapy (CGTC)	October 2012
Satellite Applications (SAC)	December 2012
Offshore Renewable Energy (OREC)	March 2013
Digital (DC)	June 2013
Future Cities (FCC)	June 2013
Transport Systems (TSC)	August 2013

Table 2 Longer established Catapults, in process of renewal. Source 'Catapult Network Review', EY (2017).

Services Provided

Catapults offer a space with the facilities and expertise to enable businesses and research to collaborate and develop new products and services on a commercial scale. Though each Catapult defines their services based on their technology specialty, in general the services provided include (TBS, 2013):

- development and research capability
- technical expertise and access to cutting-edge specialist equipment
- expertise in accreditation and approval of regulatory and technical requirements
- advice on taking ideas and product to market, developing supply chains and scaling businesses
- access to people and organisations who are working on common challenges in the same area
- help with accessing funding

Specific examples of services provided by some relevant Catapult centres are mentioned below:

Case of CPI of HVM

CPI has national technology centres in Printable Electronics, Industrial Biotechnology and Biologics. A new centre on Formulation is currently under construction. These develop processes form laboratory concepts through prototyping facilities and pilot plants into commercially implementable processes and products.

The CPI method is to:

- Carry out market analysis together with businesses or partners that have defined technology or market need.
- Set-up a team of technology, market and commercial professionals to design a set of assets that can be used to develop a range of technologies which meet the market need.
- Find a combination of private and public investment to build and operate the development assets.

- Private companies – both SME and large companies – then use the assets and CPI expertise to prove, develop and scale-up their technology to at least TRL 7.
- Companies then invest their own funds to take the technology to market and create value.
- The development assets are retained and developed by CPI for use by other companies and projects to build a UK capability in the sector.

CPI is the only open access centre of its kind in the UK with such an extensive combination of equipment and specialist knowledge. CPI has designed an environment that fits the needs of companies whatever their size and demands, and consistently delivers customers' requirements, on time and to budget.

CPI has a growing asset base of £55m, which is available to companies that want to develop new products and processes on an open access, low risk basis. According to CPI's website, they are always seeking new technologies and new equipment to expand our portfolio and knowledge base.

External Reviews: Challenges and/or Recommendations

Considering the short time, the Catapults have been in operation, it is difficult to assess the effectiveness or success of this project, even more so, to consider them as possible mode to reapplication. However, in an attempt to review the performance of the establishment and implementation process, BEIS has commissioned Ernst & Young to review the Catapults' performance to date (EY, 2017). As a result of the review a Catapult Network Review was published in November 2017, noting both the successes and areas where improvements are required to put them on a trajectory that maximises the benefits of innovation to the UK economy.

The main findings and recommendations extracted from EY are summarised below (complete information in Executive Summary published on November 2017 can be found in https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/662509/Catapult_Review_-_Publishable_Version_of_EY_Report__1_.pdf):

Challenges

Implementation Process

Implementation of the Catapult concept has been inconsistent and could have had a significantly greater impact in delivering innovation, economic benefits and value for money that would have been more consistent with the benefits envisaged when the concept was initiated. This is because, with a few notable exceptions:

- There has been no single, commonly agreed and consistently communicated purpose statement for Catapults that has been applied across the network and reflected from strategy through delivery plans to performance measurement and evaluation.
- Innovate UK governance has not been sufficiently robust, particularly around financial and performance management, with limited evidence of timely intervention where Catapults' performance targets and wider objectives have not been met (other than in very recent examples).
- There is limited evidence that Catapults have had effective performance management in place.

- Catapults have not achieved their funding model expectations as per their envisioned operating models and they remain overwhelmingly reliant on public funding.
- Whilst it is not possible to quantify the economic impact robustly with the data available, there is some evidence that individual Catapults may have had a positive economic impact. This is especially the case for HVMC and CGTC, where they have historically centred delivery plans to drive economic benefit to the UK. This, combined with the case studies that were presented to us by HVMC and CGTC, gives us a higher degree of confidence that these two Catapults are likely to have generated a positive impact relative to the other Catapults.
- However, in broader terms, with the Catapult network's overall lack of a clearly articulated set of objectives, or a framework for measuring impact, and the current level of operational performance, it is unlikely that the impact of the network overall has been significant so far. Hence our view, taking in to account everything we have seen, is that, to date, the Catapult network is unlikely to have provided the benefits and value for money envisaged at the outset.
- There is limited evidence of extensive collaboration between Catapults and limited synergies achieved through being part of the Catapult network, which, if addressed, could help make the Catapult brand more effective in the UK.

