MIT Industrial Performance Center
Innovation. Productivity. Competitiveness.

WORKING PAPER SERIES

Beyond RTO Benchmarking: Towards a Typology of Innovation Intermediaries

Ezequiel Zylberberg
Postdoctoral Associate, MIT
ezylber@mit.edu

MIT-IPC Working Paper 17-002

June 2017

ACCELERATING INNOVATION in BRAZIL

400 Main Street, E19-733, Cambridge, MA 02139
ipc.mit.edu

Beyond RTO Benchmarking: Towards a Typology of Innovation Intermediaries

Ezequiel Zylberberg
Postdoctoral Associate, MIT
ezylber@mit.edu

Abstract

Decades of scholarly research have shown that research and technology organizations (RTOs) play many important roles in national systems of innovation. However, extant benchmarking studies fail to fully capture the complex and dynamic space that these intermediaries inhabit. Further, because these studies focus largely on RTOs in industrialized countries, they do not to account for the important functions they take on in developing and emerging economies, including diffusing global industry standards and best practices. This paper argues that RTOs have been too narrowly construed in the literature, and that they should be reconceptualized as a type of innovation intermediary – an organization that connects otherwise poorly articulated actors in an innovation system and aids in the transmission of knowledge between them. Primary and secondary research on organizations in industrialized, emerging and developing economies is employed to inform a new typology of innovation intermediaries. The ideal types proposed include utilities, creators, conveners and contractors. Utilities depend heavily on public funding, operate in line with the state's agenda, and work closely with small and medium size enterprises (SMEs). On the other end of the spectrum, contractors receive little public funding, operate in line with industry needs, and find it difficult to work with undercapitalized SMEs. Creators and conveners exist between these two endpoints, depending on the state for guaranteed and competitive funding while still operating in line with industry needs. This typology is then employed to discuss the newly created network on SENAI Innovation Institutes in Brazil, and to provide recommendations regarding their strategic direction moving forward.

1. Introduction

Firms often rely on external partners to innovate (Mowery, 1983; Mowery and Rosenberg, 1993). They need to access, acquire, assimilate and exploit external resources to develop and sustain competitive advantage (Chesbrough, 2003; Cohen and Levinthal, 1990; Zahra and George, 2002). These resources can be found in many of the organizations that together comprise national innovation systems (Freeman, 1995; Lundvall, 1992), and increasingly, in the global supply base (Sturgeon and Lester, 2004; Whittaker et al., 2010). Among the various organizations that firms rely on to innovate are research and technology organizations (RTOs), a general term[1] used for institutes, both private and public, that link firms to university research, provide contract research, and more generally engage and assist with the innovation process at various stages, from basic research to scale-up (Howells, 2006; Martínez-Vela, 2016; Rush et al., 1995; Utterback, 1975).

There have been several studies published in the last few decades that define, describe, and set benchmarks for RTOs. Many of these studies distill key success factors (Åström et al., 2008; Gijsbers et al., 2005; Martínez-Vela, 2016; Rush et al., 1995; UNIDO, 1979). Successful RTOs access guaranteed as well as competitive public funding to conduct research and develop

[1] While this paper uses the term RTO, these organizations go by many names in the academic literature, including research and technology institutes (RTIs). In should be noted that scholars have examined various organizations that share characteristics with RTOs, including: regional institutions (McEvily and Zaheer, 1999), government support institutions (GSIs) (McDermott et al., 2009), knowledge brokers (Hargadon and Sutton, 1997; Hargadon, 2002; Obstfeld, 2005), project-based organizations (Gann and Salter, 2000; Hobday, 2000; Whitley, 2006) and innovation intermediaries (Howells, 2006; Tether and Tajar, 2008). Some of these cases will be employed in this paper to provide a richer understanding of how SENAI’s ISI network might operate moving forward.

competences necessary to help firms commercialize innovations, bringing new products and services to market. In many cases, this involves building direct and sometimes intimate working relationships with universities and research institutions. The literature also notes that RTO success is often measured in terms of publications and patents, classic innovation output indicators. However, these indicators fail to fully capture the complex space that RTOs and other innovation intermediaries inhabit in innovation systems, especially in developing and emerging economies. In these places, innovation intermediaries must fulfill other important functions such as disseminating standards and best practices to support upgrading and value chain insertion by companies.

This paper begins with a closer look at existing RTO benchmarks. The central finding is that stable funding is an important (perhaps the most important) factor associated with long-term success among RTOs. A second point is that scholars have missed many other forms of intermediation in innovation systems. Thus, the discussion here moves beyond the RTO as an organizing model, looking to other organizational forms in order to develop a fuller understanding of how innovation intermediaries might foster dynamic innovation systems. To map the possibilities, an inductively derived typology of roles that innovation intermediaries occupy in innovation systems is presented. Data collected through interviews, site visits and secondary data sources underpin the typology, and these findings and examples are employed illustratively throughout the paper.

Innovation intermediaries (or RTOs, broadly defined) can operate primarily as *public utilities*, furnishing services aimed at inducing broad-based technological development or industrial upgrading in a given jurisdiction. This includes providing metrology, standardization, testing and quality (MSTQ) services and access to equipment and infrastructure. They can operate as *knowledge creators*, collaborating with universities to produce original research that both advances knowledge and also creates possibilities for new products and services downstream. They can operate as *stakeholder conveners*, bringing small and medium size enterprises (SMEs), large firms and research institutions together to solve specific problems. Finally, they can operate as *contractors*, offering contract services and customized and off-the-shelf products.

To be clear, this typology is not meant as a means of categorizing the different innovation intermediaries studied. The organizations that form part of this study can, and often do occupy multiple roles simultaneously. For example, TNO (Netherlands) exhibits characteristics of several ideal types, including knowledge creator, stakeholder convener and contractor, depending on the program or project. The purpose of the typology is to broaden our understanding of how innovation intermediaries strengthen innovation systems, especially those in developing and emerging economies. The paper concludes by suggesting that either the SENAI Innovation Institutes gain access to reliable, long-term basic funding, or they begin to look beyond classic RTOs for models. The ISIs should either work to change their surrounding environment in a way that allows them to operate like classic RTOs, or shift their business models so that they operate in a way that is better aligned with the reality they face.

2. Review of RTO Benchmarks

RTOs have been prominent features of many industrialized countries' innovation systems for a long time. For example, TNO was established in 1932. The Fraunhofer Society (Germany) was established in 1949. While all RTOs examined in this document have evolved considerably since they were first established, they have always been concerned primarily with the task of driving innovation in their respective economies. This often requires public funding of some sort. Indeed, one feature that all traditional RTOs share is that they receive some guaranteed or competitive basic funding, which allows them to develop the deep knowledge necessary to induce demand for R&D services further down the road (Arnold et al., 1998). Basic funding allows RTOs to fulfill one of their more important roles in innovation systems, that of knowledge creation.

In one of the first major RTO benchmarking studies published, Rush and colleagues (1995) examine eight RTOs in Europe and Asia of varying sizes and areas of technical expertise. Their sample includes RTOs as large and broad as ITRI (Taiwan), which employed 5,500 people and brought in $350 million in revenues in 1991, and was deeply involved in everything from basic research to technology diffusion; and as small and focused at CITER (Italy), which employed 17 people and brought in $3 million in revenues in the same year, and was only active in technology diffusion. Public funding (both earmarked and competitive funds) accounted for between 22 and 80 percent of these eight institutes' budgets, with RTOs less dependent on public funding often less involved in research and more involved in services.

