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SENAI + ISIs: The *Silicon Valley Consensus* Meets Organizational Challenges in Brazil

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SENAI + ISIs: The *Silicon Valley Consensus* Meets Organizational Challenges in Brazil

INTERIM REPORT

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1. Introduction

This is an interim report on research exploring the organizational issues surrounding innovation policy in Brazil. The research is still in progress, and very much incomplete. The conclusions are thus necessarily tentative and subject to revision.

The research reported here is one component of a much larger project at the Industrial Performance Center (IPC) at the Massachusetts Institute of Technology (MIT), sponsored by Brazil's *Serviço Nacional de Aprendizagem Industrial* (SENAI). The research has been developed in connection with the implementation of the *Institutos SENAI de Inovação* (ISIs) initiative, which was designed to promote innovation in the country's manufacturing sector.

The research is motivated by a concern that public policy has come to focus on the promotion of advanced technology at the expense of traditional industries, where the bulk of employment opportunity is located, especially in middle income countries. As such, this concern is not peculiar to middle-income countries or to Brazil, but is a general problem as public policy has moved away from the *Washington Consensus* and the promotion of competitive markets, and towards what might be called the *Silicon Valley Consensus* (SVC), with its emphasis on "innovation and entrepreneurship, in the knowledge economy".

The research reported here is built around case studies of two organizations that served as models for the ISIs. At the same time, it is also informed by earlier research at the IPC, on the organization of product development within the private sector, on the promotion of technology innovation by the U.S. military, and on the organization of off-shore software development. It is also informed by a separate survey of ISI directors conducted by Susana Cordeiro, PhD candidate in MIT's Department of Political Science.

The report is divided into five sections as follows: the first provides general information on the program which we are studying, the research site, and other relevant background. The second part consists on a brief description of the research methods used and case studies centered around two organizational units associated with the program. The third and fourth sections are devoted to the analysis of each of these case studies separately. A last section concludes.

2. Background of the Study

2.1. General Research Problem

In the waning decades of the 20th century, economic policy came to be dominated by a neoliberal consensus built on standard economic theory, with reliance on the market as the motor of growth and development. The key ideas are still influential in the design of economic policy, but the consensus built around it has since dissolved. And a new consensus about development policy has emerged, which sits uneasily alongside the old, captured by the mantra: innovation, entrepreneurship and the knowledge economy.

The central idea of what might be called the *Silicon Valley Consensus* is that growth and development are now driven by formal scientific and engineering knowledge embodied in new products, involving discontinuous technological changes, which are introduced into the marketplace by small, entrepreneurial firms and require a similarly trained labor force to bring them to market. The role of government in this new view is to ensure the production of the technically trained people who can keep abreast of the evolving technology by supporting engineering and scientific educational institutions, fostering a culture of risk taking and entrepreneurship, and ensuring the material infrastructure upon which it depends. While this does not necessarily involve the provision of direct funding for new ventures, it does generally require adjusting the legal environment, the patenting system, and the regulations governing the interaction between business and university research.

It is however not altogether clear that autonomous technological trends are pushing in this direction, and there is some danger that the mantra is a self-fulfilling prophecy; that heavy investment in new technology intensive industries will be made at the expense of more traditional industries; in new products at the expense of production processes; and in higher, technical education as opposed to basic literacy and numeracy, and in vocational skills that are critical to conventional production processes. Indeed, to some extent, the mantra must be a self-fulfilling prophecy – to the extent the government invests and encourages development in industries dependent on highly educated manpower, it creates a demand for this manpower and moves the trajectory of development in the direction which that manpower is trained work.

Our own perspective on innovation has been formed by a series of studies of the organization of product design and development in private industry conducted in the 1990's and

early 2000's and by a subsequent study of DARPA, a U.S. Defense Department agency which supported the early developments in digital technologies, the world-wide web, the GPS, and a variety of innovative weapons systems and troop supports[1]. These studies place major emphasis in the innovative process on the role of communities of practice, molded out of people with diverse backgrounds and perspectives and the need in organizing for innovation to create and maintain such communities.

Growing out of this perspective is the question of how much contemporary innovation emerges from established communities, following the contours of existing industries and technological domains, and how much innovation depends on creating new communities that cross the traditional boundaries in which the economy has been organized. Particularly illustrative of the latter is the cellular telephone which involved the integration of radio and telephone technology and came as it evolved to incorporate elements drawn from the photography industries, entertainment (both audio and visual), written and voice messaging systems, newspaper journalism, and so on. It is with this background that we try to understand the cases discussed in the present study.

2.2. Research Context: SENAI, ISIs, and their role supporting Brazilian manufacturing

To explore the implications of these broader processes in the Brazilian context, the locus of this research is SENAI, one of the country's most traditional vocational training organizations. SENAI is a semi-autonomous organization governed by the industry associations at the state level, but coordinated by a central department that determines general management and regulatory guidelines, as well as promotes knowledge exchange between regional units. The organization was created in January 22nd 1942, by the decree 4.048 from President Getúlio Vargas to provide skills training for the manufacturing labor force[2]. Since then, it has trained over 70 million workers mostly through programs oriented toward traditional industries[3].

SENAI operates as a hybrid organization, because it is financed through a one percent payroll tax on manufacturing employment imposed by the Federal government, but it is governed by business associations at both the national and the local level. In terms of revenue, 15% of the resources stay with the national department, and 85% with regional units[4]. As the regional

organizations are relatively autonomous and operate independently, policy and budgets are largely defined by the elected local business representatives on the governing boards. The national staff provides coordination and exercises oversight over the local programs. At both levels, the organization maintains a staff composed by academics, technical professionals with industry experience, as well as business people that help them carry out a portfolio of activities that today include professional education, technological services, and applied research and innovation.