EY urged to the UK government the implementation of their recommendations **before** continuing with the implementation plan of new Centres. Only then, if there is still a decision to establish new Catapults, they recommend the following points to be considered before any formal arrangements are made to proceed with launching a new Catapult:

- Does the proposed Catapult meet the core criteria to be considered as a Catapult?:
    - Is this a multi-billion £ industry that is important to the UK?
    - Is there a definable cluster of activity in the UK?
    - Is there demand showing market intervention needed to remove barriers to commercialisation of innovative products and services, which can be addressed by a Catapult?
- Could the proposed Catapult operate on a set of viable core objectives?:
    - Would it have the ability to provide infrastructure, skills and expertise to act as a platform for innovation pursuits in specific sector or technology domains within its industry where there is a market failure?
    - Could it work alongside the R&D capability in the UK, accessing CR&D funding, to develop innovative solutions addressing key sector or technology domain challenges?
    - Could it work with industry to commercialise innovation in a way that drives long-term benefit to the UK economy?
- Is there a credible ecosystem and resources to support an optimal operating model for the proposed Catapult?
    - Is there an interest and willingness to participate from key stakeholders within academia, industry, Government and other Catapults?
    - Is there a selection of credible candidates who would be motivated to lead, and plausibly be employed by, the proposed Catapult?
    - Is there confidence in sustained sponsorship and governance from HMG for the proposed Catapult?

Governance

- There has been a lack of consistency in the performance data reported, lack of transparency in the flow of funds, some lack of clarity on the use of funds and non-timely availability of this data. For example, EY identified material differences in Innovate UK and Catapult data for the quantum of core funding provided or received (these have now been reconciled by Innovate UK). Quoting from EY report 'We were surprised this analysis had not previously been undertaken as a core part of the regular review of Catapult performance.'
- 'In our opinion, these points are indicative of IUK's sub-optimal financial management to monitor and analyse whether Catapult funding has been well spent, in a way that seeks to maximise returns to the UK economy.'
- Catapults that had a chairperson with relevant business and industry experience (e.g., experience of setting up businesses) performed relatively more strongly than those that did not.
- The UK innovation policy landscape is currently undergoing considerable change with the creation of UKRI, which will bring together Research Councils, IUK and Research England, and will therefore have the ability to influence key Catapult governance decisions.

Performance Management

- The KPIs that have been used to monitor performance of the Catapult network have had limited effectiveness in guiding Catapults to achieve their business objectives and deliver maximum economic benefit for UK plc.
- In EY's opinion, there have been too many KPIs and those KPIs have been too focused on inputs, with insufficient emphasis on outputs and outcomes. This has been recognised by BEIS and Innovate UK, who are working on developing a new KPI reporting framework.
- Consequently, Catapults have not used KPIs provided by Innovate UK to systematically focus on the real outputs of their activities for UK plc, nor have they used KPIs to drive business performance.
- There is no evidence of analysis linking input KPIs to output KPIs, e.g., capex, staffing and engagement KPIs measure activity and do not necessarily convert to achievement of funding targets.
- There is evidence that Catapults do not view the Innovate UK KPIs as necessary to understand the performance of the business and that some Innovate UK imposed KPIs are not used for internal reporting purposes, such as number of patents created.
- There is evidence from some Catapults of continual year-on-year reduction of performance targets as agreed performance targets are not achieved.
- Catapults are involved in the delivery of wider government policies, receiving c.25% of funding from 'Public Other' sources (HVMC representing the bulk of this). These projects have been generally aligned with the Catapults' scope and objectives and did not distract Catapults from making progress against their delivery plans.

Economic impact

- In assessing the success of the network in achieving this, it should be noted that impacts associated with innovation and R&D often take many years to materialise as technology takes time to diffuse through the economy.
- Therefore, while there is some evidence that the Catapults have generated additional economic impact, in EY's view, given the lack of a clearly articulated set of objectives and a framework for measuring impact, together with the performance of the Catapult network since inception, it is more likely than not that, to date, this additional economic impact has not been significant.
- A comprehensive evaluation framework has now been developed by BEIS and IUK. If implemented correctly, this is expected to improve delivery and help demonstrate value for money.

Catapult operating model

There are certain characteristics EY identified which will increase the likelihood of a Catapult having a strong chance of long-term success:

- A focused strategy and delivery plan that articulates clearly how the activities of a Catapult addresses a particular market failure / failures and, logically, how those activities are ultimately expected to drive economic benefits to UK plc.
- Having set out a focused strategy and delivery plan, maintaining alignment, and executing against, the criteria and core objectives of the Catapult.
- A limited number of KPIs, with economic impact KPIs at the heart of the performance management regime, and full alignment of KPIs with the overall strategy and plans for Catapults.
- Strong collaboration with academia, industry, Government and other Catapults.
- Strong internal leadership.
- Strong external governance with agreed interim milestones in place such that progress towards the longer-term aspirations can be assessed and timely intervention made where concerns are identified.

Whilst, in principle, some organisations could be integrated into the Catapult network, the over-arching precondition required prior to further analysis is that the existing Catapult network and governance needs to be addressed first.

Recommendations

Governance

- Ensuring CEOs are not hired on an interim basis, but on a permanent contract in order to have commitment from both sides to ensure the success of the Catapult Options should be assessed as to whether incubating a new Catapult within a UK <u>public body (such as a university) prior to private sector launch would maximise chances of success whilst managing VFM.</u>
- Programmes of the scale, size and complexity of the Catapult programme require senior BEIS and Innovate UK official support and involvement. It is recommended <u>direct ministerial oversight of the Catapults and active ministerial involvement in the governance process</u>.