In a more recent study of the GTS Institutes (Denmark) vis-à-vis their European counterparts, many of the findings from nearly twenty years earlier remain valid (Åström et al., 2008). The study finds that in 2007, all five institutes examined had some percentage of guaranteed public funding, although the Scandinavian institutes – GTS, IRECO, now called RISE (Sweden) and

SINTEF (Norway) – depended far less on the government for earmarked funds than did TNO and Fraunhofer. This study succeeds in bringing nuance to the deceptively simple concept of basic funding. The authors suggest that few institutes actually receive public funds unconditionally. As Table 1 shows, most governments are moving to competitive funding models conditional either on performance or on adherence to state-defined areas of strategic interest. These models allow the state more of a say in what sorts of competencies are incubated and developed.

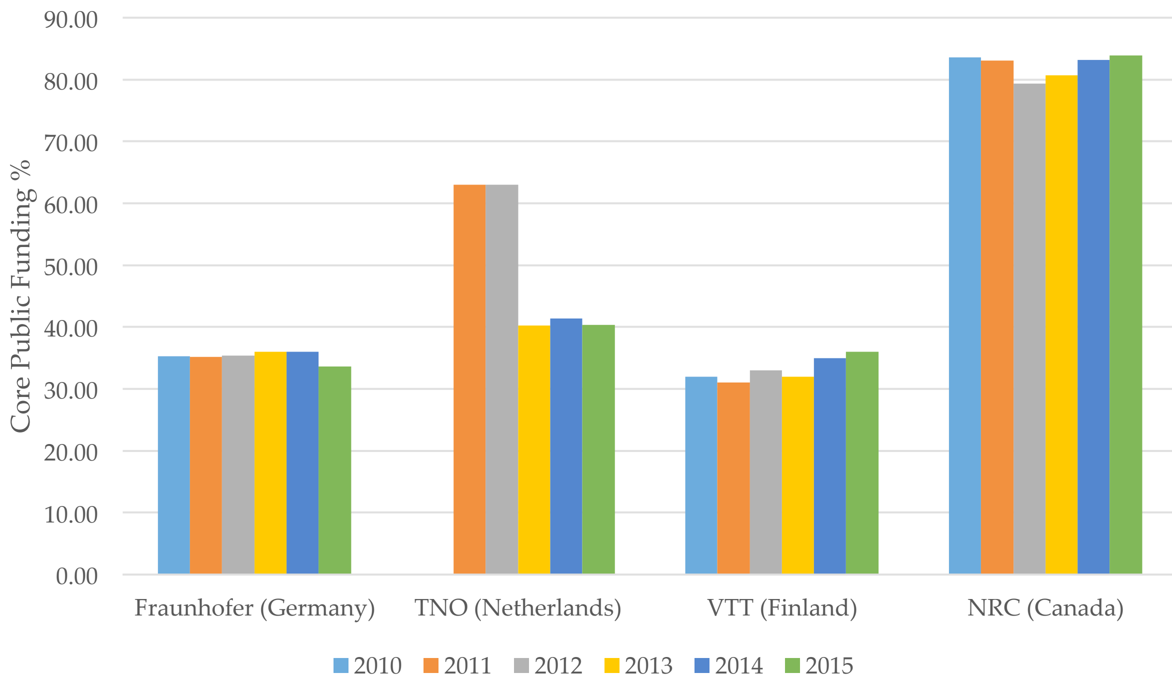
Table 1: Varieties of Basic Funding

Type of Funding	GTS	IRECO	SINTEF	FhG	TNO
Unconditional basic funding			X		X
Performance-related basic funding	X	X		X	
Strategically targeted basic funding (competitive)	X	X	X		
Strategically targeted basic funding (allocated)					X
Expansion/restructuring basic funding		X			
Other public R&D funding	X	X	X	X	X

Note: FhG is shorthand for Fraunhofer-Gesellschaft
Source: Åström et al., 2008

Despite the shift to conditional public funding models, most RTOs have access public funds on a consistent basis. This holds just as true for industrialized country RTOs (See Figure 1) as it does for RTOs in developing and emerging economies, albeit for different reasons. Most developing and emerging market RTOs depend heavily on unconditional basic funding because the industrial base that they were built to serve is underdeveloped from a technological standpoint. As Rush and colleagues (1995) find, the lack of sophisticated clients can be a significant constraint on RTO development. NSTDA (Thailand) was founded in 1991 and is modeled after successful RTOs from other countries. About 20 percent of its funding comes from contract research, while the other 80 percent comes from the government. While this funding distribution is skewed more towards government funding than that of most of the other RTOs, it is strikingly similar to that of NRC (Canada).

Figure 1: Core Funding as a Percentage of Total Revenues, Selected RTOs, 2010-2015



Source: Institute annual reports

As might be expected, reliance on basic funding is correlated with fidelity to state priorities. As Table 2 shows, RTOs that are more reliant on basic funding and have been given clearly defined roles are more likely to see adherence to state imperatives are their primary priority. AIST in Japan relies extensively on the state for basic funding (79 percent), and as a result, focuses on R&D projects that aligned with state priorities. While CSIR (South Africa) relies little on the state for basic funding, it does have a clearly defined, legislated role in the South African innovation system, and thus views adherence to government priorities as paramount. On the opposite end of the spectrum is DTI (Denmark), which only relies on the state for 10 percent of its total funding, and does not have a clearly defined role vis-a-vis the state. As such, DTI views serving industry as its primary aim. The less tied to the state an RTO is, the more likely it is to prioritize industry's needs. This often means working closer to the market and further from basic science.

Table 2: RTO Activities, Basic Funding and Priorities (2011)

Organization	Basic Research	Applied Research	Experimental Development	Basic funding as % of total	Priority	State-defined role
AIST (Japan)	Strong focus	Strong focus	Strong focus	79%	State	No
NRC (Canada)	Secondary focus	Strong focus	Secondary focus	79%	Balance	Yes
CSIRO (Australia)	Secondary focus	Strong focus	Secondary focus	61%	Balance	No
IPT (Brazil)	Little/no focus	Strong focus	Strong focus	33%	Balance	No
CSIR (South Africa)	Secondary focus	Strong focus	Secondary focus	28%	State	Yes
FhG (Germany)	Little/no focus	Strong focus	Strong focus	22%	Balance	No
DTI (Denmark)	Little/no focus	Strong focus	Strong focus	10%	Industry	No

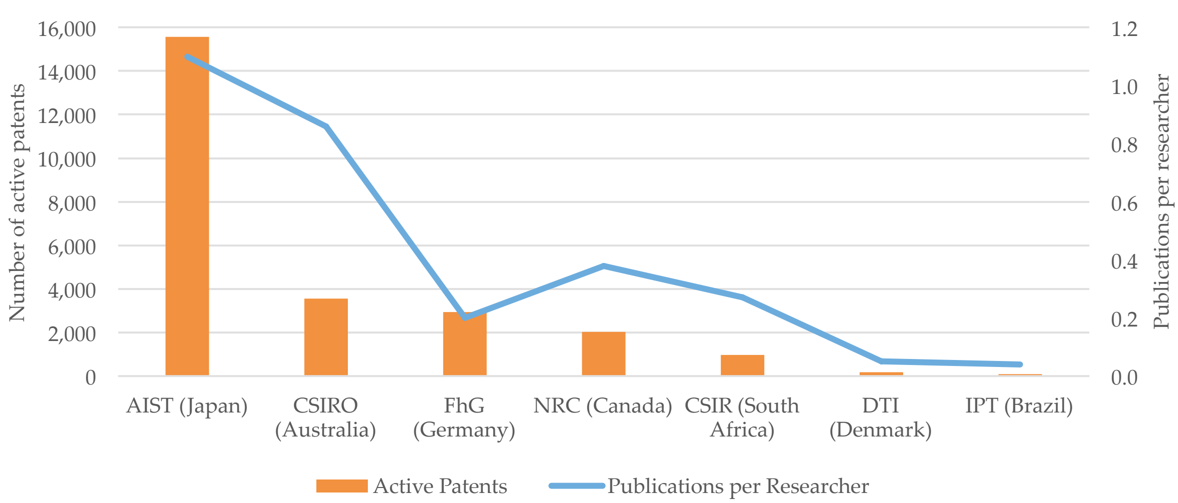
Little/no focus   Secondary focus   Strong focus

Source: Institute annual reports, existing benchmarks

Why is basic funding important? Åström and colleagues (2008) outline a three-stage model by which RTOs create knowledge. The first step is the generation or acquisition of a certain competence or set of competencies. The second involves further developing the competence (on a precompetitive basis) through collaborative work with customers and partners. The final step is the diffusion of mature knowledge to a customer on commercial terms. The first two stages require public funding, and that while stage three is ideally privately financed, it often depends on the client. The authors unequivocally state that "when the potential customer is an SME, a public subsidy is most of the time an absolute necessity" at all stages (pp. 7). Whether an RTO plays the role of technology leader or service provider depends, in part, on the capabilities in the local industrial base and the state's willingness to fund an RTO to resolve market failures (Arnold et al., 1998).

