# UNIVERSITY-INDUSTRY COLLABORATION: A SUCCESSFUL CASE IN THE ELECTRONICS AND SOFTWARE DESIGN AREA IN MEXICO

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*SUMMARY*

*We analyze the project environment and execution flow of some successful collaborations implemented by a Mexican research institute, the Center of Semiconductors Technology (CST) at Cinvestav-IPN in the metropolitan area of Guadalajara (MAG), with local and transnational firms in the area of electronics and software design. This case study, built from field and documentary evidence as well as interviews with key actors within firms located at MAG, emphasizes the importance of having a world-class R&D group as a required condition to build bi-directional channels for conducting joint research and development projects with a high-technology industry. In particular, we show that collaborative research projects are the main linkages developed by CST with an appreciable influence in the creation of a new industrial sector that has contributed substantially to the gross product of MAG.*

The main role of universities has been to train students for the labor market and this is considered their primary connection with society. Basic research has been added to their teaching activities, which usually involves public investment and publication through specific channels of dissemination (Laredo, 2007). In recent times, the links between industry and universities were conceived in terms of developing and commercializing the fruits of academic research (Gibbons *et al.*, 1994; Etzkowitz and Leydesdorff, 1997). International experience suggests that technology transfer from universities to industry has been formalized through government policies, specific legislation, tax incentives, venture capital to initiate start-ups or spin-offs, and the creation of technological parks, business incubators and accelerators (Markman, 2008; Iacono and Nagano, 2014; Friesike *et al.*, 2015; Watkins *et al.*, 2015).

The university-industry collaboration has been studied from the perspective of university researchers and administrators (Arvanitis *et al.*, 2008; Ankrah *et al.*, 2013) and also from the perspective of industry (Hall *et al.*, 2011; Ho *et al.*, 2014; Kneller *et al.*, 2014). In peripheral countries studies have described the university-industry link, proposing conceptual and methodological models of technology transfer and entrepreneurial skills from the university (Casas *et al.*, 2000; Gutierrez, 2004; Vega and Saniger, 2010; Villasana, 2011; Necoechea *et al.* 2013; Tonelli and Zambalde, 2015).

We examine a successful model implemented in Mexico in order to collaborate with the electronics industry established in the Metropolitan Area of Guadalajara (MAG) in the state of Jalisco: that of the Center of Semiconductors Technology (CST) of Cinvestav-IPN (*Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional*). The latter was created in 1961 as a public research center and nowadays

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has 28 research departments distributed in nine campuses throughout Mexico (De Ibarrola *et al.*, 2002). Cinvestav-IPN groups carry out research in Exact and Natural Sciences, Life Sciences and Health, Technology and Engineering, Social Sciences and Humanities. However, in contrast to Cinvestav's practices, CST was created in 1988 as a technology transfer center rather than an academic scientific unit (De Ibarrola *et al.*, 2002). CST was founded as a joint project of IBM, the Ministry of Economy and Cinvestav with a main goal: to provide services to the MAG electronics industry in the areas of design and development of digital integral circuits. MAG was conceived as a space where companies could be competitive given certain regional factors: cheap labor, industrial parks, transport infrastructure and relative proximity to the USA market (Partida, 1996; Dussel, 1999; Gallagher and Zarsky, 2007). Technology transfer through foreign direct investment has been studied for MAG and Tijuana, another Mexican region with a large cluster of electronics industries and located in the state of Baja California (Rivera, 2006; Padilla, 2008). In particular, it was found that higher local capabilities, associated to the research groups in universities and research centers in Jalisco have been crucial to attract more complex types of technology projects.

From the perspective of regional knowledge spaces, Santos (2001) has studied the telecommunications sector in the western region in Mexico from the perspective of regional knowledge spaces. She used the term Mexican Silicone Valley to designate the MAG and identified the CST as a training center for high quality human resources. She described how some of the engineers trained at the CST are incorporated to some regional firms and in turn they develop new platforms. On the other hand, there are two local agencies that provide institutional support and have built innovation regional networks in order to develop technological capabilities to create small and medium enterprises (SME): the Electronics Telecommunications and Information Technologies Industrial Chamber (CANIETI) and the Electronics Industries Chamber (CADELEC). Ordoñez *et al.* (2005) and Guillemin (2014) have described that, during the reconstruction of the MAG electronics cluster, new technological SMEs and some original design manufacturers (ODM) implemented new technological practices with support from CANIETI, CADELEC and CST.