- IUK needs to strengthen its financial management capabilities to have a transparent, accurate and reliable view of how funds have been allocated and used (e.g., provide additional training and recruit appropriately skilled resource).
- IUK should have a centralised, dedicated Catapult management function. This management function should have a holistic view of the Catapult network performance, as well as enable coordination between Catapults and be responsible mainly for:
    - Regularly analysing relative performance of Catapults
    - Developing and continuously improving management information reporting, e.g., developing dashboards with drill-down capabilities or automating processes
    - Analysing individual Catapult activities, identifying areas of overlap and opportunities for aggregation and sharing of resources
    - Creating 'one version of the truth' for performance reports for the Catapult network
    - Introducing controls and checks across reporting processes to minimise risk of errors

Funding

Process. Catapults should continue to strive for the 1/3, 1/3, 1/3 funding target, as in principle it strikes a good balance between the core purpose of a Catapult and the different stakeholder groups. However, these targets should be phased in over time in line with the maturity of the Catapult, with some flexibility in early years immediately post start-up, and relatively less flexibility in later years when a Catapult is more established.

Strategy. Catapult targets should be set to aim to achieve the 1/3, 1/3, 1/3 target within five years from inception, however the split of funding should be determined on a case-by-case basis supported by evidence relating to:

- The maturity of the Catapult: in its formative years, Catapult effort is likely to be expended on activities such as building organisational capability, brand relationships, etc., therefore the target split of funding should be phased.
- Sector or technology trends: some sectors and technologies are likely to experience impacts from the wider economy which may pose opportunities and challenges around the availability of funds – in particular commercial funding. The changes in market conditions should be reflected in planning.
- Total available CR&D funds: total CR&D availability (through IUK and globally) is likely to fluctuate annually and should be considered as part of establishing viable CR&D targets for Catapults.

Public Funding Access. Innovate UK needs to be clear on the availability of CR&D funds so Catapults can plan their activities accordingly and remain broadly aligned to a 1/3, 1/3, 1/3 funding model. Assuming overall core funding continues at the FY17 level of c.£150mn per annum for the foreseeable future, Innovate UK should have provision to ensure that Catapults can plausibly access c.£150mn per annum of CR&D funding, and that each individual Catapult can potentially access CR&D funding to meet its 1/3, 1/3, 1/3 target. If Innovate UK is backfilling CR&D shortfalls through diverting core funding, any reductions in core funding should not result in a situation where Catapults are unable to carry out their core tasks and meet their core objectives.

THE CARNOT MODEL

The France's Carnot, as well the UK's Catapult are both are relatively recent attempts by European countries to emulate what they see as the best features of Germany's Fraunhofer-Gesellschaft to improve the flow of technology from the national research base to private industry. Both initiatives assign a designation ("Carnot" in France and "Catapult" in Britain) to a group of existing institutes of applied research with the hope that the designation will develop into a recognised symbol of excellence, as has been the case with the Fraunhofer name (National Research Council, 2013).

Key Figures and Facts

- At present there are 38 Carnot Institutes distributed across France.
- The Carnot network accounts for 18% of the French public laboratory workforces, with 30,000 research professionals, including 9,000 PhD.
- 50% of the R&D funded by companies in French public research, involving 9,600 R&D R&D contracts with industry, of which 4,000 are SMEs and IMEs.
- €420m in R&D contracts directly funded by companies.
- Carnot spins out 65 companies per year.
- 1,050 priority patents filed in 2016.

Origins and Constitution[14]

In 2003, the Ministry of Industry and the Ministry of Research and Technology jointly drew up the Innovation Plan, a series of recommended measures to support innovation in France. This plan was augmented in 2005 by the research ministry's Pact for Research, which set forth proposals that provided the basis for the Law for Research, enacted in 2006. The purpose of the Law for Research was to support greater cooperation between various actors in the research ecosystem, to network public and private research activities, to provide improved conditions for scientific careers, and to encourage the integration of the French research system into the European Research Area (ERA).

The Carnot initiative arose out of the Pact for Research, which sought to reinforce the activities of existing public research institutes that were already involved in research partnerships with private and/or public entities.

The program designates what are regarded as the best of those institutes as 'Carnot Institutes', and awards them government funding through the ANR, with the level of funding linked to the volume of each Institute's contract research revenue from industry. The Carnot designation is intended to be a 'seal of excellence'. The Carnot programmed was inspired by the example of Germany's Fraunhofer-Gesellschaft

Underlying the Carnot initiative is the recognition that France's strengths in basic research do not necessarily translate into enhanced innovation capacity in French industry, a reflection of the

[14] Extracted from National Research Council, 2013.

historically weak links between public research organisations and the private sector (National Research Council, 2013).

The Carnot designation, as well as additional government money, is bestowed based on a given institute's demonstrated willingness and ability to engage in contract research work for industry.

The Carnot and Catapult institutes are also being provided with core funding from their respective governments, with the expectation that most of their revenue will be derived from contract research. Although the institutes in these programs are being accorded a considerable degree of autonomy, they are expected to align their activities with coherent national innovation strategies. (National Research Council, 2013).