Two common output indicators by which RTOs are often benchmarked include patents and publications. If we consider Åström and colleagues' (2008) model of knowledge creation, it should be no surprise that the RTOs with higher rates of public funding are those with more patents and publications (See Figure 2). In sum, RTOs require basic funding to fulfill their primary roles in innovation systems. This was just as true twenty-five years ago as it is today. It is just as true of organizations based in industrialized countries as it is of those based in developing and emerging economies. And while we may be witnessing a shift away from guaranteed to competitive basic funding, it bears stating that most European RTOs have been operating for many decades, giving the time to develop their technological capabilities necessary to thrive despite the shift towards less stable public support.

Figure 2: Patents and Publications at Select RTOs, 2014



Source: Institute annual reports

RTO benchmarks compare how efficiently different organizations transform inputs like researchers, funding and infrastructure into outputs such as patents and publications, as well as spin-offs. In doing so, they create a narrow means of establishing what constitutes success and what constitutes failure. In fact, the most successful RTOs may be those with high enough competencies to engage in contract research, which gives them an ability to self-fund and stay close to the market, where patents for basic research are less relevant. Furthermore, by tracing only inputs and outputs, benchmarks place the organization in a black box. The truth is that RTOs play multiple important roles in innovation systems, only one of which is knowledge creation. As Gijsbers and colleagues (2005) put it, "the old 'bridging metaphor', based on the concept of a linear transfer of technology, has become outdated" (pp. 70). The relevant benchmark, therefore, depends on the context. If we adopt a broader view, examining RTOs in emerging and developing economies, as well as examining organizations that are not quite RTOs but share several qualities with them, we can begin to understand what it is that innovation intermediaries actually do.

3. A Typology of Innovation Intermediaries

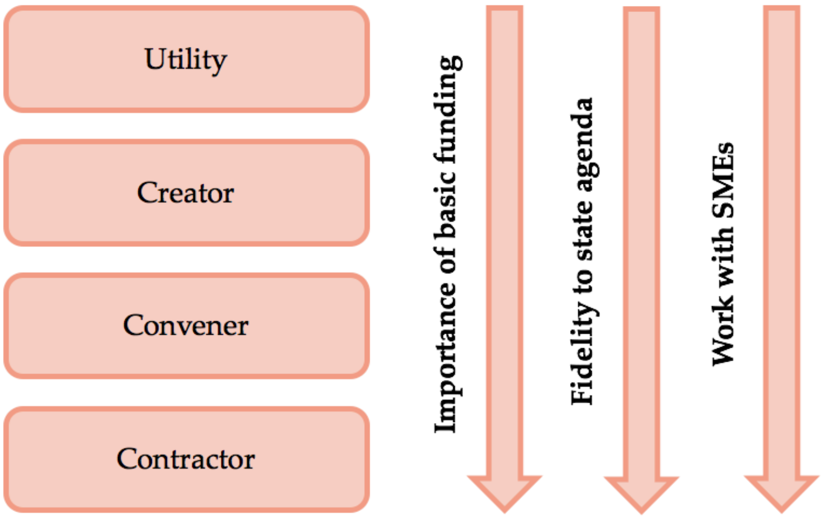
Conventional wisdom states that in order to be effective drivers of innovation, RTOs need reliable access to public funding. But if we look beyond the narrow confines of the traditional RTO, we find a variety of models that offer means of operating without direct, long-term access to public funding. In essence, this section moves beyond the RTO in particular to include various kinds of innovation intermediaries. In so doing, it creates a graded typology, outlining the four principal roles that innovation intermediaries can occupy in a given innovation system, and how those roles imply different sorts of inputs, as well as different means of diffusion and engagement. Innovation intermediaries can operate as *utilities*, *creators*, *conveners* and *contractors*. Again, these roles are not mutually exclusive. In fact, most innovation intermediaries play more than one role at a time.

The term *innovation intermediary* is useful in that it refers to the broader process of intermediation without succumbing to the norms and rigidities that the term RTO has acquired in the literature (Howells, 2006; Tether and Tajar, 2008). The term RTO implies a linear view of the innovation process as well as a relatively straightforward set of characteristics, including some degree of public finance aimed at producing patents, publications, and eventually, innovations. An innovation intermediary might have access to public funding or it might not. It might be a public organization or it might be private. Some innovation intermediaries act principally as purveyors of public goods, or *utilities*. This type of innovation intermediary provides infrastructure for research, metrology and certification services (MSTQ), and often furnish SME support services. One program that is not an RTO, or even a single organization, but approximates this ideal type is the Manufacturing Extension Partnership (MEP), a public-private partnership that supports manufacturing firms in all 50 states (and Puerto Rico) in the United States (McEvily and Zaheer, 1999; Shapira, 2001). The term *utility* implies a significant reliance on public funding to address market failures.

Innovation intermediaries can act as knowledge *creators*. This is the role most closely associated to that of the traditional RTO. In order to create knowledge, an RTO might collaborate with a university to gain access to extant basic research. In some cases, the RTO might engage in basic research itself (see AIST, for example). However, more commonly, an RTO creates knowledge by conducting applied research, engaging in experimental development, and then diffusing a given technology, for example via patent licensing or spin-off. This role also requires considerable amount or public finance, as discussed in the previous section. Intermediaries can also act as *conveners*, bringing critical players in an innovation system together. This might involve bringing firms and research institutions together to solve a specific problem or creating public spaces and public events aimed at fostering formal and informal links among ecosystem actors. Two RTOs that convene actors quite effectively are TNO and Fraunhofer.

Finally, innovation intermediaries might take on the role of *contractor*. This role is closest to market, and requires the least amount of public funding, or none at all. It includes offering contract R&D services, producing customized goods and services on the basis of the organization's repository of projects and ideas, brokering knowledge between clients in different industries, creating training programs for industry clients, and increasingly, following their clients and setting up research or technical centers overseas. This role is often undertaken by RTOs with very little access to public funding, including some of the Scandinavian RTOs, as well as by private innovation intermediaries like R&D services providers, project-based organizations and consultancies. The importance of basic funding, fidelity to the state's agenda, and ability to work with SMEs all diminish as one moves from the *utility* to role to the *contractor* role. See Figure 3 for a fleshed out typology of innovation intermediaries.

Figure 3: Innovation Intermediary Typology



Less reliance on the public sector for funding implies a less obvious need to adhere to the state's agenda, as has been previously discussed. Because working with SMEs is costly and seldom profitable, it is often done by organizations with access to public funding. SMEs are often under-resourced, and thus do not have the discretionary funding necessary to pay for projects. Furthermore, these firms are often under-staffed, meaning that they may not have the absorptive capacity (Cohen and Levinthal, 1990) to make use of externally sourced knowledge unless it is firmly implanted within the firm by the RTO, including the requisite training of personnel. Finally, SMEs, especially those that are technology-intensive, may be more advanced in their niche than other actors in their national innovation system, but lack complimentary capabilities.