Over the last seven decades, SENAI has supported national manufacturing as it went from having a 25% participation in the Brazilian GDP in the 1940s, to over 45% in the 1980s, and back to 21% in 2016[5]. The sector continues to be important for job creation, employing 10.5 million workers, or 22% of the country's labor force[6], though largely low and medium-tech sectors, such as food and beverages, petrochemical products, automobiles, and metallurgy correspond to over half of the total value generated by manufacturing in the country[7]. In the case of textiles and garment sectors, this contrast between low value added and labor intensiveness is even starker. Together they represent the second largest sector in terms of employment generation (1,5 million direct and 8 million indirect jobs created, 75% of these being filled by women)[8], despite representing only 1% and 1,6%, respectively, of the total industrial GDP in Brazil[9].

Given the strength of the traditional sector, it is no surprise that SENAI has been historically known for prioritizing its role on training for these labor-intensive industries. However, more recently, the organization has adopted a new role in promoting technological services and innovation encouraged by federal policy[10]. While education and training continue to constitute the bulk of its activities, a number of regional SENAIs now have business incubators and technology centers providing technical advice and testing services to industry. One recent example of this trend was a large loan (approximately R$ 1 billion) SENAI took from *Banco Nacional do Desenvolvimento* (BNDES) for the establishment of 25 innovation institutes (ISIs)[11]. These new centers, based on the German Fraunhofer system, are spread across the country, each specializing in one technology and housed within a regional SENAI unit. The innovations institutes thus bring to the fore the potential conflict between the historic mission of the country's economic infrastructure and the new mantra of development policy.

The incentives to diversify have also been strengthened by recent structural changes beyond SENAI's organizational borders. One of the interviewees mentioned cuts in the *Programa Nacional de Acesso ao Ensino Técnico e Emprego* (PRONATEC)[12], a large federal program that was established in 2011 to expand access to vocational training across the country, as one of the causes behind this latest push for structural change. In the absence of PRONATEC resources, SENAI was forced to reduce its labor force from 40,000 to 30,000 employees in the last two years. The impact was similar for students that depended on the program's funds to subsidize their education: the number enrollments in SENAI courses went from 3,7 million people in 2014 to 2,6 million today. The impacts of such cuts have been even greater because they happened in combination with other factors. For example, the recent political and economic crises in the country, and the government-led austerity measures that followed, have increased the pressure on SENAI to give up part of its core, tax-based funding to other priority areas[13, 14].

The existence of a specific funding source backed by legislation does provide considerable administrative stability to SENAI, and has been crucial to maintain critical staff and infrastructure over extended periods of time[15]. However, SENAI leadership has been emphasizing in recent years the need for seeking financial independence, regardless of the status of the political environment[16, 17]. One of the reasons for such a move is the proportional nature of these compulsory transfers, which makes them fluctuate according to national industrial performance. Another reason is that while the rate (1%) of taxes directed to the system has remained constant since the 1940s, SENAI's purchasing power enabled by this core funding has been diminishing over time. Some of SENAI's managers we interviewed mentioned that technological change has been a key contributing factor to this process, because as workers are replaced by machines, the absolute amount spent on payroll decreases and, consequently, so it does the compulsory contributions transferred to the organization's budget.

If internally the ISIs are understood as part of SENAI's effort to update and broaden its mission, and at the same time respond to these macro-level changes, external stakeholders in the private and public sectors see SENAI's transformation as an opportunity to unleash structural changes at a larger scale. By taking advantage of existing organizations with expertise in technological upgrading, the ISIs can be part of a broader effort to strengthen the innovative

capacity of the Brazilian economy, which has been viewed as weak and incapable of sustaining long term growth and development. The active support for the project from the group *Mobilização Empresarial para Inovação* (MEI)[18], which is an association of the largest corporations in the country, corroborates the idea that the private sector also sees SENAI as an important player in the effort to promote technological upgrading in the country.

Despite the apparent agreement on the importance of these reforms and the broad policy direction guiding them, the implementation of the new SENAI model has exposed organizational, political, and economic challenges. Indeed, the process of reallocating resources from low-tech to high-tech sectors entails a different balance of powers within the organization, with winners, losers, and long periods of negotiation. The new model also changed the nature of the work SENAI's own staff needs to perform, to which some are quicker to adapt than others. The same people who have for years worked around traditional educational programs, now must fulfill flexible job descriptions and engage with the private sector through the provision of technological services and development of applied research projects. Perhaps most importantly, this transition poses new strategic questions to SENAI, such as how to support technological upgrading without reducing employment. If at the time of its foundation the system of mass production made manufacturing a large-scale job creator, the increasing automation that has taken place in recent decades imposed limits on the possibility of both being achieved simultaneously[19, 20]. It is by exploring these and other conflicts that our research hopes to better understand the transition between SENAI's "old" and "new" mission.

3. Research Methodology

This research project is organized around two case studies suggested by the then president of BNDES, and confirmed by others in the SENAI leadership, as the organizational models they expected to replicate when the bank lent support to the original project.

One of these organizations is the *Centro Integrado de Manufatura e Tecnologia* (CIMATEC) founded in 2002 in Salvador, Bahia. It represents one of SENAI's most prestigious technology centers focused on advanced manufacturing[21]. The second model was the *Centro de Tecnologia da Indústria Química E Têxtil* (CETIQT), founded in 1949 in Rio de Janeiro. CETIQT represents SENAI's most important unit working to support the textile, garment, and

fashion design industries, which represent some of the most traditional sectors in the Brazilian economy. Because they are both related to the SENAI's network, but at the same time present different sectorial focuses and organizational histories - representing the "new" and the "old" economy, respectively -, they reveal alternative challenges and opportunities for the development of ISIs and their potential influence in the Brazilian economy.

