HIGH-TECH INNOVATION IN EMERGING MARKETS

THE CASE OF MEXICO

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Abstract

This paper presents an exploratory study of innovation systems supporting the electronics and IT industry in Guadalajara, Mexico. Specifically, this study focuses on the effects of linkages with Regional Innovation Systems (RIS) and Supernational Innovation Systems (SIS) at the firm level. Analysis of data gathered in a 2004 survey of 39 companies in Guadalajara suggest that the RIS is more effective than the SIS in building and maintaining innovative capacity through R&D departments and overall R&D activity. The findings imply that, in the case of Mexico, the most effective policies to promote innovation will focus on regional linkages and capacity-building, rather than looking to firms with supernational linkages as a main source of capacity building and spillovers.

1. Introduction

This paper examines the development of Guadalajara's electronics and IT industry and conducts analysis on which parts of this sector have the most comprehensive infrastructure to nurture and capture innovation. This research is rooted in the context of innovation system theory, which provides extensive discussion on ways in which institutions and networks of learning and knowledge capture can drive innovation in the national and regional contexts. The application of this theory has been carried out through various case studies that map and analyze the innovation systems of nearly any industrialized country in the world and a variety of sectors and regions within these countries. The end result is a body of literature that can be used to compare and contrast how different countries have developed their innovation systems through time and which can be used to determine whether any one system is a roadmap for the successful development of a similar system in another part of the world. However, and perhaps understandably so, there is less research on how innovation system theory relates to emerging markets and to what degree the concept of an innovation system in an emerging market environment may differ from that of an industrialized nation.

One emerging market that has not been given much attention in this regard is Mexico. The country presents a unique case in that it is the only emerging market physically connected to the United States – one of the most industrialized countries in the world. The state of Jalisco is home to the "Silicon Valley of Mexico," located in and around the city of Guadalajara, but it has strong roots in the electronics and IT industry in the United States. Thus, this sector in this region presents an opportunity to explore the

interplay between not only regional and national actors, but actors within the US that may have an effect on the development of this industry in Mexico.

Innovation system theory presents a useful model for mapping and analyzing this interplay, since its focus is on institutions and actors that support innovative activity in a region or nation, or within a specific industry. Being that the electronics and IT sector is reliant on innovation and that this sector in Guadalajara is the result of a confluence of regional, national and supernational phenomena, innovation system theory is a logical fit for this type of study. The seminal works on innovation system theory by Nelson (1993) and Freeman (2002) chose the nation as the unit of measurement for innovative capacity, and a literature on innovation systems at the regional level have arisen as well, notably with Saxenian's (1996) study of innovation in the high tech sectors of Silicon Valley and Boston's Route 128 region. Other authors have since examined different pieces or angles of innovation system theory, such as how it relates to technological "catching up," emerging markets, and of course Porter's (1990) work on the role of industry clusters in the creation of national competitive advantage.

In the context of the research mentioned above, this paper is an attempt to analyze the innovation system in Guadalajara and, as a result to begin to fill a research gap within emerging markets innovation theory, particularly with regard to markets that aim to compete in high-tech markets. On the policy side, this research is significant in that it will provide policy makers an understanding of where Mexico and Guadalajara may be succeeding in growing this industry, but more importantly, where it may need further policy support.

The main proposition of this study is that the innovation system supporting the Guadalajara electronics and IT industry is a regional phenomenon, but one that is also intimately connected to and affected by industry and market forces in the United States. This proposition is examined through empirical analysis of how these regional, national and supernational innovation systems may play a role in the innovative capacities of firms on a micro level. Using data from a 2004 survey of 39 electronics and IT companies in Guadalajara, the innovation activities and intellectual property accomplishments of the sector are examined. Preliminary results show that companies in Guadalajara that are most explicitly connected to non-Mexican-based innovative forces (usually in the US) are those that are subsidiaries of multinationals or that obtain contract work with non-Mexican companies. However, these connections seem to have little effect on a Guadalalara-located company's generation of intellectual property or the existence of R&D facilities. Furthermore, companies that have the least formal connections to multinationals use, on average, more of their revenues from annual sales to finance further innovative activity. Lastly, only half of these companies, regardless of their ties with multinationals, work closely with other regional innovators (universities, research institutions, suppliers and other companies) on their innovative activities.

The results overall suggest that the innovation system within this region is being utilized but can be improved upon, and the supernational innovation system that MNCs have at their disposal is either not functional or not utilized. Furthermore, the latter point raises the issue that has long been argued in trade and economics contexts -- that, although Mexico has been able to attract foreign direct investment, its industrial policy does not encourage spillovers from this FDI and, therefore, the industry is not developing

as a result of local innovation and knowledge. There are various possible policy arguments to be made on both the regional and supernational levels, as a result of this research. The most compelling point to the importance of targeting future government investments in further developing the regional innovation system (RIS) and strengthening regional linkages between universities, research centers and non-MNC companies. Some of this can be accomplished through pure financial investments to already existing programs. Other strategies may include sponsorship of new programs such as joint projects between non-MNCs and local universities and fiscal incentives or grants to produce intellectual property or increase R&D. On the supernational side, the lack of innovation occurring as a result of SIS linkages suggests that the policy strategy with regard to MNCs in this sector needs to change. Rather than relying on MNCs simply to bring in FDI dollars and hopefully provide spillovers, MNCs can be more actively engaged in the region's innovative capacity through incentive models used in the past, or through incentives to create joint ventures with local companies.

The next sections of this paper will more fully lay out my background and arguments and are as follows. Section 2, provides research background on innovation theory in the national, region and emerging market context. Section 3, outlines the historical development and current outline of innovation systems in Mexico and Guadalajara. Section 4 discusses the empirical methodology and data set that are used to examine Mexico's IT sector in the context of the innovation systems from Section 3. Section 5 presents research findings, and Section 6 discusses the resulting implications for innovation system theory and S&T policy in the region. The final section discusses

limitations to this research and future research directions that are apparent from this study.