Despite these difficulties, many traditional RTOs continue to prioritize working with SMEs. Many collect and publish numbers on the percentage of revenue generated from contracts with SMEs. For example, in 2015, 46 percent of VTT's (Finland) income came from SMEs.

Approximately 42 percent of the High Value Manufacturing Catapult's (UK) income came from SMEs. There are two reasons why RTOs prioritize and track the degree to which they work with SMEs. The first is politics. The state is often concerned with supporting SMEs because they make up an important part of the industrial base. RTOs that demonstrate that they are working to support SMEs are more likely to have access to public funding. The second is technology. RTOs work most often with what Arnold and colleagues (1998) call "technological competents," SMEs with strong technological capabilities. In these cases, the SME can help improve an RTOs competences, and even bring its technologies to bear on problems facing larger firms.

4. Classifying Innovation Intermediaries

The typology outlined here is rooted in the empirical material collected for this study. These ideal types have been developed on the basis of field visits, interviews with key personnel, previously published academic studies and other secondary materials. In this section, each ideal type is linked to the empirical cases on which it is constructed. The cases include various classic RTOs, many of which are based in Western Europe. However, they also include RTOs based in developing and emerging economies, public and quasi-public intermediaries in both industrialized and developing contexts, as well as private organizations such as consultancies and non-profit research institutes. All of the organizations examined here exhibit qualities of most, if not all, of these ideal types. They are categorized according to which qualities are most strongly expressed.

4.1. Utility-type innovation intermediaries

Innovation intermediaries that serve as *utilities* support firms' upgrading efforts by providing access to infrastructure, researchers and technicians, by diffusing best practices and standards, as well as by connecting previously disconnected actors. The academic literature includes many case studies examining innovation intermediaries that act primarily as utilities. Lee et al.'s (2010) case study of intermediated networks in Korea explores how public agencies support collaboration among SMEs. McEvily and Zaheer's (1999) examination of the MEP provides convincing evidence that firms with ties to regional institutions are best placed to acquire competitive capabilities. McDermott et al. (2009) and Corredoira and McDermott (2014) explore the role of Argentine government support institutions (GSIs) in supporting firm-level product and process upgrading efforts in previously isolated producer communities. These GSIs build up knowledge through interactions with domestic and international partners, and act as repositories for best practices, international standards and locally appropriate technologies.

What many of these organizations have in common is that they are closely tied to the public sector. The MEP is sponsored by the National Institute of Standards and Technology (NIST), and focuses primarily on improving the competitiveness of American SMEs through the provision of federally and state funded technology services (Shapira, 2001). While the MEP is not an RTO, it is a partially government-funded program that shares the same mission of technology diffusion aimed at improving competitiveness in the American industrial base. An RTO that embodies the role of public utility is the NRC (Canada). This organization is funded primarily through the public sector (84 percent). As one might expect, it expends significant resources on building and fostering innovation capacity in SMEs.

According to one industry practitioner interviewed for this study, the Industrial Research Assistance Program (IRAP) is the primary mechanism by which NRC reaches Canada's industrial base. Through this program, firms receive advisory services from one of 255 Industrial Technology Advisors (ITAs), full time field agents that have retired from successful careers in the private sector, and in some cases, have received support from IRAP themselves. Through the IRAP program, the NRC reaches 10,000 firms a year, only 2,500 of which receive public funding. It increases NRC's surface area dramatically, employing experienced field agents to make its services available to firms traditionally overlooked by more commercially oriented RTOs. While only some firms receive funding to support technology adoption, all benefit from advisory services aimed at helping them adopt new technologies, find strategic partners, access foreign markets and improve productivity.

The NRC model has been exported to developing and emerging economies as well, in particular, to Mexico and Thailand. While the program is still emergent in Mexico, it has been in place in Thailand for some time. Thailand's NSTDA is funded primarily through the public sector (80 percent of budget). Its Industrial Technology Assistance Program (ITAP) was developed with support from the NRC. As is the case with the Canadian IRAP program, ITAP provides technical experts to organize technical training and seminars, assist with technology acquisition, provide industrial and technology information, and facilitate linkage to other industrial service organizations or research institutes. While IRAP is fully funded by the government, firms have to cover 25 percent of the cost.

While SME support is an important element of what utility-type innovation intermediates do, it is by no means the only role they play in innovation systems. Many intermediaries that exist in this category also play an important role by offering services known collectively as metrology, standards, testing and quality (MSTQ). As Pietrobelli and Rabellotti (2011) argue, institutions that provide MSTQ services are vital for developing and emerging economies in that they create possibilities for firms to engage with global value chains (GVC). They reduce transaction costs as well as information asymmetry between global lead firms and developing country suppliers. This is important because meeting basic requirements for documentation, quality, and IT-compatibility with foreign buyers is almost always the first step for being considered as a supplier in GVCs. Such intermediaries in Argentina's wine and automotive components sectors support suppliers' upgrading efforts (Corredoira and McDermott, 2014; McDermott et al., 2009). RTOs in industrialized countries sometimes internalize MSTQ as well. Apart from conducting basic and applied research, AIST (Japan) houses the National Metrology Institute of Japan.

Once a publicly funded research and certification body focused on the built environment, the Building Research Establishment (BRE) in the UK was forced to seek new sources of revenue upon privatization in the 1990s. While the organization continued to depend heavily on the local and central government until the late 2000s, public funding makes up a negligible portion of turnover today. BRE generates a majority of its revenue by certifying construction materials as being aligned with UK or European standards. Thus, the organization serves an important public function: ensuring that the materials that comprise the built environment meet certain quality, health and safety standards. That function happens to be lucrative as well, as certification is easily scaled, and costs a minimal amount on a per unit basis. What this highlights is the importance of international (regional and sometimes global) standards, which are often required for export success and participation in GVCs. The public utility function can be critical for discovering, codifying, translating, and disseminating international standard for local firms.

To sum up, innovation intermediaries that operate as public utilities can serve a number of important functions in innovation systems. They support technological upgrading efforts on the part of SMEs and provide MSTQ services as well as access to global standards, which both foster greater global integration and export potential on the part of firms. These functions also produce positive externalities, for example, inducing previously non-R&D-intensive firms to invest in R&D, improving quality and increasing productivity, and encouraging firms focused squarely on the domestic market to seek success abroad. However, working with SMEs entails high transaction costs and requires that intermediaries cover a sizeable and often less visible portion of the industrial base. MSTQ services, in particular, are almost always subsidized by the government. The cases examined here, including the MEP, NRC, NSTDA and AIST all count on the public sector for more than 80 percent of their budgets. It is no surprise then, that they operate much like public utilities, offering services that the market would likely not furnish due to the high transaction costs and poor returns involved.

4.2. Creator-type innovation intermediaries

The role of knowledge creator is most closely associated with traditional conceptions of RTOs. As Åström and colleagues (2008) note, RTOs create knowledge by developing or acquiring a certain competence, further developing that competence on a pre-competitive basis, and then diffusing actionable knowledge, products or services to a client on commercial terms. It is acknowledged that creator-type innovation intermediaries develop competences in myriad ways, through partnerships with universities or through internal research projects. There are a number of studies that outline the organizational processes by which RTOs generate and organize their internal competences (Arnold et al., 1998; Leitner, 2005; N. Mrinalini and Pradosh Nath, 2000). One less commonly discussed means of acquiring competences that will be discussed here is the *spin in*. Apart from a brief discussion of the spin in process, this section will focus primarily on the knowledge diffusion process, specifically on licensing and on generating spin-offs.