In the present report we analyze the collaborative model adopted by Cinvestav at CST, its project environment and execution flow. We carry out an exploratory analysis of the different linkages established by CST with the MAG electronics industry. The analysis of interviews with local MAG companies in this case-study shows that collaborative research projects are the most important linkages developed by CST researchers in MAG. We will present empirical evidence that characterizes the efficiency of CST collaborative model. Other CST mechanisms of collaboration with the MAG industry involve licensing, business development and training to meet the needs of MAG firms. There are other universities located in the MAG (*Universidad de Guadalajara, Universidad Autónoma de Guadalajara, Instituto Tecnológico de Estudios Superiores de Occidente, Instituto Tecnológico y de Estudios Superiores de Monterrey*), but all of them have linkages with the MAG industry that are mostly related to training specialized personnel (Dussel, 1999).

The innovation processes generated by CST are a consequence of international collaborations under the triple helix model (Etzkowitz and Ranga, 2010) and the global production networks (Ernst, 2002). The respective network characterization, contributing to the building of the CST knowledge space, was implemented according to the work of Casas *et al.* (2000). The triple relational dynamics involves public regional research centers (like CST), the private sector and public-private organizations like CANIETI and CADELEC. One of the consequences of this process involved transnational firms like Intel and Continental, which in turn incorporated research and development activities that contributed to the social and economic development of the MAG region. In this regard, we conclude that, for peripheral countries, the collaboration within global innovation networks is part of the learning process associated to scale a higher value-added industrial production. Evidence of these processes involve associated spillovers, technological and organizational accumulated capabilities, as well as the promotion and strengthening of domestic firms and technology-based industries (Ordoñez *et al.*, 2005; Guillemin, 2014; Rivera Ríos *et al.*, 2014).

Below, we present the methodology used in the analysis, followed by the presentation of the CST collaborative model, its project execution and flow analysis, and the impact of CST national and international linkages. Finally, conclusions are presented. Along this report, the term 'university' is used indistinctly to refer to universities and research centers as CST.

## Methods

We had access to the historic files (1989-2011) of the collaborative projects of CST with the electronics firms located in the MAG and, in some cases, with the parent plants of transnational corporations. A synthesis of technological projects developed under contract by the CST is shown in Table I. We identified 36 companies and 103 technology projects. In this sample, 25 firms are foreign-born (21 from USA, three from Germany and one from France-Italy) and 11 correspond to local firms. The evolution of the USA-Mexico university-industry projects is depicted in Figure 1 with a total of 97 projects.

A series of interviews were performed to various senior officers of electronics firms located at MAG (Continental, Intel, IBM, HP) who were responsible for the research management of their corporations. The interviewees were requested to describe the most important interactions each had with CST. We were interested in the origin of the knowledge transfer that took place in the process and the impact achieved on the firm value chain. The project execution model was provided by CST personnel and the characterization of the environment under which the projects were implemented resulted of interviews and documentary analysis properly referred below.

We identified four companies with whom CST has maintained sustained relationships: IBM, HP, AT&T and ITEL. The CST design services offered design of application-specific integrated circuits (ASICs), system design, design of printed circuit boards (PCB), as well as consulting and writing codes for processors. Generally, all projects involve services. Due to the secrecy of the projects there are no documented details.

## The CST Collaborative Model

There are different working models of university-industry linkages depending on the time scale and personnel responsibilities. Throughout the years, universities have learned how to deal with industry, have adopted some of their procedures and prefer to patent the knowledge and results of their scientific research rather than publish them in specialized journals or present them in international conferences (Boardman and Ponomariov, 2014; Cabrero *et al.*, 2011). Industries may acquire the intellectual property rights of university inventions in order to exploit them commercially