2. **Research Background - Prior Innovation System Theory and Evidence**[1]

Since the seminal works of Freeman (1987) and Nelson (1993), innovation system theory has been debated by economists, sociologists and other social scientists in the context of industrialized and newly industrialized economies, thus the term National Innovation System (NIS). An NIS is generally defined from either a narrow or broad point of view. The narrow definition focuses on institutions that specifically promote the creation and use of new knowledge, whereas the broad definition also considers the wider political, economic and cultural setting that supports the innovation process. The latter, for example, might include not only include firms, universities, and research centers, but also trade policy, macroeconomic policy, and other policies that provide incentives for innovative activity. While it is difficult to draw conclusions on what NIS models will create growth and innovation in all countries, case studies of NISs tend to focus at least one of three features: industrial policy, institutional development and institutional linkages. Nelson (1993), in his book featuring case studies for 13 different countries, asserts that strong educational and training institutions correlates with the existence of innovative firms in-country. He also finds that, on the policy side, firms that are encouraged to export as a result of monetary, fiscal and trade policies are also more competitive. The literature on National Innovation Systems as a general subject has given rise to two more recent areas of research: the "catching-up" of emerging markets and the concept of Regional Innovation Systems (RIS).

The concept of "catching-up" is most simply defined as the process by which an emerging market or developing country can begin to converge with the technological

[1] A table outlining the findings of key literature is also provided at the end of this section.

capabilities of already industrialized countries, but the role of an NIS in this process is debated, and the model for examining the catching-up phenomenon is varied. For example, on the subject of developing countries, Gu (1999) argues that certain levels of NIS development should correspond to a country's level of economic and institutional development. However, as Intarakumnerd et al (2001) demonstrate in their study on Thailand, the existence of a strong NIS in an emerging market may not always match its level of development. In this study, it is found that Thailand has experienced economic growth based on exports of increasingly science-based products, but the NIS is weak. Long-term growth, the authors assert, will still depend on the development of a more integrated NIS. Studies examining technological catching up from an NIS standpoint also tend to focus on industrial history and policy. For example, Amsden (2001), argues that countries with strong manufacturing experience prior to World War II tended to perform better economically in the last half of the 20th century. Within this group of countries, though, performance was also reliant income distribution equality and on how industrial policy encouraged domestic innovation. Mathews' (1997) study of the Taiwanese semiconductor industry asserts that the key factors contributing to this sector's success were: the public sector's significant role in acquiring and disseminating knowledge, and strategic alliances that allowed for information cooperation and resource sharing among companies.

The body of literature on Regional Innovation Systems (RIS) began as a concept mentioned in NIS literature. While researchers such as Nelson (1993) and Freeman (2002) recognized that regional networks may help shape national innovation, the region as a discreet unit of measurement is not usually analyzed in their work. Cook et al (1997)

and Chung (2002) argue that there is value in examining innovation at the regional level. Chung attempts to link the RIS back to the NIS, asserting that policymakers should use the various RISs in a given country to help map and develop the strategic direction of NIS. Cook et al (1997) argue that the RIS is important because its scale is more manageable than the NIS, and the regional unit of measurement is more easily linked to innovation that takes place at the firm-level. Cook et al go so far as to propose their own framework for analyzing and RIS, based on three elements; financial, learning and corporate cultures. Saxenian (1996) supports the notion of regional innovation in her comparative study of California's Silicon Valley and the Boston-Area's Route 128, where she concludes that the development of a high-tech sector is dependent upon the institutional networks and cooperation that exist within a given region. The value, overall, in studying the region as opposed to the nation in this context is that innovation essentially takes place on a micro level and is then disseminated.

Other related literature that touches on innovation system concepts is also worth mentioning. While Furman et al (2002) and Furman and Hayes (2004) do not explicitly map and examine innovation systems in their studies, they use econometric analysis to empirically determine what factors drive national innovation. The evidence strongly points to the case for innovation systems as a necessary component for innovative capacity. Furman et al (2002) use patent activity as a measure of innovation and find that innovation is determined by a common innovation infrastructure (like an NIS), innovation within industrial clusters (such as an RIS), and linkages between these two factors. Furman and Hayes find that, while innovation-oriented policies are key to developing a country's innovative productivity, continued investments in innovation

(such as R&D and education) are also a necessary component. Lastly, perhaps one of the most widely recognized related works mentioned in connection with innovation system theory is that of Michael Porter (1990), who uses the industry and industry cluster as a main unit of analysis in national competitiveness and incorporates them into a "national diamond" model of: factor conditions, demand conditions, related and supporting industries, and firm strategy structure and rivalry.

The body of literature on innovation systems is varied, and over time the tradition has moved from pure system mapping (for example, see Freeman 1987 or Nelson 1993), to empirical analysis that essentially test components of this theory (as in Furman et al 2002 and Furman and Hayes 2004). Yet, in the entire range of work that has been done on the subject, the linkages between regional, national and supernational innovation systems are hardly explored in detail. In the age of globalization, these linkages take on a new importance, as resources and knowledge can be moved more easily than ever before across regions and across national borders. For developing countries especially, understanding and leveraging these relationships is valuable in acquiring and creating knowledge for domestic industries that have to compete internationally. This paper attempts to contribute to innovation research by addressing these issues in a case study format. Mexico's electronics and IT industry is a mix of both nationally-owned and multinational companies, and it presents a opportunity to test whether explicit linkages to supernational innovation actors affect innovation activity at the firm level. Before delving into methodology and data, the section that follows outlines national and regional innovation systems that support innovation in the "Silicon Valley of Mexico."