Aims and Objectives

The primary aim of France's Carnot initiative is to foster stronger ties and partnerships between that country's extensive public research organisations, on the one hand, and "other socio-economic actors," on the other hand, mainly private companies.

The clear objective of Carnot Network is to increase the economic impact of R&D actions led by laboratories of the Carnot Institutes in partnership with businesses in terms of creating jobs, national turnover, and thus competitiveness.

The most important priority of the programme is knowledge transfer from public research organisations to other entities, particularly private companies, through contract research, licenses, and IPR creation in public, academic, and non-profit institutes.

The goal of the Carnot Institutes is the improvement of society through renewable energy, personal health care, improved transportation and mobility, civil safety, homeland security, and information and communications technology (ICT). Accordingly, the Carnot Institutes concentrate on a number of thematic areas:

- Life sciences and health technology.
- Materials, mechanics, and processing.
- Earth sciences and natural resources.
- ICT—micro- and nano- technologies.
- Building, civil engineering, and land use planning.
- Environment and energy, propulsion, and chemistry.
- Soft

Governance Structure

The Carnot institutes are selected, monitored, and funded by France's National Agency for Research (ANR). France's Carnot initiative features an association to which each Carnot institute belongs. Carnot provides support services, branding and networking, **but no common governance or direction.**

In order to take advantage of their complementarity and synergies for the benefit of their business partners, the institutes are organised in an operational network facilitated by AiCarnot.

AiCarnot[15]

The Association des Instituts Carnot (AiCarnot) acts as a coordinator and network developer of the various individual Carnot institutes. It secures public financial support for each institute, works to define the medium-term objectives, and defines and manages intellectual property rights policies. AiCarnot has developed long term relationships with regional and thematic entities providing technological support to companies, including OSEO, the French competitive clusters, research clusters, professional organisations, and the French Chamber of Commerce.

French public research organisations, including Carnot institutes, are periodically subject to external evaluations supervised by the government Agency for the Evaluation of Research and Higher Education (AERES). The evaluations are conducted by independent experts (Visiting Committees) who not only have no connection to the institution under examination and in a majority of the cases are not even French. Some of the AERES reports are published.

Services Provided

Contract Research

The nature of the research collaborations between Carnot institutes and companies vary considerably from institute to institute. In general, collaborations may involve very specific research sought by a company with respect to which the company pays for the full cost of the project; R&D collaborations, consortia, and joint laboratories involving cost sharing; and special projects for small and medium enterprises. Many contracts involve personnel from both the Carnot institute and the industrial partner.

CEA LETI (microelectronics and nanotechnology) administers PEPITE, a program that provides short term (6-12 months) project engineering for small companies seeking to use mature technologies held by CEA LETI.

Carnot IFPEN Transports Energie offers Joint Industry Projects (JIPs), consortia in which the institute does all of the research itself, shares the results with participating companies, and retains industrial ownership. IFPEN also performs "research demonstrators which perform the last step in the validation of a technology prior to industrialisation.

Support for Manufacturing

Twenty Carnot institutes offer competencies in "materials, mechanics, and processes," which support French manufacturing companies and industries. A number of institutes offer companies access to on-site pilot manufacturing facilities on which they can prove processes and equipment, and/or tools and platforms through which factory environments can be simulated.

[15]Extracted from National Research Council, 2013.

Training to Companies' Employees

Carnot institutes' research contracts with companies sometimes stipulate that the institutes will train employees of the companies in the technologies that are the subject of research.

Location, Infrastructure and Capabilities

The Carnot Institutes offer a large spectrum of capabilities, providing the ability to respond to the research and innovation needs of companies in most economic sectors.

Diverse Infrastructure and Capability

CEA LETI, for example, which specialises in microelectronics, features 8,000 square meters of CMOS compatible clean rooms equipped with 200 and 300mm fabrication tools. The STAR Carnot Institute (Science and Technology for Research Applications) operate a multi-purpose production platform for advanced materials, tools for materials deposition, and clean rooms.

Some institutes, such as Carnot CETIM, are virtually entirely dedicated to industrial automation technologies and systems, simulation of industrial processes, metrology, and other themes directly relevant to manufacturing. CETIM's website details 120 recent projects that have boosted competitiveness of French industry, generally through incremental improvements in materials and industrial production processes.

Selection of Carnot Institutes

The Carnot network is made up of heterogeneous group of publicly funded organisations distributed across France who are selected by the ANR. Although ANR selects Carnot institutes, the Carnot designation is given by the Ministry of Higher Education and Research. The criteria for Carnot designation require a candidate institution to:

- Clearly define its research strategy;
- Maintain or create a sound internal organisation;
- Retain downstream research in-house to enrich more applied research;
- Be substantially engaged in contract research with other socioeconomic actors.

The first Carnot designations, in 2006 and 2007, were for a renewable 4-year period. Subsequent designations run for 5 years. By 2017, 38 Carnot institutes have been designated across France, with a staff of 30,000 accounting for 18% of the French research personal.