TABLE I
DISTRIBUTION OF COLLABORATIVE PROJECTS DEVELOPED BY CST

| Table | Firms | Type of interaction | Highlights |
|---|---|---|---|
| | | Collaboration with major companies | |
| 1989-95 and 2009-11 | IBM | Telecommunication integrated circuit devices; digital electronic devices; software device drivers; application electronic cards for the workstation and PC computers; motherboard for PCs; VLSI IC design. | USA R&D |
| 1993-11 | HP | Digital semiconductor devices, printed circuit boards and electronic cards; paper handling firmware design. | USA. Design group, until 2005. |
| 1994-11 | AT&T | Telecommunication devices, CSU/DSU, frame relay and HDSL systems; industrial consulting; VLSI IC design. | USA |
| 1999-11 | Intel | FPGA and electronic cards design. | USA R&D |
| | | Collaboration with companies incubated by the Cinvestav UG & CST spin off | |
| 2008 | Mixbaal | Failure analysis of cells and PV concentration systems (500X). | MX. Spin off, 1994 |
| 1999-00 | TDCOM | ASIC Design Verification. | MX. Spin off, 1998 |
| 2010 | Modutram | Development of intelligent system, software and hardware design to paths tracking. | MX. Incubated firm |
| 2009-10 | IDEAR | Designing a detection system by digital image processing. | MX. Spin off BEA, 1993 |
| | | Collaboration with national and transnational companies | |
| 1998-11 | General Electric; Motorola; A2E Technologies; Transwitch; Dantel; Rolm; Atmel; Sanmina SCI; 3M; Phogenix; Texas Instrument; Chip Express; Xerox; Xilinx; Altera; Actel; Schlumberger. | IC design application specific (ASIC); system design; design of printed circuit boards (PCB's); firmware and software design; consulting. | USA |
| | Xignux; Adavox; Hongos de Mx; Medisist; Champ Encinal; Apliatec; Plamex | | MX |
| | Interface; Bell Labs; Siemens; Level One; STMicroelectronics. | Electronic telecommunications systems design. | USA/ Germany/ France |

Compilation based on the Cinvestav historical files (1989-2011).

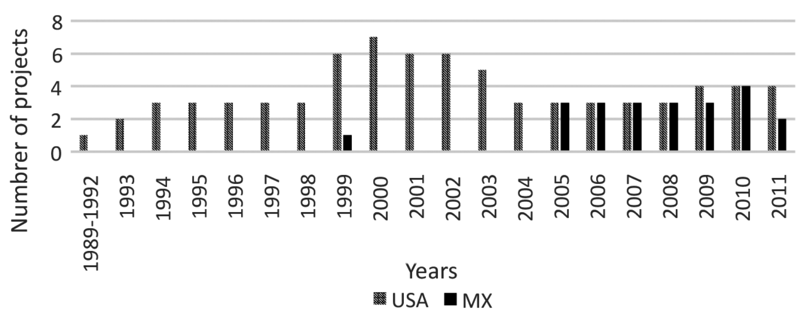


Figure 1. Evolution of university-industry projects developed by CST with USA and Mexican firms (1989-2011). Prepared by the authors on the basis of Cinvestav historical files.

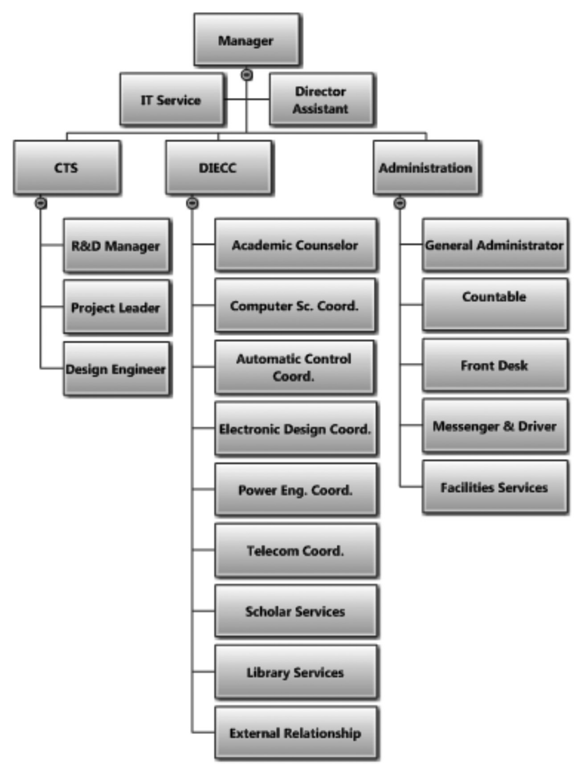


Figure 2. Organization chart of Cinvestav, Guadalajara. Source: Cinvestav historical files.