Table 1

Selected Background on Innovation System Theory and Evidence

Author	Country Studied	Focus	Relevant Findings
National Innovation Systems (NIS) Seminal works			
Nelson (1993, editor)	Europe (6 countries), Canada, Australia, Israel, Latin America (2 countries), Asia (3 countries)	NIS	* Competitive firms carry out their own innovation * The existence and availability of highly-trained workforce correlates with the existence of competitive/innovative firms * Firms that are encouraged to export through fiscal, monetary and trade policies are more competitive
Freeman (2002)	Great Britain, US	NIS	Both national and sub-national innovation systems played important roles in the growth of Great Britain and the United States. Countries that "catch-up" also usually must make adjustments to their national innovation systems.
Technological "Catch-Up" Literature arising from NIS theory			
Gu (1999)	Examples of South Korea and Taiwan	NIS in developing countries	An NIS is not path dependent, so specific policies will vary from country to country. But underlying principles of knowledge creation and networking are applicable across countries. Developing countries lack in being able to create knowledge and the "mood for change."
Intarakumnerd, Chairatana, Tangchitpiboon (2001)	Thailand	NIS in laggard developing countries	The structure of an NIS in countries that are less successful at technological catch up are different from developed countries and other developing countries that are more successful. Thailand NIS is weak, but growth and technological catch-up have been strong. However, this eventually led to economic crisis.
Amsden (2001)	Asian countries (7), Latin American Countries (4), Turkey	How do late industrializing economies succeed in industrial development?	Industrial development after WWII is correlated with manufacturing experience prior to WWII and income distribution equality. This factors drive how industrial policy was able to take shape.

Mathews (1997)	Taiwan	Development of Semiconductor Industry	Case study of Taiwan's efforts to create a semiconductor industry. Key factors contributing to success were: * Public sector played large role in acquiring and disseminating knowledge to Taiwanese companies. * Strategic alliances formed among national companies allowed for sharing of knowledge
Regional Innovation Systems (RIS) Literature Arising from NIS Theory			
Saxenian (1996)	US	RIS in US Electronics Industry	The development of and success of two the high-tech regions in the US is dependent upon the institutional networks and cooperation that exist within these regions.
Cook, Uranga and Etxebarria (1997)		RIS	The RIS is important because it allows for research at a more manageable scale (as opposed to the NIS). The RIS is made up of three elements: financial, learning and corporate culture
Chung (2002)	Korea	RISs as a way of viewing the NIS	The RIS is the best unit in which to view a country's innovation. Policymakers should utilize the talents and characteristics of RISs to develop a broader NIS.
Related Research of Note			
Furman, Porter and Stern (2002) .	US, Canada, Asia Pacific (3 countries), Europe (12 countries)	National Innovative Capacity, using patents as a unit of measurement	Patent activity in a country is determined by: * existence of common innovation infrastructure * innovation on industrial clusters * strength of linkages between common innovation infrastructure and clusters
Furman and Hayes (2004)	US, Mexico, Canada, Europe (22 countries), Asia Pacific (4 countries)	How do countries catch-up with leaders in innovative productivity?	Innovation-oriented policies are essential, but not enough, to develop a country's innovative capacity. Continued investments in innovation (such as R&D and education) are also key.
Porter (1990)	US, Asia (2 countries), Europe (5 countries)	The role of industries and industry clusters in national competitiveness	Comparative advantage is not enough to keep a country competitive. Instead competitiveness depends on the interplay between: factor conditions, demand conditions, related and supporting industries, and firm strategy structure and rivalry

3. National and Regional Innovation Infrastructure in Mexico

3.1 National Policy History

Before addressing the empirical analysis, this section lays out the context in which Guadalajara's electronics and IT sector exists, both on the national and regional levels. Mexico's innovation system is a product of its history, and its post WWII industrial development has been marked by major stops and starts, as it moved from import substitution industrialization (ISI) in the 1950s-1970s and eventually into a more liberalized and privatized market beginning in 1982. As is the trend across many developing countries, the protectionist policies of Mexico's ISI period allowed industry to develop manufacturing experience, but it was not forced to improve processes and innovate on products because industry was exposed to little competition from foreign producers. A reversal of ISI policies began in 1970 and attempted to encourage international competition via exports. However, this period was also hindered at various times by a peso devaluation, a balance of payments crisis and a slow down in the oil market – all of which limited industry growth and long-term investments in innovation (such as R&D). Finally, when Mexico began to open itself up to free trade and more liberal policies in the 1980's, the hope was that the new policy direction would expose the country to more international competition and investor support for industry, thus allowing an increase in innovative capacity. However, the credibility of Mexico's policy commitment was marred by looming international debt obligations and the resulting lack of investor confidence in the Mexican market (Fernandez 2000)

The entry of Mexico into the North American Free Trade Agreement (NAFTA) in 1994 further solidified the country's commitment to free trade. While it is generally

accepted that NAFTA has encouraged huge inflows of foreign direct investment (FDI) into the country, the trade agreement was not necessarily a direct ticket to increased local innovation (from increased investment and knowledge spillovers) and economic growth. Research on how NAFTA has specifically affected Mexico's innovative capacity is hard to come by, partly because of the challenge of isolating the effects of NAFTA from other issues such as Mexico's peso devaluation and industrial history. Schiff and Wang (2003) make an attempt at isolating "NAFTA-effects" by quantifying the relationship between NAFTA and total factor productivity (TFP) in Mexico, and they come up with two main findings. First, they find that Mexico's trade with Canada and the US "has a large and significant impact on TFP in Mexico's manufacturing sector." Secondly, "NAFTA has led to a permanent increase in TFP in Mexico's manufacturing sector of between 5.5% and 7.5% and to some convergence between the economies of the US and Mexico." (Schiff and Wang 2003, 4). However, the data they examine is from the time period of 1981-1998 (1998 is only four years after NAFTA), and a longer-term analysis would prove more useful in determining the net effects of NAFTA on factors indicating innovation – such as TFP. Carrillo (2004), on the other hand, studies the strategies of automotive-industry maquiladora plants on the border of Mexico pre- and post-NAFTA and finds conflicting results to those of Schif and Wang. According to Carrillo, while post-NAFTA strategies have focused on upgrading and forming local relationships and industry clusters, "this upgrading process has not given rise to a balanced pattern of regional development" (Carrillo 2004, 12). Although industry clusters have developed, Mexican-owned supplier development, and thus endogenous innovation, has been limited overall.