Parent organisations of the various institutes include universities and National Centre for Scientific Research (CNRS), and other governmental or quasi-governmental entities. Many Carnot institutes operate through multiple research centres in various parts of France.

Funding Model

The ANR provides support funding to Carnot institutes based on an incentive formula that takes into account revenues from contract research for public and private entities, income that flows from the ownership of intellectual property, and income from SMEs. ANR funding increases proportionally as each of the other revenue streams grows. Eligible income for ANR matching funding includes income from research partnership contracts financed by public or private entities (excluding states, the EU, international organisations, and national agencies) which are either end users of the results or entities acting as intermediaries for user companies.

Because the Carnot institutes are public organisations, over half of their funding is derived from various government sources in the form of core funding or research contract revenue.

Partnerships between Carnot institutes and companies take a number of forms:

- Direct partnership research contracts with companies.
- Collaborative contracts in response to requests for proposals from ANR, the French Interministerial Single Fund, and the EU Framework Programme.
- Joint research teams and laboratories;
- Supervision of PhD students financed by companies

The heterogenicity of the publicly founded Carnot centres results in different funding models depending on the centre. A number of them are public research organisations which were founded during the *dirigiste era*[16] that executed *grandes programmes*[17], and which have reoriented their mission and approach in recent decades (National Research Council, 2013).

Some of the centres also performed basic as well as applied research receiving, therefore, grants from basic research funding bodies.

Intellectual Property Rights (IPR) and Related Activities[18]

AiCarnot has promulgated a code of best practices with respect to IP and knowledge and technology transfers (KTT) for the Carnot institutes. The code provides guidelines with respect to research partnerships between the Carnot institutes and "socio-economic actors" (in most cases companies):

- each party will have proprietary rights with respect to the R&D results they develop alone during the collaboration.
- results that the parties develop together are jointly owned, with conditions regarding the exercise of IP rights "defined according to specified and negotiated terms, for example, in proportion with their contributions in terms of inventing and funding"
- a free right of use of the partnership's research results is held by the Carnot institute solely for the purpose of subsequent research.
- transfer of IPR by Carnot institutes is to be considered on a case by case basis with an appropriate compensation
- the rights to prior knowledge which the parties bring to the collaboration cannot be modified by the collaboration unless specifically negotiated

---

[16] France post-war growth model of state-led modernisation (Levy, J., 2008)

[17] "During the *trente glorieuses* (thirty glorious years of postwar economic expansion), the government held a large ownership stake in the economy, provided financial backing for "national champion" companies, and tasked public applied research organizations with executing *grandes programmes*, large-scale R&D programs to support the development of strategic industrial sectors. The *grandes programmes* gave certain French industries a lasting technological advantage (rail, atomic energy, aviation, telecommunications), but "by absorbing most of the R&D funds, they deprived other sectors of even the most basic support for technology innovation." (National Research Council, 2013).

[18] Extracted from National Research Council, 2013.

- at the same time, the partners grant free access to their prior knowledge for the sole purposes of the joint research
- licenses for the technology developed by the partnership "will be limited to a definite period and to specific fields and territories.

External Reviews: Challenges and/or Recommendations

According to the report of the National Research Council of the USA (National Research Council, 2013), despite the impressive results of the Carnot Network in some of the innovation indicators, such as number of annual contacts with companies, and the number of spin-offs, the "Carnot initiative, standing along, cannot remedy some of the more intractable weaknesses in the French innovation system, such as manpower shortages, the acknowledged shortcomings of the educational system, chronic underinvestment in research by industry, and the comparative lack of interest by young people in careers in engineering and science. In 2011, five years after the inception of the Carnot initiative, a study by two French academics concluded that research cooperation between public and private sectors in France contributes less to companies' innovation capacity than is the case in Germany, based on an econometric study of the share of innovative products in total turnover. The European Commission attributed these findings to the difficulty encountered by companies in cooperating effectively with public research organizations, the complexity of the knowledge-transfer system, and the difficulty private companies experience in finding the right research partners. **These findings underscore the fact that addressing the challenges facing France in innovation will take a major effort spanning many years**."

THE ITRI MODEL

Origins and Constitution

ITRI is non-for-profit organisation founded in 1973 to provide applied industrial research for Taiwanese industry. It resulted from the merger of three research-oriented organisations previously operating under the Ministry of Economic Affairs: the Union Industrial Research Laboratories, the Mining Research & Service Organisation and the Metal Industrial Research Institute. The growth of ITRI was inextricably linked with the development of the Taiwanese semiconductors industry in the mid 1970s. At the time the problem for the policy maker was to foster the emergence of a whole new sector in the absence of significant infrastructures and competences. Universities might have provided a starting point, but they were not considered as a suitable environment for commercialisation processes. **The decision was taken to transfer technology in from abroad and to invest heavily in training through ITRI.** (Mina et al., 2009).