(Arvantis *et al*., 2008; Barnes *et al*., 2002; Wright, 2014). The latter seems to be the situation in the case of CST.

One of the most successful ways of transferring technology from universities to industry is through collaborative research under demand (Casas *et al*., 2000; Kneller *et al*., 2014). The industry establishes requirements and deliverables, generates a joint project schedule and provides the funds to be commissioned to the university group. This approach requires the existence of a specific R&D group that performs technology development within the university organizational structure. In order to be successful, this R&D group must match the organizational structure of a small company so as to facilitate the respective technology transfer. This type of organizational structure does exist at Cinvestav Guadalajara (Cinvestav-G). The organizational chart shown in Figure 2 depicts two research groups: the Department of Electrical Engineering and Computer Science (DIECC) and CST.

DIECC was founded in 1995 and is the academic group responsible for Cinvestav-G graduate programs and the scientific projects in electrical engineering (EE) and computer science (CS). The operation of DIECC is financed by the Federal Government and its scientific projects are supported by national and international agencies. On the other hand, CST activities involve mainly design and development of prototypes (integrated circuit devices, electronic systems and software codes), test programs and fabrication documents for the electronics industry established at MAG. All CST projects are based on contracts with firms under non-disclosure agreements (NDAs) and strict schedules. Its organization involves one R&D manager, project managers and leaders, as well as design engineers. The CST personnel is devoted full time to carry out commissioned projects for the industry. CST is a self-sustaining operation funded by projects contracted with MAG firms. CST engineering projects are strategically associated with the original equipment manufacturers (OEMs), original design manufacturers (ODMs), the Institute of Electrical and Electronics Engineers (IEEE), standardization organizations like the International Telecommunication Union (ITU), industrial chambers like the CANIETI and with the Federal and Regional Ministries of Economy. Currently, Cinvestav-G has a faculty of 26 Ph.D.-holding researchers working in a systemic way in joint projects from CST (Cinvestav, 2015). The backing of the state government to an industrial organization such as CANIETI, and the alignment of universities and research centers such as the Cinvestav-G, gave support for the consolidation of the electronics industry (through creating suppliers) and TICs industry (through training, certification and infrastructure) (Eugenio Godard, IBM, personal interview, 05/26/2014; Julio Acevedo, HP, personal interview, 0/17/2014).

CST is an example of a R&D group in a public research center devoted fulltime to do technology development in a university environment. Its mission, goals, organization and working scheme can be adapted to serve any other type of industry needs: biotechnology, pharmacology, nanotechnology, aeronautical and space, software, chemical, food and beverages, etc. (De Ibarrola *et al.*, 2002).

**Project Execution Environment and Flow**

The design and development of electronic products is a multi-national activity. It requires the participation of people with different talents and skills: project management, electronics, software, mechanical, testing, materials, etc. In Figure 3 we depict an example of a CST project execution environment. As can be appreciated, the design and development of some products is an activity distributed among several geographically separated R&D groups. Working in a distributed environment like this one requires the use of a bulletproof project management system (PMS). A good PMS minimizes the risks of project failure and guarantees the success of the project in time. Time synchronization of the activities of the different R&D groups is imperative in order to succeed. The delay of one of the R&D groups induces the delay of the entire project team, and sometimes results in hundreds of people in standby and millions of dollars in losses.

Figure 4 shows the project execution flow for a typical CST linkage called 'on demand' or 'under contract'. The process begins with the sign-off of a confidentiality contract (NDA) which legally binds both partners to protect the information, invention and industrial secrets that will be shared by the parties during the development of the project. The execution of the project starts with the reception of the set of requirements, which in turn are used by the engineers to generate a project proposal. Thus, the contract represents a legal binding between partners and is enforced by law. The technical design specifications (TDSs) are documents written by experts in technology development. The design task is controlled by a design leader and executed by a group of engineers. Prototypes are required to complete the design process. Finally, deliverables are tangible or intangible objects contracted and produced during the execution of the project.