4.2.1. Spin in

The idea of a *spin in* was first elaborated and implemented by Michael Volpi, Vice President of Business Development at Cisco Systems. He famously asked "Why not custom make a start-up to build exactly the product we want, and then buy them later if they succeed?" (Cited in McJunkin et al., 2000, pp. 6). When both making and buying are problematic, then why can't a lead firm "build to buy?" This strategy allowed Cisco to develop a new technology beyond the bureaucracy of the firm, leading to faster development, while also ensuring that there would not be a culture clash when it was integrated, as often happens with acquisitions (Mayer and Kenney, 2004). The spin in strategy was first employed through the development and later, the purchase of Ardent Communications.

The same strategy has been adopted by some RTOs, although clearly in a very different form. Of course, RTOs seek to acquire competences from the external environment, sometimes by hiring research teams with relevant skills, sometimes by incubating startups proficient in a technology that they would like to further develop. Indeed, RTOs like RISE (Sweden), CPqD (Brazil), and

CESAR (Brazil) have developed their own incubators for this very purpose. Still, attracting an entrepreneur to set up his or her enterprise within the confines of an RTO cannot always be an effective means of building competences. First, the RTO may not have the absorptive capacity necessary to understand the acquired or incubated knowledge, or to develop it further with a view towards commercialization at a later date. Second, there is not guarantee the entrepreneur will be involved with the RTO long enough, and moreover, the presence of the start-up could reduce pressure to build up competencies in house. In short, the spin in strategy is not without risk and cannot be a replacement for a commitment of significant internal competency-building efforts through discretionary public resources.

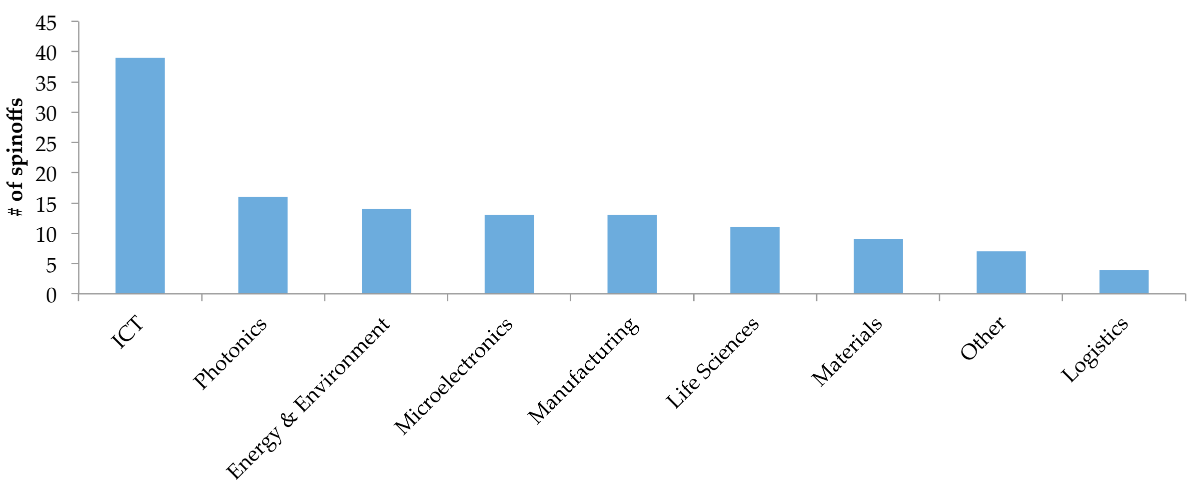
4.2.2. Technology licensing

As is often the case with universities, technology transfer via licensing is rarely lucrative for RTOs. According to a manager at one large RTO, patent licensing is mostly about public relations. In this case, licenses only generate €500 thousand to €1 million on an annual basis, a paltry 0.1-0.2 percent of the organization's annual turnover. Because licensing is an important means of branding RTOs as technology leaders, these organizations often encourage researchers to patent new discoveries. They may then market them through various online platforms. These marketing efforts aims to match entrepreneurs and SMEs with relevant technologies. As one might expect, licensing generates the highest proportion of total revenue for the RTOs that apply for and receive the highest number of patents. Licensing makes up a sizeable portion of revenues at AIST (19 percent), CSIRO (13 percent) and Fraunhofer (8 percent).

4.2.3. *Spin off*

When an innovation intermediary creates new knowledge for which there is no immediately obvious use or market, it might opt to encapsulate the technology and spin it off as an independent company. Many of the leading global RTOs have codified this process. Fraunhofer Ventures (See Figure 4) and TNO Companies have successfully spun off many companies (Martínez-Vela, 2016). Various Brazilian institutions have successfully spun off companies as well, although the process remains less codified than it does in European institutions. CPqD (Brazil) was created as the internal R&D department for Telebras, the state-owned telecommunications firm, in 1976. Through the 1970s and 1980s, CPqD developed a series of core competences on the basis of its internal research as well as its relationships with universities such as Unicamp. However, CPqD found itself at a crossroads in the 1990s, when it became apparent that Telbras would be privatized, meaning that CPqD would have no guaranteed funding stream or customer.

Figure 4: Total Fraunhofer Ventures Spin-Offs as of 2015



Note: 126 spin-offs in total
Source: Uygun, 2016; data from Fraunhofer Ventures, 2015

CPqD's survival strategy involved codifying its extensive knowledge base to create off-the-shelf products and services, lobbying to retain some public funding (which it did through the creation of Funttel in 2001), and spinning off technologies for which there was no obvious market. Padtec, a fiber optics hardware manufacturer, was spun off in 1999. Since then, CPqD has spun off ten companies than generate nearly one billion Reais in annual revenues. The latest spin-off is BrPhotonics, a startup that emerged from CPqD's optical division in 2014, when founder Julio Cesar De Oliveira produced a business plan and presented it to CPqD. Because there was no domestic market for the technology he sought to commercialize, he was told to find a foreign partner, which he did in GigPeak, a US-based fabless semiconductor design house, which transferred its integrated photonic modulator technology to Brazil. It also leveraged funding from FAPESP's PIPE program, as well as equity funding from FINEP, to further develop the technology. It remains co-located with CPqD today, sharing equipment and applying for R&D funds with its partner. As a Vice President of CPqD puts it "porous boundaries are a fundamental aspect of CPqD's relationships with its spinoffs." BrPhotonics is a product of Brazil's innovation ecosystem, as well as a product of CPqD's internal innovation ecosystem.

Innovation intermediaries that transform applied research into products and services with market potential are classified here as knowledge creators. This category best captures the role that RTOs traditionally embody. As Figure 3 suggests, such organizations depend less on public funding than do the utility-type innovation intermediaries. By extension, they have a heightened commercial imperative, and thus have a more difficult time working with SMEs. These organizations might incubate startups in order to spin-in new ideas and technologies, but representatives of various organizations interviewed for this study stated that this is the least important means of generating and developing new competences.

4.3. Convener-type innovation intermediaries

As Gijsbers and colleagues (2005) make clear, viewing RTOs as cogs in a linear, deterministic process of technology development is problematic. Indeed, these organizations add value beyond the applied research they conduct and the innovations that they spawn. One important role that RTOs, and more broadly, innovation intermediaries play is that of convener. This role involves bringing various actors in a given innovation ecosystem together to solve specific problems, or to tackle challenges too large to be addressed by any single entity on its own. Although most RTOs and innovation intermediaries operate as conveners in one way or another, the two organizations that fulfill this role most effectively are TNO and Fraunhofer.

Organizations that act as conveners rely heavily on competitive public funds to do so. For example, TNO's Technology Cluster Program allows various companies with a similar set of questions to aggregate their resources and leverage public funds in order to find solutions. The Dutch Ministry of Economic Affairs caps each cluster at five companies, which must all be SMEs. A typical company participating in the TNO's Technology Cluster Program employs 10 to 25 people. Each firm contributes €2,000, and the government contributes an additional €40,000 for a total of €50,000 per cluster. The funds only cover the hourly cost of hiring researchers at TNO. TNO convenes day-long meetings with each firm, as well as a few joint meetings in which all firms participate. The aim is to bring companies together and to build trust between them so that they might collaborate on technology development efforts further down the road.