> ***'ITRI's greatest achievements have been the creation of entirely new high-tech industries that did not previously exist in Taiwan. It obtained the necessary technologies from foreign multinationals, assembled teams of researchers to master the requisite product and process technologies and spun off start-up companies from its own staff, in some cases forming entire industry supply chains. As new industries became established and competitive, ITRI curtailed its support and moved on to develop another generation of new industries. In this way, ITRI fostered Taiwan's semiconductor, LCD, computer, and photovoltaic industries and industries. ITRI places large bets on what it sees as industries of the future, committing substantial resources to largescale, long-term R&D projects. While this involves substantial risk, the payoffs for success have been enormous, helping to transform Taiwan from a developing country to a major technology-intensive economic power.'***
>
> '21st Century Manufacturing': The Role of the Manufacturing Extension Partnership Program'
> (National Research Council, 2013)

'The Industrial Technology Research Institute (ITRI) has been one of the most important instruments of industrial policy in the Far East. It has been credited with a fundamental role in the history of economic development in Taiwan and is still a model of intervention for developing countries.' (Mina et al., 2009). As stated in the US National Research Council's report '21st Century Manufacturing', "The creation of ITRI, perhaps the most important milestone in the entire course of Taiwan's industrialization, was the brainchild of an elite group of highly competent bureaucrats and business leaders, most of them holding degrees in engineering. They frequently had extensive experience working for multinational high technology companies and were in a position to apply their practical experience to the development of indigenous companies and industries. They were relatively unhindered by political pressure—the Kuomintang Party (KPT), which held a monopoly on political power until 1990, had a tradition of relying on “scientific” government planning when it arrived on Taiwan in 1949, and technocrats “had already won a large measure of independence from party and military control.” This pattern was maintained during the decades of KMT rule but is eroding with the advent of democracy and challenges to KMT policies by the Democratic People’s Party (DPP).” (National Research Council, 2013).

ITRI was founded by legislative act and is a not-for profit organisation. It has therefore developed a separate VC/incubation branch through which it can attract capital and eventually retain excess returns.

Key Figures and Facts

- Total staff: 6,064, including 1,397 PhDs and 3,515 Masters (ITRI,2017).
- Alumni number: 24,550 (ITRI,2017).
- Accumulated patents: 26,509 (ITRI,2017). In 2016 (ITRI, 2016), 1,573 were granted, of which 98% were innovation patents, and 2% were utility models.
- Start-ups and spin-offs: 302 (ITRI,2017).
- Industry services per year: 16,253 (ITRI,2017).
- Transferred technologies per year: 579 (ITRI,2017).

Aims and Objectives

ITRI is committed to utilising its R&D results to drive industrial development and create economic value.

ITRI draws upon research conducted all over the world in companies, research organisations and universities and uses the knowledge to develop product prototypes and the processes, equipment and materials necessary to manufacture those prototypes.

It fosters not only the creation of companies that make new products, but of entire industry chains supporting the manufacturing process, including design, materials, equipment, testing, packaging, quality control and applications.

Governance Structure

‘ITRI’s strategic direction is determined by Taiwan’s Ministry of Economic Affairs (MOEA), but the process involves extensive consultations between and among MOEA, ITRI, and a system of highly competent advisory bodies’. (National Research Council, 2013).

‘The Technical Advisory Committee (TAC), originally an informal group of expatriate Taiwanese engineers working in the United States, evolved into a standing organization of Taiwanese with international education and work experience advising ITRI on relationships with multinational corporations.’ (National Research Council, 2013).

‘The Science and Technology Advisory Group (STAG), which advises the Executive Yuan (cabinet) on science and technology policy, includes international experts (occasionally including Nobel Prize winners) as well as eminent Taiwanese academics and holds an annual Industrial Science and

Technology Strategy Conference, which addresses themes in areas such as electronics, telecommunications, information technology and biotechnology.' (National Research Council, 2013).

'The Technical Review Board (TRB) of the National Science Council consists of foreign and domestic experts who concentrate on targeting particular technologies and adapting them at the operational and project level.' (National Research Council, 2013).

Services Provided

ITRI provides comprehensive industrial services. Leveraging its edge in patents and the professional assistance of the open lab and incubation centre, ITRI stimulates the development of emerging technologies and service innovation, thereby increasing industrial impact and economic value. (ITRI, 2017). The services include:

- Industrial Consultancy Services
- R&D Collaboration
- Open Lab/Incubator
- Technology
- Transfer
- Testing and Certification
- Education & Training
- Service
- New Ventures

With its recent R&D achievements in Smart Living, Quality Health, and Sustainable Environment, ITRI is devoted to developing intelligent systems and leading industries to embrace multidisciplinary innovation and hardware/software integration. Incorporating its key enabling technologies, ITRI continues to foster green and sustainable industries while promoting new innovations and applications. (ITRI, 2017).

ITRI's clients are focussed on integrated circuit (IC) design, optoelectronics, mechanical systems, materials and over the last 3-4 years also biotech, although the latter is not ITRI's top priority. Materials and chemical engineering are the divisions where most business with firms is done. There are two groups of client firms: start-ups (many of which are local firms producing components for overseas markets) and established companies (including multinationals). They come to ITRI to strengthen their products and access lab facilities. They also have the option of pitching to ITRI's VC branch for investment in their business. ITRI's spinoffs are less likely to come back in search for further funding (to date ITRI has spun off 15 companies). One of the advantages of ITRI is that it provides clients with a comprehensive one-shop stopping opportunity of testing services.