3.2 National Innovation Infrastructure

Clearly, due to macroeconomic factors, there has not been consistent investment in Mexico's ability to upgrade industry through innovation, and the conclusions regarding "NAFTA-effects" on innovation are mixed. However, throughout the policy regimes previously mentioned, a long list of public organizations were established to support industry, and today those that remain make up the institutional framework helping to sustain and create innovative capabilities. The main functions of these institutions can be divided into two categories: incentives, knowledge creation and sharing.

Incentives. According to research by Casalet (2000), there are around 18 national institutions that support innovation and industrial development in Mexico. The key institutions since liberalization are generally oriented toward export activities, foreign investment and SME development. Two of the most important are Bancomext (Mexico's bank of foreign trade) and NAFIN (provides support to SMEs). Bancomext is committed to promoting Mexico's non-oil exports and has 37 offices throughout the country. Just a few of the services that Bancomext provides for qualified businesses include credit and financial assistance, technical assistance for a range of issues (i.e. creating a business plan, obtaining certifications, designing a promotional catalog of products, improving production processes), and training and certification (Bancomext 2005). The organization also has a vast amount of trade data on sectors of interest. NAFIN mainly provides credit support to SMEs but also offers technical assistance on quality standards, production chain issues and business training.

Two other programs worth mentioning are fiscal regimes administered at the national level – Maquiladora and PITEX programs. Both have been in existence since

before NAFTA, but maquiladoras especially have gained more attention in post-NAFTA years. Both have the same goal of attracting foreign investment by firms who want to take advantage of Mexico's lower costs of production and labor but produce mainly for export. The two programs are different simply in the exact structure of their tax breaks.

Knowledge Creation and Sharing. Actual knowledge creation dissemination is essentially the end goal of any innovation system, so it is appropriate to include a discussion on the institutions that support these efforts in Mexico. According to Casa , de Gortari and Luna (2000), Mexican higher education institutions (HEIs) carry out the majority of R&D activity in Mexico, but the country is still a laggard in terms of knowledge production at an international level. Its technology and engineering programs receive little government or private sector support, and the knowledge production (measured in terms of scientific publications produced) is below average for industrialized nations and for some Latin American countries. That being said, Mexico's science and technology council – CONACYT – appears to be a key driver of knowledge creation in Mexico, although not necessarily through the university system.

CONACYT reports directly to the president and participates in and administers a wide array of programs focusing on S&T (science and technology) development. Casalet (2000) highlights CONACYT's research centers, some of which have been in existence since the 1940's. The centers are located in various regions and focus on a variety of activities in basic research and development, training (including Master and PhD degrees) and consulting services. There are 28 centers nationwide with different technical focuses: 9 on exact and natural sciences, 9 on social sciences and humanities, 7 on technological development, 1 on information services (INFOTEC) and 1 on financing higher education

(FIDERH). The centers, which generally operate independently of each other, also promote networking among local firms through seminars, forums and other public activities. Medium-sized domestic firms likely gain the most from the activities of these centers, which makes sense if one reasons that these firms are the ones most likely to have the necessary knowledge capital for the markets and technologies but cannot support their own research activities.

3.2 Regional Innovation Infrastructure: Guadalajara

This subsection focuses specifically on the infrastructure supporting the electronics and IT industry in and around city of Guadalajara -- "Silicon Valley of Mexico" – in the state of Jalisco. The development of this sector has been actively taking place since the mid-20th century, and since 2000, electronics have accounted for 60-70% of the state's total exports. Furthermore, Jalisco is responsible for approximately 20% of Mexico's total electronics exports (again, since 2000).[2]

Thus, Jalisco is a state where this industry matters, and Guadalajara is the state's (and perhaps the country's) most well-recognized electronics and IT cluster. The region currently hosts offices and plants of twelve original equipment manufacturers (OEMs), some of which are the world's best-known companies in this sector (i.e. IBM, H-P, Intel, Kodak and Hitachi). Likewise, the area is home to fifteen electronics manufacturing services companies (EMS), many of which are also multinational (i.e. Solectron, Flextronics, Sanmina-SCI). There are also 21 original design centers (ODCs), most of

[2] Statistics provided by CADELEC in July 2004. CADELEC is the region's industry group that supports and develops the electronics industry supply chain.

which are nationally-owned, and 151 software companies (SW). Guillermo Woo divides this region's development into three stages (Woo 2001, 122-126).

The first stage began in the late 1960's and early 1970's, with the entry of the first multinational electronics firms. Accepted wisdom concludes that companies such as IBM, Kodak and Motorola decided to set up entities in Jalisco (and Mexico in general) purely for cost-saving reasons, but Woo points out that the initial attraction was also due the quality of the labor force and the region's educational infrastructure. These two factors subsequently enabled local plants to compete with their sister plants in other parts of the world and develop processes that improved their ability to fill orders and maintain efficient cost structures and quality in manufacturing. Woo's second stage of development highlights the move from an industry existing mainly of the OEMs to the formation of OEM suppliers and subcontracting facilities to support the OEMs. His third stage points to the liberalization associated with NAFTA and the effect of the 1994 peso devaluation. Together, these two changes encouraged local production via subcontracting and reduced the cost of production overall. Thus, generally speaking, this region of Mexico was attractive to leaders in the global electronics industry because of education, cost and manufacturing experience that has been acquired over the years. In the mid-1990's the Mexican government identified a need to further develop this industry country-wide, and there are certain key institutions, with a presence in Guadalajara, whose mission is to develop and organize this sector in support of OEMs, EMS and local

skill development.. These organizations can be classified into three different types (by order of importance): Networking, Knowledge Creation and Sharing, and Incentives.[3]

Networking. There are three organizations in this region that serve as resources for and work with industry to facilitate relationships at different levels of the electronics and IT supply chain. First, CANIETI (Cámara Nacional de la Industria, Electrónica, de Telecomunicaciones e Informática) is a national chamber of commerce for the industry, with its Western branch in Guadalajara. CANIETI's role is broad in that it works with the largest companies located in the region, the state and federal government and other local public-sector organizations to promote Guadalajara as a center for production and innovation in this industry. The organization is responsible for organizing regional conferences and seminars on key topics such as trade law and government-sponsored industry promotion projects**.** CANIETI is likely one of the first stops for any entity having potential interest in investing in, working with, or otherwise promoting this sector.