We have used mixed methodologies, including quantitative analysis to explore macro-indicators on trade, productivity, and sectoral growth, as well as micro-level indicators, such as budgets, investments, and government transfers from and to SENAI/ISIs. Complementarily, between 2015 and 2017 we have completed four fieldwork trips to Brazil, where we conducted 52 semi-structured interviews (so far) with 82 participants. Interviewees were selected from three broad groups: i) key actors in the design and implementation of the older SENAI programs; ii) officials central to the creation and direction of the new ISIs; iii) managers and executives in manufacturing firms which draw upon the services of SENAI both in the acquisition and development of their skilled labor force and for technical aid and advice. In this context, particular attention has been devoted to the interaction between the traditional SENAI mission and the newer innovation thrust.

4. CETIQT and the Textile and Garment Industries in Brazil

For the last 60 years, CETIQT has been one of the leading schools for training workers for the textile and garment industries, with a large campus in Rio de Janeiro. It is by common consensus in need of modernization, although it is not clear exactly what form that modernization will take. It has had four directors in the last 5 years; the most recent of them, reportedly stronger and with a clearer mandate for reform took over the organization in 2016. We are still trying to understand the reforms that are being introduced and the debates surrounding them. Thus far, we have actually spent more time exploring the relationship between SENAI and these industries in different parts of Brazil than CETIQT itself, so our conclusions here are especially tentative.

Our interviews so far seem to support the concerns about the neglect of traditional industries in the formulation and execution of innovation policy. Brazil is remarkable in that it is one of the few countries outside of Asia which managed to retain most of the textile-garment

value chain within its own boundaries[22]. From the production of the yarn and fabrics, to the design, cutting, sewing, quality control, distribution, and sale of finished pieces in retail networks, most of these activities are performed by national firms. Unlike Asia, however, Brazil's textile and garment industries operate within a fairly closed system: exports represent just 6% of the sector's annual revenue in 2015 of US$ 39 Billion, and imports in the same year were below US$ 5 Billion[23].

Yet, our interlocutors seemed unaware and basically uninterested in the unique position the textile and garment industries were in. This underlying attitude is suggested in an interview with a group of engineers preparing a report about the future of textile and garment manufacturing in Brazil entitled *A Quarta Revolução Industrial do Setor Têxtil e de Confecção: A visão de futuro para 2030*[24]. The report was based on a detailed study of the industry in the United States and other developed countries, and included field visits and extensive interviews with engineers and managers there. Their forecasts were built on the assumption that the path of Brazilian textile, garment, and fashion industries would eventually follow the same path of, and emulate the business ecosystems found in places like New York City and Milan. Little attention was given to the unique characteristics of these industries in Brazil, which limited the applicability of foreign models. When asked about how they expected to address this contradiction, their response was: *"That is a good question; we have never really thought about it*".

After the initial surprise, respondents tended to attribute the survival the sector to the large internal market and the protection of the market through government-imposed tariffs. Another element mentioned was the fact that Brazil has a very large cotton fiber industry, which could supply raw materials at a very competitive price. Both of these explanations imply that the industry is in a monopoly position, which to some extent is true: WTO data from 2014 puts Brazil as imposing the 6th highest average tariff on textiles in the world (23%)[25], and the 10th highest average tariff on garments (35%)[26]. In terms of cotton production, WTO data for 2015/2016 shows Brazil as the 5th largest producer in the world, with 6% of the global market share[27]. However, our research suggests that both CETIQT and its industry partners were actually much more dynamic and innovative than a monopoly position would lead one to expect.

CETIQT has the potential to provide a contrasting perspective on the organizational tensions within the ISIs program as the study progresses, because it represents an understudied example of how SENAI can support innovation even in sectors where technology development is assumed to play a limited role. For now, though, the research will use it as a window into the textile and garment industries, and ultimately into the potential conflicts between traditional and advanced innovation strategies.

4.1. The Relationship Between SENAI, CETIQT, and the Textile & Garment Industries' Organizational Structures

CETIQT plays a unique role within SENAI, and it does so in two respects. First, it is attached organizationally and financially to the national department, and not to the regional department of Rio de Janeiro, as is the case with all the other SENAI units in that state. With the national department exercising direct control over its organization and program, the regional staff and governing bodies have limited influence over how CETIQT operates. Second, CETIQT is defined by, and oriented towards a specific industry, rather than a region or a technology, as is the case with other SENAI programs. These two characteristics have had important role in shaping how the organization has transformed itself from having a regional identity towards a national one.

Created in the late 1940s explicitly to support the technological upgrading of the textile and garment industries, CETIQT had most of its clients concentrated in Brazil's Southeast Region (in states such as São Paulo, Minas Gerais, and Rio de Janeiro)[28]. But as we will see later in the case of *Cia. Hering*, the macro-economic crises that took place in the 1980s and 1990s hit the textile and garment sectors particularly hard[29]. Following the liberalization of the economy and increasing imports of artificial yarns and fabrics, surviving firms adopted strategies that decentralized production to other areas of the country with lower labor costs, as well as increased investment in technology so they could compete in quality (instead of quantity of output) with emerging Asian producers.[30]

The current distribution and composition of the textile and garment industries across the country is significantly different the one that existed when CETIQT was founded. There has been increasing activity in the South and Northeast regions of Brazil, accompanied by a decrease

in the presence of firms in this sector in the Southeast[31]. For example, a 2014 study from the *Banco do Nordeste* (the Brazilian Development Bank for the Northeast Region) showed that while states like Santa Catarina (South) and Ceará (Northeast) are responsible for, respectively, 19,4% and 5,4% of the national production, Rio de Janeiro retained only 1,75% of the national market share[32]. At the same time, technology and capital-intensive parts of the value chain, which are largely concentrated in the textile sector, tended to remain in the wealthier states in the South and Southeast, while the labor-intensive stages of production (mostly in garment) moved North, towards the Northeast and Center-West regions[33].