**CST Impact of Specific Linkages**

Despite a rather modest investment and a slow start of the operations, CST has generated a handful of successful collaborative projects commissioned by a wide spectrum of local and transnational firms (Table I). CST has demonstrated in the international market its high technology proficiency in designing electronic systems and devices, as well as being instrumental in the implementation of some start-ups. Another benefit generated by CST is the exposure of Mexican engineers to high-level technology, especially in developing integrated circuits and computers. As a consequence, CST has been involved in training a small but burgeoning number of software firms that have emerged at MAG. In particular, the government of Jalisco, the Mexican

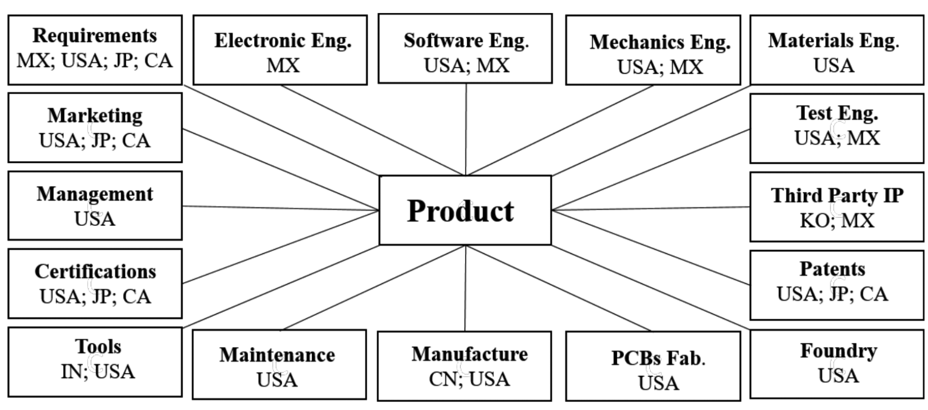


Figure 3. Example of a CST project execution environment. Source: Interviews with CST personnel.

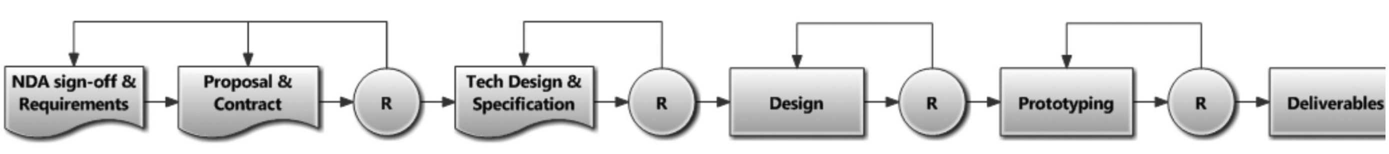


Figure 4. Project execution flow. Source: Interviews with CTS personnel.

state where MAG is located, has recognized that CST has participated in the creation of a new industry sector that has contributed to ~1.4% of the state gross domestic product (Palacios, 2008).

In 1988 there was no industry in Mexico requiring semiconductor design services. At that time, most of the electronics companies located in Mexico were manufacturing plants, with the responsibility of assembling components and systems. In this context, CST adopted a new strategy in order to survive: it offered CST design services in USA. This key decision led CST to be the first Mexican group playing in the USA market, offering high tech design services. In 1989, IBM at Kingston, NY, contracted with CST the remapping technology of two telecommunications integrated circuit devices for their mainframes and workstation computers. The success of this project opened to CST the IBM doors to work with other IBM R&D groups: Poughkeepsie, NY; Boca Raton, FL; Raleigh, NC and Austin, TX.

CST has carried out a lot of design work for IBM, as depicted in Table 1. By 1995, CST was designing mother boards for IBM PCs: some of the fastest mother boards in the world were designed at CST for IBM computers. CST has also nursed four high technology private companies: BEA, Mixbal, TDCOM and DDTech. Three of these start-ups are still in the market but one of them (DDTech) closed six years after it was established. In this way, Cinvestav-G has made an important contribution to the economic development of Mexico by fostering the growth of industries in a new and competitive sector such as the high technology industry of electronics and software design.