The institute offers a highly integrated environment covering activities from IC design to Micro-Electro-Mechanical Systems. When a company becomes a client at ITRI it gets 25% (year1), 15% (year 2) and 5% (year 3) facilitation rental rate for the use of local facilities. Within 18 months the firm can apply to join the ITRI incubator and ITRI can exercise the option of investing in the company, even though this option is established by gentlemen's agreement and not by contract.

Overall, after the success of the largest spin-offs (UMC, TSMC[19] and Taiwan Mask) the perception is that it is becoming more difficult to spin out companies. This is partly attributable to the technological differences between IC design and displays, where technology opportunities for Taiwan have moved. It is also felt that ITRI needs to do more fundamental science to lead technology development from the front of the global competitive process.

Infrastructure

Location, Facilities and Capability

Originally, ITRI was formed through the combination of **three existing research centres** subordinated to MOEA which were relocated to a new site in Hsinchu in 1973. It consisted of 400 employees and was funded by a government budget of USD $213 million.

'In 1974, the Electronics Industry Research & Development Centre was established within ITRI to create a domestic semiconductor industry, subsequently being renamed as the Electronics Research & Service Organization (ERSO). In 1990, new laboratories were established for computer and communications research and biomedical engineering. Currently, ITRI's R&D activities are centered on six core laboratories pursuing "deeper and new" ideas and eight technology centers which focus on particular themes emphasizing a multidisciplinary approach and drawing on the specialized competencies of the core laboratories. ITRI's Business Development Unit is responsible for commercializing research results, technology transfer, and relations with foreign research partners.' (National Research Council, 2013).

Currently, most of ITRI's operations are concentrated at one main site in Hsinchu, with only one other satellite location, ITRI South, in Tainan. ITRI is located close to Hsinchu Science Park, and together with two universities and numerous high-tech companies, comprise one of the most famous and successful innovation clusters in the world. Most points within this complex are within walking distance of each other, a proximity which fosters personal interchange and cross-pollination of ideas.

Normally, ITRI uses its own state-of-the-art pilot facilities. The Institute for larger pilots can, however, access to facilities of the Taiwan Semiconductor Manufacturing Company (TSMC). The average duration of advanced project is around 3 years, as opposed to approximately four years for experimental projects. The duration of a research contract is typically one year. Partners include universities and various national research centres in various areas such as health and computing. In addition, ITRI has joint research centres of small proportions at six national universities in nano-materials and biomedical, micro-to-nano manufacturing engineering, semiconductors, environmental technologies, communications and IC chips, optoelectronics. Agreements entail the sharing of staff (all of whom already have positions at either ITRI or the university), facilities and IP.

ITRI has recently been keen to enhance its innovation culture. It was felt that more risk-taking and creativity were needed to further develop and diversify the Institute's activities in new directions.

[19] 'Some of ITRI's spin-offs have been spectacularly successful, including the United Microelectronics Company (UMC) and Taiwan Semiconductor Manufacturing Corporation (TSMC), today two of the most competitive semiconductor manufacturers in the world.' National Research Council, 2013.

International co-operation with global leaders in research has also become highly strategic: a scheme of institute-to institute relationships, for example, has been put in place to develop cutting edge research in areas of strategic importance. Partners include Carnegie Mellon, MIT, AIST (Japan), UCB, CMU, NRC (Canada) and MSU (Russia).

ITRI has a total Staff of 6,074, of which 1,397 hold PhD and 3,515 have master's degree. For ITRI the rotation or transfer of its employees to the industry is an important indicator. ITRI at 2017 had a total of 24,550 alumni. (ITRI, 2017).

Funding Model

ITRI's budget is currently about $600 million per year, half of which is provided by the government and half by the private sector. ITRI employs 5,728 personnel, of which 1,163 hold PhD and 3,152 masters' degrees. ITRI's staffing of research projects is "very bare bones," even in technology areas regarded has having breakthrough potential.

The Institute's revenues appear to come in even proportion from the provision of industrial services for client organisations and from dedicated government programmes managed by the Ministry of Economic Affairs (MOEA). Note, however, that the figure for industrial services still includes revenues from government procurement contracts (accounting for about half of this subtotal according to internal sources). (Mina et al., 2009).

ITRI projects fall into two categories: technology development projects contracted with government and industrial service projects, contracted with the private sector, but also with government. In charge of Technology Development projects are Programme Offices from the MOEA Department of Industrial Technology, the Department of Energy and the National Science Council. A strategy planning division allocates resources between advanced projects (1/4 research budget), exploratory projects (1/4 budget) and R&D Fundamental Construction Projects (1/2 research budget). Advanced projects are supported for a few years to focus on 'hard' technologies, possibly in co-operation with academia and across disciplinary domains when necessary. The proposal of projects is both top-down (R&D Planning Division and General Director Office) and bottom-up (R&D Labs and Centres). Project selection takes place through an Advanced R&D Advisory Committee, which includes the top-level management of the centre, consultants, including professors from local universities, and international experts. A Technology Advisory Committee, including members of Advanced R&D Advisory Committee, is instead charged with the task of advising on technology development, and components and technologies' integration.