From our interviews with staff from regional SENAI units in Santa Catarina, Rio Grande do Norte, Goiás, and São Paulo we could observe the ways in which this decentralization process shaped SENAI's work too. In trying to support local firms and their specific needs, the organization built sectoral expertise, training, and technological infrastructure in different parts of the country. Furthermore, as it will be detailed in the *Cia. Hering*'s case, local capabilities were developed consistently with local demands. In states like São Paulo and Santa Catarina, services were concentrated in areas such as research and development and engineering education. In poorer regions in the North, most activities consist of basic training for workers with no previous experience in the garment-making, or consultancies to small entrepreneurs on business management.

As SENAI decentralized and diversified its portfolio following the industry's transformation, CETIQT has faced growing competition and questions about its relevance. It lost the proximity to the private sector which had moved elsewhere, as well as its competitive advantage in terms of being the only (or at least one of the few) centers in the country that could provide technological training and infrastructure. CETIQT managers have been trying to respond to these challenges by implementing a series of reforms, many of which are still ongoing. Our research is still exploring the details of what is happening, but at least three main processes have been identified in the interviews.

First, SENAI's National Department promoted a series of leadership changes in CETIQT over the last 5 years, in an effort to harmonize the two organizations' agendas. This meant that the new directors gradually increased investments in upgrading CETIQT's physical infrastructure, as well as promoted the expansion of technological services, applied research and

innovation, and new modalities for the education programs, such as online distance learning courses. The goal was to adapt the organization to the external demands from the private sector for new services, but also to address internal demands within SENAI that pushed for greater financial sustainability.

Second, these changes were accompanied by modifications in CETIQT's structure that included its reorganization around five broad areas: education, technological services, innovation, administration, and a business development. The new innovation unit has 30 researchers, who were recently hired to conduct R&D activities on textile chemistry and development of new fibers. The business development unit's role is to foster closer ties with the private sector, bringing in projects and investment. In the education unit, the manager created dedicated teams to develop additional sources of revenue, such as customized training programs for firms with specific needs.

The actual story of how these changes were implemented was not straightforward, especially given that SENAI itself has sometimes viewed the garment and textile industries as having limited potential for dynamic technological development. For example, when the national department looked for a place to locate a new ISI focused on chemical technologies (which preceded the establishment of the current innovation unit), they did not decide to place it in CETIQT because they wanted to support innovation in that sector. Instead, the key decision factor was apparently their ability to control CETIQT policy directly, without the assent of regional governing body. In fact, the research program that the director of the ISI was explicitly hired to pursue was not a program directed at the textile industry. He deliberately sought to avoid orienting it in that direction in order to prevent conflicts with other ISI centers. It was only recently, with the tenure of the current director, that the ISI was formally incorporated into CETIQT's innovation unit.

A third, and final issue that emerged from the research conducted so far was CETIQT's effort to build its comparative advantage by complementing the work of regional SENAI units, rather than establishing a relationship of direct competition with them. Our interviewees recognized that in states with mature textile and garment industries, local SENAIs are better equipped to support them with training and technological services of low and medium complexity. CETIQT would then continue to work in these areas, but only to fulfill the demand

from Rio de Janeiro. On the other hand, given its history, staff, and infrastructure, they pointed out there is still a place for CETIQT as an organization specialized in advanced training, research and development. By maintaining and expanding its profile as a national reference in high-level work, CETIQT expects to remain relevant despite of the new industry configuration.

4.2. The Case of Cia. Hering

We explored a different perspective about how the relationship between SENAI, CETIQT, and their industrial partners has evolved over time by studying one of their clients, *Cia. Hering.* The company was founded in 1880, with headquarters in Blumenau, in the state of Santa Catarina, but with production now concentrated in the states of Goiás (since 1997) and Rio Grande do Norte (since 2000)[34]. With 7,000 employees, a retail network of 821 stores, and market value of US$1.25 Billion (2014), *Cia. Hering* is one of the 100 largest companies in Brazil[35, 36]. The case is interesting because it contradicts the image of textile and garment industries as static, relatively backward, and surviving behind a protective tariff wall – a view that seems to undergird much of the innovation policy discussion. This is also true for other firms we visited, but in some ways, *Cia. Hering* stood out due to its unique business strategy, and in terms of the way it has been supported by public policy and SENAI.

The company has historically focused on the production of textiles and garments, also working as a subcontractor for branded clothing companies in the 1980s and 1990s until establishing its own retail network in 1993[37]. At about this time, a combination of an acute economic crisis and the broad liberalization of the Brazilian markets changed the structure of competition in the country[38]. *Cia. Hering* survived this period of macro-economic instability by implementing a production strategy based on the decentralization of production through subcontracting to small firms, a strategy that the garment industry uses throughout the world[39].