While TNO's Technology Cluster Program has been developed as a means of reducing the transaction costs associated with driving technology development in small firms, Fraunhofer's consortia-based approach to applied research has been about linking small firms, large firms and research institutions to collaborate on research and diffuse new innovations. These consortia are typically subsidized by competitive public funds, like the European Commission's Horizon 2020 program. Each company participating in a consortium has some of their related expenses reimbursed; between 20 and 30 percent for large firms and up to 50 percent for SMEs. Universities and RTOs are fully reimbursed for the work they do. Fraunhofer takes two different approaches to developing and managing consortia, a complementary competency-based approach and a value chain-based approach. The former is most often associated with radical innovations while the former often produces incremental or process innovations.

The complementary competency-based approach involves bringing a Fraunhofer institute, a university, and an SME together to conduct applied research. In this case, each actor brings a specific competency, or set of competencies to the table. An example of this approach is CARIM, which is convened by the Fraunhofer Institute for Chemical Technology (ICT) and RI-BA Composites (Italy), an advanced composite materials designer and manufacturer, with the aim of developing a light-weight, carbon fiber wheel for automobiles. Also involved are three SMEs and two research institutions. The value chain-based approach brings lead firms, suppliers, and research institutions together in order to ensure that the critical parts of the value chain are involved in both the development and implementation of new technologies, facilitating their implementation. In these cases, the large firm is interested in the SME's technology, the small firm wants market access, and the research institutions want to generate revenue and participate in solving real world problems. As Berger and colleagues (2013) found in the context of the United States, innovative firms face difficulties bringing new products to market without linkages to a robust ecosystem of partners, including suppliers and specialized service providers.

While the newly created Manufacturing Innovation Institutes (MIIs) in the United States are not classified as RTOs, they are likely to play an important intermediary function by fostering the development of advanced manufacturing technologies and improving U.S. manufacturing competitiveness. Because the network is relatively new, and the institutes focus on very different industries, there have been a variety of models adopted. However, those that are furthest along have developed as public-private partnerships that bring together key stakeholders in a consortium. For example, the Advanced Regenerative Manufacturing Institute (ARMI), which is closely tied to the Advanced Tissue Biofabrication Manufacturing Innovation Institute (ATB-MII), is a consortium of 47 industrial partners, 26 academic partners, and 14 government and non-profit partners. The convening function is not limited to formal, structured programs.

An emerging market intermediary that serves primarily as a convener is the Durban Automotive Cluster (DAC) in South Africa, a PPP between the eThekwini Municipality and the automotive manufacturing sector in the state of KwaZulu-Natal. The cluster brings lead firms and suppliers together to increase the sector's productivity, diffuse best practices and support insertion by suppliers in their clients' regional and global supply chains. Oftentimes, RTOs and innovation intermediaries that fulfill convening functions simply serve as meeting hosts, providing a neutral space where erstwhile competitors might get together for informal gatherings. While these functions are ancillary to their central purpose, they are nonetheless important means of creating coherence and increasing the density of interaction in often disconnected or spatially dispersed innovation systems.

4.4. Contractor-type innovation intermediaries

Innovation intermediaries that respond most directly to market incentives are those associated with the *contractor* role. The organizations included in this category often have limited access to public funding, and in some cases, do not seek it. Because this is the case, these organizations seldom need to operate in alignment with the state's agenda. Nor do they need to work on behalf of SMEs. As has been previously made clear, few classic RTOs fit this category. All classic RTOs count on some access to public funding. Intermediaries that successfully embody the contractor role do one (or many) of the following things well: broker knowledge, create products and services, create captive markets, codify their offerings, and internationalize with their principal clients. This role requires intermediaries to think more like businesses than like public utilities, as they do not have the basic funding, nor, in some cases, the public mandate that classic RTOs enjoy.

Many organizations identified by Hargadon and Sutton (1997) to be knowledge brokers tend to organize themselves around projects. Hargadon (2002) defines knowledge brokers as organizations that exploit "fragmented social structure by bridging multiple domains and moving ideas from where they are known to where they are not" (p. 44).[2] He describes the process of knowledge brokerage as one that requires an actor to, 1) have access to multiple knowledge domains, 2) gain access to multiple domains, 3) learn about the problems and the existing resources in each of these domains, 4) link old knowledge with new problems and new knowledge with old problems, and 5) introduce innovations into disparate domains. Emblematic examples of knowledge brokers include engineering design consulting firms like IDEO and management consulting firms like McKinsey & Company. These organizations do not require public funding to develop competences. They use projects to create organizational repositories of tools and libraries of ideas and solutions on which they can rely to solve problems for others at a relatively low marginal cost of production.

In some cases, intermediaries encapsulate the knowledge acquired either through publicly-funded research or project-based work to develop off-the-shelf products and services. In Brazil, CPqD has leveraged its competences, developed through decades of consistent public funding, in order to develop a suite of services and products related to telecommunications network management systems. In particular, the organization has developed and now commercialized (in Latin America and Europe) operations support systems (OSS) and business support systems (BSS) – products vital to the delivery of telecommunication services. CPqD is only starting to explore a product-based strategy, while the BRE began pursuing this strategy a few years ago.

[2] The process of brokerage requires one to make two assumptions, one about the nature of innovation and another about the structure of the social world. For knowledge brokerage to yield new, commercially viable ideas, one must assume that innovation is recombinant in nature (Schumpeter, 1934). Furthermore, for knowledge brokerage to be possible, one must assume that the social world is divided into numerous isolated domains, or small worlds (Burt, 1992).

Two years ago, BRE's leadership decided to develop a stronger market orientation. Today, 25 percent of the organization's turnover comes from products. There has been a shift away from research as the organization's main revenue generating activity, and towards the development of research-backed products. The shift is one away from offering bespoke research services and towards codifying existing knowledge to produce tools. Research is labor- and cost-intensive. It is difficult to scale. Products, on the other hand, often have a small cost of marginal production (especially software), and are therefore optimal for generating revenue without heavy expenditure of internal resources. As one BRE executive interviewed for this study puts it:

> *What we used to sell was time and materials. Someone would come along and say 'I need to borrow your expertise for this period of time. Can you tell me what you know about X?' We would write papers for them and/or research documents, and they would pay us for it based on time and materials. That constrains you by the amount of time you've got and the number of people you've got. Whereas actually, if you develop products, they become scalable, replicable, and they're not time-bound.*

As the case of BRE demonstrates, creating a product or platform reduces the costs of production. Like BRE, some traditional RTOs also codify their research to create products. One TNO manager suggests that the creation of products and platforms is a useful strategy for various reasons, only one of which is the cost of production. In the case of TNO, the creation of platforms appears to be valuable for clients because it de-risks a technology that the client would like to incorporate. If TNO hands its applied research off to a client, it might be at technology readiness level (TRL) 3 or 4. This research may not actually have market potential, meaning that the firm has taken on a great deal of risk by purchasing or co-developing this technology. On the other hand, if TNO furnishes its client with a minimally-customized platform, it can hand its client a product closer to TRL 5 or 6, meaning that the firm takes on far less risk when it incorporates the technology. Its core has been tested in other markets, with other clients.

BRE generates a sizeable portion of its income through the provision of certification services. These services are very important in that they create and enforce a common understanding of what constitutes suitable building materials. Positioning oneself as the certification body is also an important means of carving out a lucrative market, as BRE as found. Various Brazilian intermediaries have pursued a similar strategy, leveraging protected spaces in the Brazilian R&D services market to thrive. Two such organizations are CESAR (Pernambuco) and Eldorado (Sao Paulo). These organizations have received certification from the Ministry of Science, Technology, Innovation and Communications' (MCTIC) Committee for Information Technology (CATI), and are thus two of the few research institutes that firms can employ to spend the R&D earmark required by the Informatics Law. Thus, these organizations do not receive any guaranteed basic funding, but leverage their position in a protected market for R&D services to grow. The same is true of research institutions certified to execute projects associated with other industrial policies, as is the case in oil & gas (ANP).