## Concluding Remarks

We have presented an exploratory analysis of the university-industry collaborative model developed by CST in the metropolitan area of Guadalajara, Jalisco, Mexico. The success of this model stresses the importance of having a world-class R&D group in order to build bi-directional channels for conducting joint research and development projects in the high-technology industry within the field of electronics. The close interaction of the CST research group with the managers of the local firms has also been instrumental. In terms of public policies, the analysis shows that an R&D group devoted fulltime to develop high-technology projects in a university environment can be successfully adapted to serve any other type of industry needs. There is also another lesson to be drawn from this study of the CST projects: some university-industry linkages in a developing country like Mexico can be as successful as those developed in Brazil, Canada, Japan, Switzerland, UK and the USA (Arvanitis *et al.*, 2008; Bodas *et al.*, 2008; D'Este and Patel, 2007; Dutrenit and Arza, 2010; Kneller *et al.*, 2014).

The collaborative research work developed by CST has been recognized by several local academic institutions (National Prize in Science and Technology, 1990 and 2009; National Prize in Innovation, 2008; Jalisco Prize on Science and Technology, 2006 and 2009) and also several international awards (IDC's Trends in Digital Access Market, 1996-2002; Network Computing Editor's Choice Award, 1998; Application Excellence Award - Frame Server Products, 1998; Telecommunications Product of the Month, 1997). Finally, we may conclude that the success of the CST model can be explained by two factors properly combined: an active group of researchers and a receptive group of local managers developing highly qualified and specialized human resources involved in joint research projects with the local industry situated in the Metropolitan Area of Guadalajara. The CST's technological capabilities led to the creation of accelerated training programs. In particular, Intel launched in 2014 the Design Center of Guadalajara, located in the neighborhood of Cinvestav-G. Likewise, Continental opened the Research and Development Center at Santa Anita, Tlajomulco. The directors of these centers referred in interviews to the Cinvestav-G training programs as useful instruments for accelerating the integration processes of engineers to industrial projects (Jorge Vazquez, Continental, personal interview, 09/26/2013; Jesus Palomino, Intel, personal interview, 05/19/2014, respectively).


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## COLABORACIÓN UNIVERSIDAD-INDUSTRIA: UN CASO EXITOSO EN EL ÁREA DE DISEÑO ELECTRÓNICO Y SOFTWARE EN MÉXICO


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*RESUMEN*


*Se analizan el flujo de ejecución y el entorno de los proyectos exitosos de colaboración instrumentados por un instituto mexicano de investigación, el Centro de Tecnología de Semiconductores (CTS) del Cinvestav-IPN, ubicado en la zona metropolitana de la ciudad de Guadalajara (ZMG) en el estado de Jalisco. Estos proyectos fueron realizados en colaboración con compañías locales y transnacionales en el área de la electrónica y el diseño de software. Este estudio de caso, basado en entrevistas a varios líderes de empresas ubicadas en ZMG, enfatiza la importancia de contar con un grupo de clase mundial en I&D como condición necesaria para construir canales bidirecionales en la concertación de proyectos conjuntos de investigación y desarrollo con industrias de alta tecnología. En particular, se muestra que los principales enlaces desarrollados por el CTS son proyectos de colaboración bajo demanda y que han tenido una influencia importante en el producto interno bruto de la ZMG.*


## COLABORAÇÃO UNIVERSIDADE-INDÚSTRIA: UM CASO DE SUCESSO NA ÁREA DE DESENHO ELETRÔNICO E SOFTWARE NO MÉXICO


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*RESUMO*


*Analisam-se o fluxo de execução e o entorno dos projetos exitosos de colaboração instrumentados por um instituto mexicano de investigação, o Centro de Tecnologia de Semicondutores (CTS) do Cinvestav-IPN, localizado na área metropolitana da cidade de Guadalajara (AMG) no estado de Jalisco. Estes projetos foram realizados em colaboração com empresas locais e multinacionais na área da eletrônica e o desenho de software. Este estudo de caso, baseado em entrevistas de vários líderes de empresas localizadas na AMG, enfatiza a importância de contar com um grupo de classe mundial em I&D como condição necessária para construir canais bidirecionais na coordenação de projetos conjuntos de investigação e desenvolvimento com indústrias de alta tecnologia. Em particular, se mostra que os principais enlaces desenvolvidos pelo CTS são projetos de colaboração sob demanda e que tem tido uma influência importante no produto interno bruto da AMG*