Whereas most brands in Europe and North America contract established firms[40], *Cia. Hering* sought to develop its own subcontractors and to exercise much tighter control over them than was typical in the industry. Part of the reason for this is that in Brazil, the manufacturer is responsible for their subcontractors' adherence to mandated labor and environmental regulations, and must pay fines if their subcontractors are found to be in violation of the law[41,42]. Another

important factor was the establishment of the *Sistema Integrado de Pagamento de Impostos e Contribuições das Microempresas e Empresas de Pequeno Porte* (*SIMPLES*)[43]. This government regulation was put in place in 1996, and then expanded in 2006 (*SIMPLES Nacional*)[44], and 2017 (*Programa Bem Mais SIMPLES*)[45]. It simplified and reduced taxation on small firms, creating an incentive to large companies like *Cia. Hering* to lower production costs via outsourcing. Participation in the program is also contingent on the adherence to labor regulations, so to avoid compliance problems, the company exercises a great deal of control over its suppliers.

The process through which *Cia. Hering* developed its subcontractors had several different variants. A network was initially created around the company's headquarters in Blumenau, by sponsoring spinoffs led by their own employees, to whom *Cia. Hering* provided capital and machinery. Because the employees already had experience as part of the company, their firms were integrated easily into an on-going process. One important element in this transition was the fact *Cia Hering* maintained control of its core capabilities in high-value added stages of production, which included clothing design, textiles manufacturing, and complex garment production. Outsourcing firms were responsible, at least initially, for simpler tasks, such as the assembling pre-cut pieces.

This basic division of labor was maintained when the company moved part of its production to Anápolis in the state of Goiás, in the late 1990s. This was virgin territory for the garment industry as there were neither firms nor manpower with experience in garment production. The company recruited entrepreneurs with no previous business experience, again providing capital and equipment, but training them in production and managerial practices. Today, although *Cia. Hering* has expanded its operations in Goiás to 4 garment centers and one logistic unit, most of them still have their work restricted to the simplest stages of production. Complex pieces are produced in by *Cia. Hering* itself, or by some of their older subcontractors in Santa Catarina, most of which upgraded their technological capabilities over time.

The company followed the same operational pattern in a third wave of expansion to Natal and other cities in the state of Rio Grande do Norte. In this instance, however, they found a region where a traditional garment industry already existed, making it easier to recruit experienced firms to become subcontractors. *Cia. Hering's* experience in Rio Grande do Norte also created unique spillovers effects that did not exist in Goiás, as other companies in the sector

emulated its business strategy, enlarging even further the number of subcontractors operating in the state[46].

In all three waves of expansion, *Cia. Hering* worked with SENAI to recruit and provide training to their own staff and subcontractors. But in each of them SENAI's role was somewhat different, or at least the concerns of the managers with which we talked to varied substantially across the three regions. In Blumenau, SENAI staff tended to be concerned with the education of textile engineers and managers. They were seeking to work with local universities to revise its educational offerings and, to summarize a long discussion, to broaden the training of higher level manpower so that their skills would be relevant in other industries as well. They worked with CIMATEC in Bahia to develop a new pedagogical strategy, which in a way, seems to undercut the strict dichotomy between advanced technology and traditional industries.

In Anápolis, however, SENAI has partnered with the company to support two different audiences. The first was the contingent of garment workers that was recruited by *Cia. Hering* without prior industry experience. Working within their own factories (rather than in SENAI schools) the company organized customized training sessions on both hard and soft skills – from technical sewing practices to appropriate behavior in the workplace. The second audience consisted of new subcontractors, also known as *Facções*. With this group, SENAI was much more focused on training managers in the specific skills associated with managing a business, and worked closely with *Cia. Hering* to develop strategies that allowed these new entrepreneurs to comply with the applicable labor, technical, and environmental legal requirements.

In Rio Grande do Norte, SENAI took on yet a different role in supporting *Cia. Hering* and other firms in the garment sector. Although it did, like in Goiás, contribute with the training of skilled personnel, most of their work was directed towards *Facções*, independent from the larger contracting firms. This has been especially true given the economic crisis that has rocked the country since the early 2010s, forcing most garment companies to curtail their operations. In the absence of large buyers, smaller local firms were able to draw on their considerable industry experience to develop new products and find new markets. SENAI's role in this process consisted mostly in providing consulting services in areas such as production optimization and business management.

4.3. Lessons Learned

So, what lessons can one draw from the *Cia. Hering* story? First, as we have already noted, it suggests a considerable dynamism in a traditional industry that has tended to be dismissed as irrelevant to the new innovation agenda. The recognition of this dynamism requires us to expand the notion of innovation to include not simply new products and process, but innovations in business organization and management as well.

It is worth underscoring here how innovative *Cia. Hering* subcontracting model actually is. It draws on the outsourcing experience of branded manufacturing in the developed countries, but it extends that experience considerably in several dimensions, most notably the degree of control which the company exerts over its subcontractors. Such strategy allowed for the creation of a model of division of labor in which the contracting firm managed to keep its core capabilities, while it also promoted economic spillovers through the creation of more productive *Facções*.

Cia. Hering's case also underscores the need for a broader notion of entrepreneurship, beyond what is commonly suggested by narratives from Silicon Valley and its young I.T. inventors supported by a network of venture capitalists. Its relationship with SENAI suggests that it is important to include more traditional businesses and sources of support -- both in terms of capital and managerial expertise --, as integral part of the policy debates around innovation.

From what we could gather so far, SENAI, with its nearly 70 years of experience, strong regional base, and ability to create *ad hoc* programs tailored to the specific needs of local businesses, is already well-suited to support certain types of innovation in traditional sectors. And, as we have seen in the textiles and garment, there is much to be learned about innovation from industries -- and SENAI's practices supporting them -- that have been overlooked because of their assumed (low) technology development potential.