Intellectual Property Rights (IPR) and Related Activities

In terms of IP protection, patenting is extremely important and has higher priority than scientific publications. ITRI holds the intellectual property derived from its research, when a research contract is concluded. Over the last four years, ITRI has filed an average of about 900 patents per year. It licenses technology to Taiwanese companies on more favourable terms than they could secure from foreign sources. ITRI also periodically auctions off blocks of its patents.

External Reviews: Challenges and/or Recommendations

According to reviews of the National Research Council of the USA (National Research Council, 2013), despite the impressive results of the Carnot Network in some of the innovation indicators

ITRI managers are critical of the geographic dispersion of research locations, which they see as undermining the benefit otherwise accruing from innovation clusters.

The overwhelming majority of Taiwan's businesses are small enterprises which lack the resources and scale for global competition.

ITRI is trying to move away from a catch-up paradigm and to focus on innovation in an environment where local firms are still rather conservative when it comes to accepting technology risks. Changes are being made in the organisation in order to enhance its innovation culture. It was felt that more risk-taking and creativity were needed to further develop and diversify the Institute's activities in new directions. (Mina et al., 2009).

The country is arguably not well prepared for an era of global patent warfare, in which infringement litigation can suppress or destroy technology-based start-up companies.

A longstanding talent shortage has been exacerbated by an exodus of skilled workers to mainland China.

The American connection, long an important aspect of Taiwan's high-tech development, may fade as the number of Taiwanese students pursuing advanced degrees in the U.S. progressively declines.

Some observers believe that ITRI is trying to focus on too many technologies with two small a budget, diluting the impact of its efforts.

BIBLIOGRAPHY

Betz, F., Carayannis, E., Jetter, A., Min, W., Phillips, F., Shin, D. W. (2016). Modeling an Innovation Intermediary System Within a Helix. *J Knowl Economy*, 7: 587–599. DOI 10.1007/s13132-014-0230-7.

Beise, M. and Stahl, H. (1999). Public research and industrial innovations in Germany. *Research Policy,* 28: 397–422.

Carayannis, E., Alexander, J. and Ioannidis, A. (2000). Leveraging knowledge, learning, and innovation in forming strategic government–university–industry (GUI) R&D partnerships in the US, Germany, and France. *Technovation*, 20: 477–488.

Catapult (2017). Catapult Network - Fostering Innovation to Drive Economic Growth 2017. Cross Catapult Network Report 2017. www.catapult.org.uk

Dodgson, M., Mathews, J., Kastelle, T., Hu, M-C. (2008). The evolving nature of Taiwan's national innovation system: The case of biotechnology innovation networks. Research Policy 37: 430-445.

Ernst & Young (2017). UK SBS PS17086 Catapult Network Review. Version 1.31.

Fraunhofer-Gesellschaft. (2010). Statute of The Fraunhofer- Gesellschaft. Revised Version 2010.

Fraunhofer-Gesellschaft. (2016). Annual Report 2016. Embracing Digitalisation.

Goddard, J., Robertson, D. and Vallance, P. (2012). Universities, Technology and Innovation Centres and regional development: the case of the North-East of England. *Cambridge Journal of Economics*. 36: 609–627 doi:10.1093/cje/bes005

Harding, R. (2002). Competition and collaboration in German technology transfer. *European Management Journal* 20(5): 470–485.

Hauser, H. (2010). The Current and Future Role of Technology and Innovation Centres in the UK.

ITRI (2016). Annual Report 2016. Smart Convergence. Innovating a Better Future.

ITRI (2017). Innovating a Better Future.

Levy, J. D. (2008). From the *Dirigiste* State to the Social Anaesthesia State: French Economic Policy in the *Longue Durée*. *Modern & Contemporary France*. 16(4): 417 – 435.

Mina, A., Connell, D. and Hughes, A. (2003). Models of Technology Development in Intermediate Research Organisations. Centre for Business Research, University of Cambridge Working Paper No. 396.

National Research Council (2013). 21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program. Washington, DC: The National Academies Press. https://doi.org/10.17226/18448

Robin, S. and Schubert, T. (2013). Cooperation with public research institutions and success in innovation: Evidence from France and Germany. *Research Policy* 42: 149– 166.

Shiu, J-W., Wong, C-Y., Hu, M-C. (2014). The dynamic effect of knowledge capitals in the public research institute: insights from patenting analysis of ITRI (Taiwan) and ETRI (Korea). *Scientometrics* 98: 2051–2068. DOI 10.1007/s11192-013-1158-6

Trischler, H. and von Bruch, R. (1999). Förschung für den Markt: Geschichte der Fraunhofer-Gesellschaft. München : Beck.

Ocampos, J.A. (2018). Innovation Intermediary Infrastructure. Benchmark and Comparative Review of International Models. Cambridge (UK). 22 February 2018 ©22 February 2018
Email: director@camnexus.co.uk