Next, CADELEC (Cadena Productiva de la Electrónica), is responsible for facilitating relationships between electronics firms in Jalisco and suppliers (both MNCs and nationally-owned). It was founded in 1998 and funded with help from CANIETI, SEPROE (state economic development organization), CONCAMIN (National Convederation of Industrial Chambers), FUNTEC (Foundation for Technological Innovation of SMEs) and UNDP (United Nations Development Program) (Palacios 2000, 38). According to Woo (2001) CADELEC is essentially at the center of the industry, as it works with the largest firms, schools and training institutes that provide human capital to

[3] Unless otherwise noted, information on Guadalajara's institutions, as outlined in this section, are sourced from author's primary research in Guadalajara.

these firms, technology parks that provide real estate to MNCs, technology development centers and the government to try and consolidate the industry in Jalisco. Tactically speaking:

> CADELEC's strategy consists of the following steps: first identifies input requirements by electronics companies, .i.e. business opportunities; next identifies potential suppliers at the local, national and international scale; then it assesses, selects and certifies prospective suppliers; and then closes the business. CADELEC proceeds by working on individual commodities on a case-by-case basis (Palacios 2000, 39).

CADELEC also participates actively in efforts to attract new investment in Mexico, educating large MNCs on real estate opportunities available in the region's industrial parks.

The third networking organization of interest is RedI (Red de Ingenieros or Engineer's Network), which also has its ties to CANIETI. This organization is in its infancy, as it was officially launched in 2003, with support from CANIETI, CADELEC, local universities and local MNCs (Texas Instruments and Intel).The project is focused on promoting the "spirit of association" in the electronics industry in Guadalajara. This organization focuses on the industry at a very micro-level, compared to the activities of CANIETI and CADELEC. Rather than directing its efforts at institutions, REDI aims to "promote the spirit of association" among engineers at the individual level. At its most basic, level, REDI promotes association in its purest form, attempting to provide an environment where engineers with MNC experience (either working within or working with MNCs) freely share ideas, learn from each other and create new opportunities for

the industry. The organization is still relatively young, but it serves as an example of local industry trying to encourage learning networks among local talent. RedI has put together various talks on how new electronics and IT technologies can be applied to products in the Guadalajara region, how to build a business plan, how to protect intellectual property, and how to pitch a plan to potential investors. Presenters have included the CEO of Hispanic Net (an organization of Hispanic engineers in Silicon Valley), managers from Intel Capital and law firm specializing in intellectual property.

Knowledge creation and sharing. The obvious source of explicit knowledge creation in Guadalajara is the educational system. Again and again, MNCs cite the availability of a large educated workforce as one of the primary reasons for located in Jalisco and more specifically in Guadalajara. One of the universities that offers a unique story with regard to its relationship with the electronics industry is that of Cinvestav (Centro de Investigación y de Estudios Avanzados del IPN), located on the outskirts of Guadalajara proper. Cinvestav is part of Mexico's National Polytechnic Institute (IPN), and the campus offers a Master of Science or Doctorate in Electrical Engineering, with specialties in automation, telecommunications, computer science, electrical power systems and electronic design. Along with its educational aims, the campus has been able to develop a unique relationship with electronics and IT industry through an organization called CTS (Centro de Tecnológica de Semiconductores). The history of CTS (which is a part of Cinvestav) is worth noting because it is one example of government and private sector working hand in hand and providing explicit technology transfer to local human capital.

Today CTS operates as a semiconductor research and design center that also consults to the private sector (mostly MNCs). However, its existence may not have ever come about had it not been for a deal between IBM and the Mexican government in 1986. At that time, IBM wanted to bring its manufacturing to Mexico but retain 100% ownership of the business, which was not allowed by Mexican law. The Mexican federal government made an exception to this law on the condition that IBM would co-developing a technology center that would train Mexican engineers. When this deal was struck, a national competition was held to determine who would work with IBM on this project.

Cinvestav won the competition and assigned four professors from the electrical engineering department of its Mexico City campus to choose a location for and launch the technology center. Guadalajara was chosen because Motorola, HP, IBM, and Kodak were all in the area and were all viewed as potential clients that would use CTS design services. From the time CTS opened in 1988 until the time Mexican FDI law changed to allow 100% ownership in the early 1994, IBM employees worked full time as consultants helping to train and transfer knowledge to the engineers at CTS. It was from these consultants that the Mexican engineers in CTS learned the design flow of integrated circuits – its most important contribution to the center. Along with the consulting services it offers, CTS has also taken on the role of small business incubator. periodically granting space and equipment to former CTS engineers who are trying to start their own ventures. One of these ventures was a chip design company that was eventually bought by Intel. The founder of this company now heads up Intel Mexico's Design Center.

Overall, the role of Cinvestav and CTS in knowledge creation and knowledge sharing within this industry has been significant, The case of CTS and the fact that one of its companies is now Intel Mexico is encouraging, but it may be an outlier, as no similar technology-transfer arrangement has been put in place since CTS was formed.