But it is also possible to envision an alternative process being derived from these conclusions, which as the case of advanced technology centers like CIMATEC expanding their portfolio of activities to foster innovation in traditional industries as well. At least in theory, there is nothing that prevents SENAI from adapting its high-tech spaces so they can promote upgrading in "legacy" sectors. This would represent broadly the opposite trajectory that CETIQT has adopted, as it attempts update its training and research programs, to build a national

reputation as an innovation leader in textiles and garments. Whether this can happen in practice, though, is a different question, leading us, in turn, to ask: what exactly are the lessons of CIMATEC? How should they be interpreted? We address these questions in the following section.

5. CIMATEC's Experience Supporting High-tech Industries in Brazil

5.1. CIMATEC's Organizational Structure

While CIMATEC has not yet developed a comprehensive strategy to engage with traditional industries, it did manage to create an organizational environment that successfully addresses the demands of firms in advanced technology sectors.

One major characteristic of CIMATEC is that it is an integrated organization. It is composed of a series of conceptually and organizationally distinct units, but the different units work together in an apparently smooth and harmonious way. From our interviews, it became apparent that the professionals working in these units share a common understanding of what the CIMATEC is about, although individual respondents described it in terms which reflect their different positions within the organization, as well as their own individual histories within SENAI. In a sense, these collective statements reflected a strong company ethos.

Ironically, the coherence of the organization makes it relatively easy to identify its separate components. CIMATEC divides its activities in two main areas: technology and innovation, and education. Each of these areas is managed by a specific director with a separate budget, but their organizational structure was designed to facilitate collaboration between them. The technology and innovation area is responsible for the provision technological services and the development of applied research. The services unit provides support to firms seeking CIMATEC's help to perform tasks such as water quality tests required by federal environmental legislation, energy efficiency assessments of machinery and buildings, and technical consulting on optimization of production processes[47].

The applied research activities consist of projects developed in collaboration with high-tech firms that tap into CIMATEC's expertise and infrastructure to create innovative products

and services. One example is the supercomputer *Yemoja*, the second most powerful of its kind in Latin America, which is housed at the Supercomputing Center for Industrial Innovation[48]. This infrastructure has allowed CIMATEC to develop a series of complex projects, as it is the case with *FlatFish*, an autonomous underwater vehicle for visual inspection of oil and gas operations in deep waters[49]. The initiative is currently being implemented in partnership with the oil company *Shell*, the Brazilian Agency for Industrial Research and Innovation (EMPBRAPII) and the DFKI Institute from Germany.

There are also three ISIs located within CIMATEC (automation, logistics, and conformation and bonding of materials)[50], but they seem to operate more as budgetary units and do not have distinct operational roles as ISIs. This is, in fact, in line with CIMATEC's fundamental principle of representing an *integrated campus* where research in different fields overlap in terms of location, implementation, and content. Most of the work is organized instead around projects, which are the key operational units.

They are managed by a Project Management Office (PMO), which relies on a secondary administrative layer, structured according to *competencies*. There are currently 33 *competencies* that represent an autonomous organizational unit specialized in one knowledge area, such as advanced manufacturing, energy & environmental sustainability, and automation & robotics[51]. The size of each *competency* -- in terms of number of staff and complexity of its infrastructure -- varies according to the demand for services, though most of them have a dedicated team and manager.

The PMO relies on a team of professionals with deep industry knowledge (often retirees) to work on business development, using their expertise to bring new projects and funding. When new initiative starts, the PMO usually pulls staff and use infrastructure from several different competencies. In this is the case the project manager and the relevant competencies leaders collaborate to allocate people and resources appropriately. When the project is complete, each professional goes back to their original assignment – or dedicates some of their time to teaching -- until there is new project that requires their services. This structure provides great flexibility for managers to organize work that is inherently multidisciplinary.

But it is the relationship between technology and educational activities makes CIMATEC particularly interesting, especially in terms of its strategy to integrate SENAI's traditional

manpower development mission with its new innovation agenda. There are four types educational programs: basic vocational training (short duration courses that prepare workers for jobs in construction, carpentry, electrician, among other); a post high-school advanced vocational degree (2-year program regulated by the ministry of education); an undergraduate program (mostly focused on engineering courses in nine specialties); and a postgraduate program offering high-level masters, MBAs, and PhD degrees, in fields such as computer modeling and technology, innovation and management[52].

There at least two elements that distinguish these programs from similar ones offered in conventional universities in Bahia. First, in each of these programs there is an effort to use projects as a major pedagogical tool, building on SENAI's close relationship with local industry. CIMATEC has formalized this principle through the adoption of a methodology called *TheoPrax,* elaborated in the 1990s by the Fraunhofer Institute of Technology in Germany[53]. Through this method students are expected to find problems relevant to local industry, to develop projects that address its problems, and finally, to provide a solution. Although there are several ways in which this project orientation is embedded in the actual curriculum -- from specific assignments to year-long collaborations -- most courses, irrespective of the degree or skill levels, were designed to foster a problem-solving mindset among those participating in the program.

Second, roughly 50% of all faculty teaching at CIMATEC (at the undergraduate and graduate level) are also involved in the development of projects. During the interviews, the education staff pointed out the organizational culture is not yet fully embedded in the teaching staff, some of whom still see their role along more traditional lines (teaching exclusively). However, CIMATEC leaders have started to transform expectations about professors' involvement in research into workplace policy. One example is the new system in which individual faculty members are assigned to competency units, and from there, are seconded to project teams close to their areas of expertise. The goal is to have at least one professor participating in every project. Another factor that has contributed with the change in organizational culture according to the respondents is the gradual hiring of younger professors, who are more familiar or at least open to perform a flexible role within CIMATEC.