Finally, innovation intermediaries without reliable access to public funding often seek to globalize, either through research partnerships or through follow sourcing, where suppliers follow their clients as they invest in new markets (Humphrey, 2003). In both cases, internationalization is more often opportunistic than it is strategic. There are numerous cases of each globalization strategy. BRE recently partnered with the University of Brasilia and the Brazilian Chamber of the Construction Industry to create a demonstrator for research into the built environment (PISAC). A director of VTT International makes clear that 99.5 percent of all innovation happens outside Finland. Therefore, a big part of his job is to help connect Finish firms with centers of excellence around the world. In some cases, VTT even engages in follow sourcing. For instance, one of its large clients, a chemical company, was poised to make a significant investment in Brazil. VTT followed them and set up an office in the country with the aim of providing the Brazilian subsidiary with R&D services. In many ways, R&D functions very much like other corporate functions, with suppliers following their big clients, and in some cases, even investing before their clients do.

Innovation intermediaries with limited access to basic funding experience a great deal of difficulty in generating new competences internally. They do not have the discretionary public funding necessary to stay ahead of market needs (Arnold et al., 1998). Some of these organizations discussed here are entirely private entities with no mandate to play a role in their country's innovation system. Others include RTOs that engage in market-oriented activities. Intermediaries taking on the contractor role do not need to align their activities with the government's agenda. One consequence of their limited reliance on the state is that they seldom work with SMEs or entrepreneurs. They might spin off new enterprises, but are unlikely to work with firms that cannot finance projects on their own, at least in a research capacity. These organizations might support under-resourced firms by offering slightly customized products and services. Finally, the fact that these organizations have limited access to public funding means that they necessarily work at later TRLs, where technologies have been stripped of a great deal of risk and uncertainty.

5. Implications for the SENAI Innovation Institutes (ISIs)

This paper has sought to create and flesh out a typology that captures the multiplicity of roles that innovation intermediaries can take on. They can operate in ways similar to public utilities, offering firms access to public goods that support their upgrading efforts. They can operate as knowledge creators, the role most closely linked to that of a classic RTO, engaging in applied research and pushing new ideas to market. They can take on the role of convener, bringing different actors together in order to solve collective problems or offering spaces that facilitate the development of dense networks. Finally, they can operate like contractors, brokering knowledge, creating and selling products and services, offering their clients R&D services on a contract basis and internationalizing to support their clients in new markets. As the cases highlighted in this paper show, the roles are not mutually exclusive. These ideal types are simply heuristics that attempt to simplify a complex empirical reality.

This typology has important implications for SENAI's newly created network of innovation institutes (ISIs). The first, and perhaps most important implication of this work is that if they cannot secure access to long-term basic funding, the ISIs must look beyond classic RTOs for models. As the RTO benchmarks overview makes clear, the ISI network may be modeled on a classic RTO, but the fact that it is not funded by the public sector means that it may need to explore other models. Furthermore, it will be impossible for the network to adopt a foreign model without properly adapting it to the Brazilian context, and SENAI must be selective about the characteristics it chooses to emulate. Unless stable public funding can be secured, it must look beyond classic RTOs in general, and towards different types of organizations that share its characteristics and constraints.

It has long been understood by scholars of strategic management that firms must be able to identify and mitigate against a broad range of external forces in order to carve out competitive positions in their given industries (Porter, 1980). It has also been understood that beyond mitigation, firms can manipulate their external environment, leveraging external resources, and even change the very rules of the game to improve their competitive positions (Baron, 1995; Oliver, 1991; Pfeffer and Salancik, 1978). The ISI network can either adapt to existing circumstances, taking on roles that depend less on state resources, or change the external environment in order to create the very resources it needs to operate as a classic RTO would. The first strategy might involve the ISI network avoiding the role of public utility, of knowledge creator and even of convener, instead becoming an entity that takes on the role of contractor.

As the typology outlined in this paper makes clear, operating like a knowledge creator or utility requires access to some substantial amount of guaranteed public funding. Organizations that fit most neatly into the knowledge creator category are unlikely to work with non-innovative firms. As one person interviewed for this study made clear, Fraunhofer's role is not to make companies innovative; it is to make innovative companies better at innovating. It works with "technology competents," not with SMEs that lack the absorptive capacity or in-house capabilities necessary to work at the technology frontier. Furnishing MSTQ services and generally supporting under-resourced firms' upgrading efforts requires public support. Organizations that most closely occupy the utility role work both with innovative firms and with non-innovative firms, inducing technology adoption in the latter. Generating and developing the competences necessary to support innovative firms requires access to public funding (Åström et al., 2008).

If the ISI network is unable to secure access to sustained basic funding at first, then it is unlikely to be able to engage in applied research that induces market demand later on. The ISIs are likely to continue working strictly in line with demand from their industry clients. However, there are means of generating and diffusing knowledge that do not require public funding. As the knowledge brokerage model demonstrates, having access to clients in multiple industries creates the possibility of recombinant innovation. And because the ISI network was designed to cover a wide range of industries, it has access to various small worlds that by definition, do not have access to each other. Thus, if the ISIs were to truly operate as a network, then they could leverage the knowledge developed to solve one problem in one industry in order to solve a similar problem in a different industry.

A case that embodies this strategy can be found in the Flextronics Institute of Technology (FIT), a Brazilian non-profit R&D center that has developed strong RFID capabilities through its work with several multinational electronics manufacturers doing R&D in Brazil as a result of the Informatics Law. FIT is now leveraging its RFID capabilities to solve problems for agribusinesses interested in developing more precise ways of tracking yields. Some ISIs have begun to consider the possibility of recombinant innovation on the basis of successful projects. A number of them have gained access to captive R&D markets such as the ANP for oil & gas, the Informatics Law for electronics, and Embrapii for projects in any industry. By gaining access to large firms' captive R&D resources, the ISIs can develop technological capabilities that may later be useful when engaging with clients in different industries. For example, SENAI Cimatec developed the Flatfish in collaboration with various partners, including Shell, and is now looking to leverage its newfound expertise in robotics to solve problems for potential clients in other sectors, including mining. Here, market-driven projects can lead to the creation of capabilities useful for driving innovation in other sectors.

Furthermore, the ISIs could codify knowledge accrued through R&D projects to develop off-the-shelf products and services, as organizations like CPqD, TNO and BRE have done. Digital products and services have a low marginal cost of production, and thus can offer high margins. These products could simply be tools that firms use to diagnose, troubleshoot and solve specific problems. They could also be training modules. Developing and delivering online training modules might offer SENAI a means of better integrating its education and technology spheres.

Finally, the ISIs could engage in follow sourcing with large clients. Many of the ISIs are already working with foreign or domestic multinational firms. Foreign multinationals often have important R&D operations overseas. Because parts of the R&D function – especially development, testing and validation – are increasingly outsourced, the ISIs could serve their principal clients with R&D services in other locations, reducing transaction costs. Further, the ISIs could help their Brazilian clients internationalize their R&D operations by making investments in technology centers with them, or on their behalf.

On the other hand, the ISIs could work to manipulate the external environment so that it allows them to be the RTOs that they were envisioned to be. This would require gaining access to some guaranteed public funding. Rush and colleagues (1995) separate RTO success factors into those that are internal to the organization, those that are external, and those that are negotiable. While they classify stable policy and consistent funding as external factors that cannot be manipulated, SENAI does have the ability to change the rules of the game and negotiate access to stable funding. Aligning the ISIs with the state agenda through work on projects in the public interest could create the possibility of public funding in the future. The creation of Funttel for CPqD provides an example of how the ISIs might gain access to a stable source of public funding.