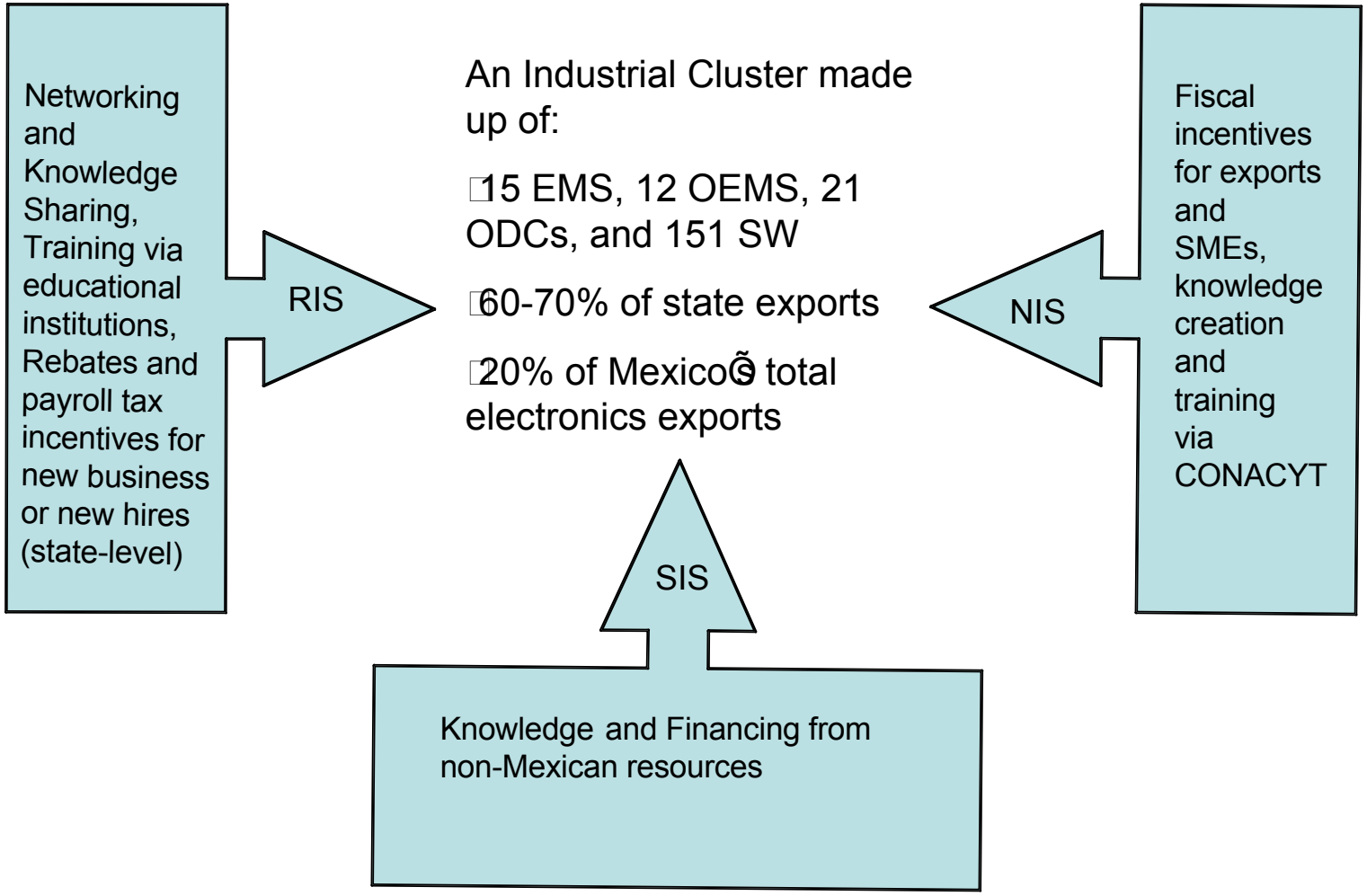
Incentives. With the Mexican federal government administering 97% of taxes, the state of Jalisco is limited in terms of tax breaks it can offer to companies who locate in the region. The incentives that are offered are administered by SEPROE (Jalisco's Secretariat of Economic Promotion) and are much more oriented toward attracting new businesses to the region, rather than the strong focus on export promotion that takes place at the federal level. Specific incentives include, rebates to companies whose investment projects create new jobs, improve or install basic infrastructure and/or install new systems to preserve the environment – all outlined under Jalisco's Economic Development Law (FTE). Through the Economic State Promotion Council (CEPE), Jalisco does offer discounts from 50%-100% on payroll taxes, depending on whether or not the company is brand new or is simply expanding its workforce. Lastly, SEPROE also helps companies obtain any municipal incentives (i.e. tax breaks, discounts on permits and rights). [4]

The take away from this section is that there is, indeed, a recognition of the importance of institutions and policies in supporting industrial development and innovative activity in Mexico. And there is the existence of an innovation system on the regional and national levels. This section should also provide a sense of the importance of

[4] Information provided by SEPROE.

MNCs to the country's and the region's development. They are encouraged strongly by the fiscal regimes at the national level, and they are considered key targets for SME networking at the regional level. Likewise, had it not been for IBM, the creation of organizations like CTS and TDCom (which later became Intel Mexico) may have never taken shape. The importance placed on MNCs suggests that knowledge and financing from outside of Mexico is important to the development of industry within Mexico. As a result, one would expect to observe a supernational innovation system (SIS) where linkages between regional, national and supernational resources all play a role in national and regional innovative activity. All three of these systems and their main strengths are represented visually in Table 2. The effectiveness of these systems in promoting innovation will be examined empirically in the sections that follow

Table 2. Roles of NIS, RIS and SIS in Guadalajara's Electronics and IT Cluster



4. Methodology and Data Set

The data set for the empirical section of the paper is taken from a 2004 survey of 39 electronics and IT companies in Guadalajara, sponsored and carried out by CANIETI over a three-month period. Respondents were General Managers, Vice Presidents or Managers of key areas such as production and procurement. The objective of the survey was two-fold: first to understand how companies in this sector use and collect technology and knowledge and, second, to understand the innovative capacity of these firms. Six areas of the firm were examined: organization, leadership, human capital, use of IT, marketing, core competencies, innovation and intellectual property. This paper takes an interest in the latter goal of the survey and focuses on variables dealing with innovation activities and intellectual property (See Appendix I for survey questions that deal with these variables and Appendix II for entire list of survey questions).