5.2. Positive Implications of CIMATEC's Organizational Structure

As mentioned before, our own perspective on innovation at the IPC has been heavily influenced by a series of studies on innovation conducted in the 1990's and early 2000's. They emphasized the key role that communities of practice play in creating the appropriate environment for new ideas to flourish. At the same time, these studies also pointed out that creating and maintaining such communities is feasible in theory but hard to implement in practice. Yet, our interviews suggest that CIMATEC has somehow managed to generate within itself communities of this kind. Relatedly, a key insight which emerges from these earlier studies is that new products and services are now mostly created through the integration of industries or technologies that, until recently, operated with little or no relationship to each other. The CIMATEC structure, which encourages teamwork among professionals from different fields, seems to be particularly well-suited to this type of boundary spanning innovation.

The educational program at CIMATEC is relevant to a different issue, tough, which emerged in the discussions which our interviews provoked. Several respondents suggested that the weakness of innovation in Brazil reflected more the national culture than the country's institutional structure. Particularly telling in this regard were the comments of a textile executive who has just returned from a reconnaissance trip to China, where he had visited several different factories and watched operations on the shop floor. What struck him was the way in which people responded to production problems as a challenge to be solved. In Brazil, by contrast, people "ran away" from problems; they were loath to depart from routine even to overcome a problem; and he recounted having to bring the owner of the family firm down to the shop floor and have him personally order a change in procedure to address an outstanding production issue.

The reluctance to depart from routine, the failure to see a problem as a challenge to be solved, would seem to reflect the nature of engineering education in the country, a hypothesis confirmed by one of the engineering students working on the IPC project who had been educated both in Brazil and at MIT, where enormous emphasis is placed on problem solving. To this extent, what appears to be a cultural bias would be in fact a product of the educational system. CIMATEC's curriculum reforms, which emphasize on projects and problem-solving as key pedagogical strategies, and its organizational structure, which incentivizes faculty and students to

be involved in projects that address real industry problems, seem to be consistent with the kind of organization that is on the path to overcome these limitations.

5.3. Challenges Emerging from CIMATEC's Organizational Structure

The same CIMATEC's organizational approach that seems to work well for activities related to high-tech industries, does not appear as well adapted to support firms in the traditional sector, which is the very tension that initially motivated our research. One of the most symbolic examples we found was a contentious leadership change that affected SENAI's Regional Department in 2014, which originated within its governing board at the Industry Federation of Bahia (FIEB) – the organization that controls SENAI locally. The long-time president of the board, who had worked closely over the years with CIMATEC, was defeated by an insurgent candidate[54]. And the new president insisted that the SENAI's resources be reoriented to serve his constituency, which for the most part consisted of entrepreneurs working in traditional sectors of the economy, in smaller cities of the interior of the state.

The election results and new policy guidelines were consistent with other events taking at FIEB around that time. One example is the *Programa de Interiorização da FIEB*, an initiative launched in 2013 with the very objective to decentralize the organization's resources and shift activities inland[55]. The new constituency taking power was, indeed, more representative of the average business owner in the state: low and medium-low tech industries, such as construction, food, and paper production make up over 60% of all manufacturing in Bahia[56]. The region's industrial GDP in 2014 represented 12% of the value corresponding to the most industrialized state in the country, Sao Paulo, for that same period[57]. Aggravating this situation was the fact that the election at FIEB coincided with a sharp deceleration of the Brazilian economy in the 2010s, which increased even further the pressure on public resources[58].

CIMATEC, on the other hand, was founded in 2002 but grew exponentially since then, reaching 700 employees and an annual budget around R$110 Million (out of which R$80 million are self-financed, independently of SENAI). As a matter of comparison, the 2016 budget for the entire regional department was R$270 million[59]. With most of its client base formed by large high-tech firms, many of which are located outside of Bahia, and sometimes even in foreign countries, CIMATEC started to be perceived as an outward-oriented organization. And because

it used some of SENAI's resources (even if for a relatively small part of its budget), it created the potential for tensions with the regional department, whose primary mission is to support the local economy. Our research is still trying to fully assess what the members of the board were reacting against, what their concerns were, and what changes in the program they were really seeking, but this combination of events and organizational characteristics seems to have contributed to an increasing isolation between CIMATEC and local business ecosystem.

The organization nonetheless did create strategies to overcome this new scenario, and the responses are instructive. Part of the response has been purely political. The insurgent president died suddenly just after the election. CIMATEC's director has since tried to spend much more time cultivating relations with his successor, bringing him along on trips to recruit support outside the region and outside the country. He has also dedicated more time to the other members of the governing board, disseminating CIMATEC's mission and emphasizing its contribution to the development of the Northeast. Finally, he created a new organizational structure that distributed power more evenly between the education and technology departments within SENAI Bahia[60]. This new structure gave each area its own director, with a clearer mandate and budget.

A second, more substantive response has been to create a redistribution of resources, which included a renewed commitment from CIMATEC to pursue a more aggressive approach to fundraising, increasing its financial autonomy. In addition, SENAI created programs outside Salvador, in the outlying parts of the state. But as we visited some of the program sites, it became apparent that despite the substantial investment involved in buildings and equipment (which are highly visible), they did not seem to be rooted in a broader attempt to address the needs of local industry. All the innovations in the educational programs being implemented in Salvador, and the self-conscious thought and reflection which went into those innovations and that surrounded their implementation, were for the most part absent.