This paper has sought to move beyond RTO benchmarking in order to identify and underscore the variety of ways in which intermediaries strengthen innovation systems. The ISIs have a unique opportunity to bolster innovation capacity in Brazil. However, if they continue to be measured against the standards developed by and for Western European RTOs, then they are unlikely to be viewed as successes in the short- or medium-term. Producing patents, publications and spin-offs requires access to long-term public funding. Therefore, the ISIs are unlikely to operate successfully as knowledge creators in their present form. In order to operate like the classic RTOs they were modeled after, SENAI will need to secure access to long-term basic funding. If not, it will need to seek models elsewhere, and operate more closely in line with the role of contractor. The activities typical of knowledge-intensive contractors, including brokerage, productization, market creation and follow sourcing, are more likely to be fruitful given the external environment.

6. Works Cited

Arnold, E., Rush, H., Bessant, J., Hobday, M., 1998. Strategic Planning in Research and Technology Institutes. RD Manag. 28, 89–100. doi:10.1111/1467-9310.00085

Åström, T., Eriksson, M.-L., Niklasson, L., Arnold, E., 2008. International Comparison of Five Institute Systems. Danish Ministry of Science, Technology and Innovation,.

Baron, D.P., 1995. Integrated Strategy: Market and Nonmarket Components. Calif. Manage. Rev. 37, 47–65. doi:10.2307/41165788

Berger, S., 2013. Making in America: from innovation to market. The MIT Press, Cambridge, Massachusetts.

Burt, R.S., 1992. Structural holes: the social structure of competition. Harvard University Press, Cambridge, Mass ; London.

Chesbrough, H.W., 2003. Open innovation : the new imperative for creating and profiting from technology. Harvard Business School; Maidenhead McGraw-Hill, Boston, Mass.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. Adm. Sci. Q. 35, 128–152. doi:10.2307/2393553

Corredoira, R.A., McDermott, G.A., 2014. Adaptation, bridging and firm upgrading: How non-market institutions and MNCs facilitate knowledge recombination in emerging markets. J. Int. Bus. Stud. 45, 699–722. doi:10.1057/jibs.2014.19

Freeman, C., 1995. The ‘National System of Innovation’ in historical perspective. Camb. J. Econ. 19, 5–24.

Gann, D.M., Salter, A.J., 2000. Innovation in project-based, service-enhanced firms: the construction of complex products and systems. Res. Policy 29, 955–972. doi:10.1016/S0048-7333(00)00114-1

Gijsbers, G., Roseboom, H., Vullings, W., 2005. Benchmarking Contract Research Organizations. TNO Delft.

Hargadon, A., Sutton, R.I., 1997. Technology brokering and innovation in a product development firm. Adm. Sci. Q. 716–749.

Hargadon, A.B., 2002. Brokering knowledge: Linking learning and innovation. Res. Organ. Behav. 24, 41–85. doi:10.1016/S0191-3085(02)24003-4

Hobday, M., 2000. The project-based organisation: an ideal form for managing complex products and systems? Res. Policy 29, 871–893.

Howells, J., 2006. Intermediation and the role of intermediaries in innovation. Res. Policy 35, 715–728. doi:10.1016/j.respol.2006.03.005

Humphrey, J., 2003. Globalization and supply chain networks: the auto industry in Brazil and India. Glob. Netw. 3, 121–141. doi:10.1111/1471-0374.00053

Leitner, K.-H., 2005. Managing and reporting intangible assets in research technology organisations. RD Manag. 35, 125–136. doi:10.1111/j.1467-9310.2005.00378.x

Lundvall, B.-Å., 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter Publishers.

Martínez-Vela, C., 2016. Benchmarking Research and Technology Organizations (RTOs): A Comparative Analysis.

Mayer, D., Kenney, M., 2004. Economic action does not take place in a vacuum: Understanding Cisco’s acquisition and development strategy. Ind. Innov. 11, 299–325.

McDermott, G.A., Corredoira, R.A., Kruse, G., 2009. Public-private institutions as catalysts of upgrading in emerging market societies. Acad. Manage. J. 52, 1270–1296.

McEvily, B., Zaheer, A., 1999. Bridging ties: A source of firm heterogeneity in competitive capabilities. Strateg. Manag. J. 1133–1156.
McJunkin, J., Reynders, T., Saloner, G., Spence, M., 2000. Cisco Systems: A novel approach to structuring entrepreneurial ventures. Grad. Sch. Bus. Stanf. Univ. Case Number EC-15 Febr.
Mowery, D.C., 1983. The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900–1940. Explor. Econ. Hist. 20, 351–374. doi:10.1016/0014-4983(83)90024-4
Mowery, D.C., Rosenberg, N., 1993. The U.S. National Innovation System, in: Nelson, R. (Ed.), National Innovation Systems: A Comparative Analysis. Oxford University Press, New York.
N. Mrinalini, Pradosh Nath, 2000. Organizational practices for generating human resources in non-corporate research and technology organizations. J. Intellect. Cap. 1, 177–186. doi:10.1108/14691930010377487
Obstfeld, D., 2005. Social Networks, the Tertius Iungens Orientation, and Involvement in Innovation. Adm. Sci. Q. 50, 100–130. doi:10.2189/asqu.2005.50.1.100
Oliver, C., 1991. Strategic Responses to Institutional Processes. Acad. Manage. Rev. 16, 145–179.
Pfeffer, J., Salancik, G.R., 1978. The external control of organizations : a resource dependence perspective. Harper & Row, New York.
Pietrobelli, C., Rabellotti, R., 2011. Global value chains meet innovation systems: are there learning opportunities for developing countries? World Dev. 39, 1261–1269.
Porter, M.E., 1980. Competitive strategy : techniques for analyzing industries and competitors. Free Press ; London, New York ; London.
Rush, H., Hobday, M., Bessant, J., Arnold, E., 1995. Strategies for best practice in research and technology institutes: an overview of a benchmarking exercise. RD Manag. 25, 17–31. doi:10.1111/j.1467-9310.1995.tb00897.x
Schumpeter, J.A., 1934. The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle, Harvard economic studies ; v. 46. Harvard University Press, Cambridge, Mass.
Shapira, P., 2001. US manufacturing extension partnerships: technology policy reinvented? Res. Policy 30, 977–992.
Sturgeon, T., Lester, R., 2004. The New Global Supply-Base: New Challenges for Local Suppliers in East Asia, in: Yusuf, S., Altaf, M.A., Beshima, K. (Eds.), Global Production Networking and Technological Change in East Asia. The World Bank. doi:10.1596/0-8213-5618-6
Tether, B.S., Tajar, A., 2008. Beyond industry–university links: Sourcing knowledge for innovation from consultants, private research organisations and the public science-base. Res. Policy 37, 1079–1095. doi:10.1016/j.respol.2008.04.003
UNIDO, 1979. Analysis of Selected Documents Relating to the Joint UNDP/UNIDO Evaluation Study of Industrial Research and Service Institutes (No. 79–341).
Utterback, J.M., 1975. The role of applied research institutes in the transfer of technology in Latin America. World Dev. 3, 665–673. doi:10.1016/0305-750X(75)90017-0
Whitley, R., 2006. Project-based firms: new organizational form or variations on a theme? Ind. Corp. Change 15, 77–99.

Whittaker, D.H., Zhu, T., Sturgeon, T., Tsai, M.H., Okita, T., 2010. Compressed Development. Stud. Comp. Int. Dev. 45, 439–467. doi:10.1007/s12116-010-9074-8
Zahra, S.A., George, G., 2002. Absorptive Capacity: A Review, Reconceptualization, and Extension. Acad. Manage. Rev. 27, 185–203. doi:10.5465/AMR.2002.6587995