The survey focuses on four different types of companies: Electronics Manufacturing Services firms (EMS), Original Equipment Manufacturers (OEMs), Original Design Centers (ODCs) that design on behalf of other companies and Software firms (SW). The 39-firm sample consists of 7 EMS (47% of total population in Guadalajara), 5 (42% of total population in Guadalajara) OEMs, 7 ODCs (33% of total population in Guadalajara), and 20 SW (13% of total population in Jalisco).[5] For the purposes of this study, OEMS and EMS are assumed to be MNCs, MNC status is consequently used as a proxy for linkages with the supernational innovation system, since being an MNC implies access to knowledge, capital and other resources on an international scale.

[5] According to CADELEC.

Using simple Cross-tabulation and ANOVA models, the analysis itself tests my hypothesis that the key innovation system supporting this industry is regional in nature, but there are effects on innovative capacity for firms that have supernational linkages. The analysis divides my tests into two sections: Supernational Innovation System (SIS) linkage effects (where MNC status is a proxy for SIS linkages) and Regional Innovation System (RIS) linkage effects (where variables denoting whether a company collaborate with universities, research centers, other companies or suppliers are used as a proxy for RIS linkages). These two sections each feature a series of six discreet tests. I consider my overall hypothesis proven if find that at least half of my SIS linkage effects tests show a significant relationship and at least half of my RIS linkage tests show a significant relationship. The findings of these tests are outlined in the next section.

5. Research Findings and Implications

Again, my overall hypothesis is that the innovation in this industry is a regional phenomenon, but with some linkages to international actors. In order to prove this hypothesis, I use a series of six tests that examine the relationships between companies with regional or supernational linkages and different proxies for innovative capacity. The findings are as follows and are also presented in Table 3 at the end of this section.

MNC Status Effects

- Test A: tests whether there is any relationship between company type and existence of an R&D department (using R&D departments as a proxy for innovative activity). Pure percentages reveal that non-MNCs are more likely to have an R&D department than MNCs. However, a cross-tabulation between these two variables, using a significance level of .1 suggest that these differences are insignificant, and MNC status has no bearing on whether an R&D department exists.
- Test B: tests whether there is any relationship between company type and patent production on the firm level (using patents as a proxy for innovative activity). The data show that the average patent production for MNCs is 7.25, which is higher than the average of ,44 for non-MNCs. However, an analysis of variance of these means (ANOVA) reveals that these differences are not significant. Thus, MNC status does not determine amount of patent production.
- Tests C-E: tests whether there is any relationship between company type and % of overall resources spent on R&D, % of worker time spent on R&D and % of annual revenues spent on R&D. Overall, the mean of these percentages in each

case is higher for non-MNCs than it is for MNCs, and the difference in these means is significant at the .1 level for all cases. However, the relationship is negative, meaning that being an MNC results in a lesser percentage of overall resources, worker time on sales put toward innovation.

RIS Linkage Effects

- Test F: tests whether there is a relationship between regional innovation system linkages and the existence of an R&D department. Overalll, 85% of firms that have linkages with regional innovation systems also have R&D departments, whereas only 42% of firms with no linkages have R&D departments. Cross-tabulation analysis shows that this relationship is significant, given my chosen significance level of .01. Thus, firms that create linkages within the regional innovation system are significantly more likely to have R&D departments.
- Test G: tests whether there is relationship between regional innovation system linkages and patent production. Data show that the average number of patents for a firm with RIS linkages is higher (4.80) than those that do not have linkages (.16). However, an analysis of variance reveals that this difference is not significant. Thus, RIS linkages do not result in a significantly higher number of patents produced.
- Test H-J: tests whether there is a relationship between regional innovation system linkages and % of overall resources spent on R&D, % of worker time spent on R&D and % of annual revenues spent on R&D. For each case, the average % of resources spent on innovation is higher for firms with RIS linkages that for firms

without. However, these differences are only significant in two cases -- % of worker time spent on innovation and % of revenue put toward innovation.

These findings are significant in that they prove that companies with linkages to Guadalajara's RIS significantly increase their innovative activity in regard to percentage of worker time spent on innovation and percentage of annual revenues spent on R&D. These linkages also correlate with a higher likelihood of having an R&D department. So, regional linkages are important to innovation. Supernational (SIS) linkages seem to suggest the opposite and have little bearing on innovative activity at the firm-level. Where SIS linkages do matter, they actually have a negative effect on percentage of resources put toward R&D. Overall, the findings support other recent research asserting the importance of the region as a unit of measurement for innovation systems.

Table 3
Summary of Findings for Relationships Between Variables of interest

	MNC	non-MNC	Significance at .1 level	Analysis Method
% of companies that have an R&D Dept	58.3	66.7	no	Cross-tab
Average # of patents	7.25	0.44	no	ANOVA
Average % of resources devoted to innovation	6.5	26.3	yes	ANOVA
Average % of worker time utilized for innovation	4.9	20	yes	ANOVA
Average % of annual sales used for innovation	1.3	14.7	yes	ANOVA

	RIS linkages	no RIS linkages	Significance at .1 level	Analysis Method
% of companies that have an R&D Dept	85	42	yes	Cross-Tab
Average # of patents	4.8	0.16	no	ANOVA
Average % of resources devoted to innovation	25.5	15.7	no	ANOVA
Average % of worker time utilized for innovation	24.3	8.3	yes	ANOVA
Average % of annual sales used for innovation	18.5	5.4	yes	ANOVA

Conclusion

This paper is an attempt to fill the research gap on innovation systems in developing countries, using proxies that estimate linkages to regional innovation systems and supernational innovation systems. Research results suggest that, for policy makers who are concerned with how best to increase innovation in this region, the main focus of government investment (monetary or otherwise) should be in further developing firm linkages with the RIS. This could include a myriad of strategies such as joint projects with local universities' engineering departments, government funding for institutions that provide workshops on IP protection, and federal or state grants for the development of local R&D facilities and intellectual property at local firms. These strategies would not only provide another avenue of networking and knowledge between companies and local innovative actors, but would also directly impact a companies ability to innovate thanks to greater institutional support.