A third response has been to look for parts of the CIMATEC research program that could be located outside of Salvador. So far, this expansion is still limited in its scope, largely because of the way in which the programs at CIMATEC are integrated, and the interlocking nature of the communities of practice upon which they depend. When participants are spread out at distance, it becomes especially difficult to draw on multiple competencies, to have research work on more

than one project, or even for a single project to draw on several competencies which it may not be able to support it full time. The one area where in which CIMATEC could potentially make a system of this kind work was in software development. However, an enormous body of literature underscores that to build large software projects around communities of practice, the participants must at least share a common vision and vocabulary[61]. This requires face to face contact to create and maintain.

5.4. Lessons Learned from the CIMATEC experience

The insurgency within FIEB demonstrates the political dangers of concentrating resources in one, or in a few locations. But overall, the philosophy which has guided the evolution of CIMATEC, read in the light of our own research at the IPC, can provide additional insights applicable to the ISI program.

The central problem of the ISI program is how to manage a network of technically specialized innovation centers spread throughout the country. Here the lessons of CIMATEC are twofold, and not necessarily complementary. Frist, CIMATEC offers a highly articulated organizational structure. As we noted earlier, that structure is centered around projects and a team of project managers, and sustained by a series of distinct functional components, business development, personnel management, (recruitment and development) and infrastructure development and maintenance. National SENAI could try and replicate this structure, either by letting the different ISI's specialize in one or another of these functions or, more likely, promulgating a series of rules which determine who will play what role in cooperative projects and under what circumstances and intervening, where the rules are ambiguous to assign responsibility directly. This would be a clean and relatively bureaucratic way to address the problem (although in practice it is undoubtedly more complicated and contentious than it looks on paper). Whether it will lead to creative solutions to business problems and actually promote an innovative culture is another question.

But CIMATEC offers a second set of lessons as a model of a complex organization held together through a community of practice (or more exactly a series of interrelated and overlapping communities). It is an organization in other words which is integrated in a non-

bureaucratic through a shared language and framework of understanding, what we have called in other studies "an interpretative community". Such communities develop through interaction, through participation of its members in discussions and debates around common projects. Our earlier research, especially on DARPA, the defense department agencies, suggests that they can be created by bringing people together through seminars and conferences to discuss their own work. For this, however, the national organization needs to sponsor meetings and conferences, not of managers and directors, but of the rank-and-file researchers, sending them to visit each other's labs and perhaps even spend time on a kind of sabbatical leave there. Ultimately, these are two very different lessons which one can draw from the CIMATEC experience. It remains to be seen which one of these lessons SENAI will choose.

6. Preliminary Conclusions

As noted initially and as we would like to emphasize here again, our research is incomplete. Any conclusions which we might draw at this stage are necessarily tentative. The next step in the project is to look more closely at the organization of the national ISI network and the patterns of cooptation among the different regional centers that have emerged in the projects in which they have been engaged so far. We will also finish a set of interviews which we have already begun (but have not been drawn upon here) about the direction of CETIQT and its role in the textile and garment industry. The conclusions which have emerged thus far relate to two different sets of issues. The first is related to the question which initially motived this research, that of the potential bias against traditional industries in Brazil's innovation programs and policies. The second concerns the specific managerial and operational issues surrounding CIMATEC that are applicable to the ISI program.

The research on the first question revolves around CETIQT, and our findings suggest the industry is far more dynamic than is generally appreciated, but that dynamism has less to do with technology in the conventional sense than it does with organizational innovations which have enabled the industry to spread out geographically and take advantage of the wide variation in wage levels across the national territory. There are a variety of technical innovations occurring in the garment and textile industry – MIT has a large research project on these developments – but

it is not clear that they offer anything like the competitive advantage for the industry or the employment opportunities which the organizational reforms which we uncovered are providing.

A third issue for the industry, and especially for the SENAI programs that cater to it, is the broadening of the education of manpower in a way that would enable graduates to move into other industries if, and when textile and garments decline. We were able to find traces of all three strategies -- organizational innovation, product innovation, and education reform. The question is whether any of them will be effective without coordination among the various organizations which support the industry and whether CETIQT is able to provide the leadership that that coordination will require.

The conclusions with respect to CIMATEC are somewhat different. Our own studies at IPC suggest that technological innovation is critically dependent on the creation of communities of practice, or interpretative communities. CIMATEC is a model of how such communities might be created and sustained. That model, however, is as we have seen, critically dependent on face to face interaction. It has also proved very difficult to replicate when the rebellion in FIEB forced it to disperse its resources across Bahia. But that is exactly the challenge which the ISI project, spread out as it is across the national territory, faces.

Besides the difficulties it imposes on the development of communities of practice, the technologies that define the various ISIs seem to reinforce, rather than integrate the traditional boundaries around which the economy has historically been organized. The structuring of activities around an industry or a place, as exemplified by the CETIQT and CIMATEC cases, seems to indicate that organizations depend on grounding forces beyond shared technological interests to create an ecosystem that succeeds in producing innovation.

It may also be true that our experience in the USA has exaggerated the importance of these new communities. The ISI program, after all, was built on a German model, and the German economy has developed by strengthening its traditional industrial structure rather than moving progressively to newer and newer industries, unlike the United States. On the other hand, economic development almost by definition involves a movement up the value chain and into new industries. This has certainly been true of the most successful late developers, especially in Asia. Or it may be that the economy is complex and that innovation in certain parts of the

economy will follow traditional lines and the ISI can specialize in these areas. Our own concern with traditional industries and building on their experience certainly suggests that this is true.

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