That being said, it makes sense that policy makers would also want to explore further engagement with MNCs, given that these companies are such a key part of the development of this region (as exemplified in the anecdote of IBM and CTS) and theoretically posses a range of resources not available to non-MNCs. Since MNCs are so large and FDI dollars are so important to this region, it may be argued Mexican policy makers have less leverage in incentivizing MNCs to support the innovative capacity of the region. However, it may be possible to negotiate agreements similar to that of CTS or provide incentives to create joint ventures between MNCs and non-MNCs.

As this study was exploratory in nature, there are certainly areas for future research and/or improvements upon the work done here. One concern that this analysis

raises is that none of the variables studied have any significant correlation or effect on patent production. While they may affect higher or lower R&D spending, on average, the same amount of patents result. One explanation for this is that, in the case of MNCs, patents may be filed at company headquarters abroad. In the case of non-MNCs it is possible that IP law simply is not being utilized as a means to protect innovation or that these companies are selling their innovations to other entities that then own the IP (as could be the case when some of the companies act as consultants). This is certainly an area for further development.

Furthermore, it is worth recognizing that this study was constrained by its sample size and the fact that it is a stand-alone, rather than a comparative, analysis. Had this survey captured the entire population of electronics and IT companies in Guadalajara, it is possible that some of these insignificant relationships would have become significant and would have shed more light on how these linkages affect innovation. Had this survey been expanded to other Mexican RISs, the analysis would perhaps be even more telling. This analysis is also limited by the survey itself. Although it asked many questions that relate back to innovation, the design was such that the majority of answers were categorical and, thus, not suited for statistical testing techniques that are more rigorous (i.e. regression analysis). All of this suggests many opportunities for future research.

Given these limitations, however, the study serves as an exploratory glimpse into how one of Mexico's most well-known high-technology clusters utilizes regional and supernational linkages to create and maintain innovative capacity. Rather than confirming the importance of the SIS in the context of globalization and of NAFTA, this study

implies that linkages at the regional level are still a key consideration in understanding and planning industrial development.

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APPENDIX I

Variables of Interest in Determining Innovation System Effects

Question # (recoded for statistical analysis)	Variable Name	Question
1	company type	Description (EMS, OEM, ODC, SW)
2	R&D dept exists	Does your company have an R&D department? (1=yes, 0=no)
3	% of resources involved in innovation	What percentage of resources are devoted to the innovation process?
4	% worker time in innovation	What percentage of worker time is utilized toward the process of innovation?
5	% of annual sales generate innovation	What percentage of annual sales are utilized to generate innovation?
6	collaboration	What entities do you collaborate with in the innovation process?
6a	collaborate with universities	Universities
6b	collaborate with research centers	Research Centers
6c	collaborate with clients	Clients
6d	collaborate with other companies	Companies in your same category
6e	collaborate with suppliers	Suppliers
7	trademarks	How many registered trademarks does your company have?
8	patents	How many patents does your company have?
9	copyrights	How many copyrights does your company have?

APPENDIX II
CANIETI Survey 2004 -- Survey Questions

Question Number	Question
	Company Name
1	Description
2	# of employees
3	% of employees that are administrative
4	% of employees that are central to operations
	Human Capital
1	Does your company have an HR department
2	What type of plans to you have to help develop your employees?
	Doctoral degrees
	Masters Degrees
	Training
	Nothing
3	What mechanisms do you use to ensure that knowledge is maintained withing the company?
	Legal Protection
	Documentation
	Electronic Documentations
	Nothing
4	What percentage of employees are technical workers
5	What percentage of employees are engineers
6	What percentage of employees have their Master degree?
7	What percentage have their Doctorates?
8	Is there a stock option planf or key personnel?
9	Where have your personnel been educated?
	Organization
1	Does your organization have a mission, vision and values?
2	How many hierarchical levels are there in your company?
3	What is the most frequently used mechanism to communicate key company objectives to employees?
	Monthly Meetings
	Email
	Memos
	Other
4	What methods do you employ to develop leadership within your organization?
5	How many people are involved in budgeting decisions involving research and development?
	Marketing
1	Do you have a marketing department?
2	Do you have a procedure for analyzing your competencies?
3	In what way has marketing encouraged innovation within the company?
	Innovation
1	Does your company have an R&D department?

2	To what extent has the R&D team fulfilled its objectives?
3	To what extent is R&D involved in the planning process?
4	What percentage of resources are devoted to the innovation process?
5	What percentage of worker time is utilized toward the process of innovation?
6	What percentage of annual sales are utilized to generate innovation?
7	What is the origin of resources used to generate innovations?
8	What have been the reasons for generating your company's innovations?
	Grow market participation
	Maintain market participation
	Open new markets
	Quality
	Cost Reduction
	Other
9	What entities do you collaborate with in the innovation process?
	Universities
	Research Centers
	Clients
	Companies in your same category
	Suppliers
	Other
10	How many projects in the past year have been:
	Behind schedule
	Not started
	In process
	Finalized
	Intellectual Property
1	Does your company currently have a legal department or legal counsel?
2	How many registered trademarks does your company have?
3	How many patents does your company have?
4	How many copyrights does your company have?
	Core Competencies
1	What are your company's core competencies?
2	What does your company do to develop your core competencies?
3	In what way is your company competitive?
	Financing
1	Have you created a business plan that has been presented to investors?
2	Have you received capital from angel investors?
3	Have you been financed by venture capital?
4	Does your company have bank financing?
5	Does your company have government financing?
6	Does your company have financing from any non-profits?