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QUANTITATIVE ASSESSMENT OF UNIVERSITY TECHNOLOGY TRANSFER EFFICIENCY IN CHILE

PROYECTO PARA OPTAR AL GRADO DE

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I. RESUMEN

La transferencia tecnológica en las universidades, entendida como la explotación comercial de los resultados de investigación, es una actividad que ha recibido cada vez más atención no solo en Chile, sino a nivel global, por su contribución a la innovación y generación de bienestar económico y social, no solo en el contexto local.

En este trabajo se presenta un análisis cuantitativo de la eficiencia de las oficinas de transferencia tecnológicas en Chile, analizando una serie de insumos (inputs) que hacen posible la transferencia, y productos o resultados (outputs) del proceso de transferencia. Para este fin, se tomaron los datos colectados en la encuesta de gestión tecnológica, recopilados por la Corporación de Fomento de la Producción (CORFO) para el año 2016. Se empleó un análisis no paramétrico, el Análisis Envolvente de Datos (Data Envelopment Analysis - DEA), este análisis permite establecer la relación entre inputs y outputs. La encuesta de gestión tecnológica recopila información de dieciséis universidades chilenas, se encontró que las universidades consideradas usan de manera eficiente los inputs de transferencia tecnológica, para producir outputs. No obstante, solo una de las universidades alcanzó una eficiencia del 84% en la gestión de transferencia tecnológica.

Al analizar la influencia del contexto económico por agrupamientos (clustering), se tomaron los datos de Producto Interno Bruto (por Región y Área Económica) y el Índice de Desarrollo Regional. Se encontró que las universidades forman tres agrupamientos característicos, de acuerdo a la mayor disponibilidad de recursos. Aquellas universidades localizadas en la región metropolitana forman un grupo compacto, los otros dos grupos concentran por un lado universidades de las regiones de Antofagasta (II) y Valparaíso (V) y la Universidad de Concepción (de la Región del Bío Bío); y por el otro las universidades de las otras regiones incluidas en este estudio (Araucanía, Los Lagos, Los Ríos, Maule y Bío Bío).

Tomando que en este estudio no se encontraron brechas significativas en la eficiencia de las Oficinas de Transferencia Tecnológica Universitaria analizadas, se concluye de manera preliminar que la estrategia nacional, canalizada a través del programa de financiamiento de oficinas de transferencia tecnológica (Programa OTL de CORFO) ha contribuido de forma exitosa en fortalecer las capacidades tecnológicas de las universidades, al permitir instalar un conjunto de buenas prácticas. Esto se ve reflejado en que las universidades analizadas, sin importar factores internos tales como tamaño, complejidad educativa o recursos humanos y económicos disponibles, así como factores externos como ubicación geográfica y entorno económico, han sabido gestionar de manera eficiente las tecnologías producidas al interior de la universidad. Se sugiere ampliar el alcance de este estudio empleando un análisis longitudinal, así como ampliar el universo muestral, incluyendo más universidades.

III. ABSTRACT

The transfer of university research results to the commercial sector, known as University Technology Transfer has gained awareness not only in Chile but globally, since it has been recognized as a factor to generate economical growth at the local, regional and national level.

In this study, the performance of technology transfer offices in Chilean universities was assessed. To this end, the Technology Management Survey 2016 compiled by the Chilean Economic Development Agency (CORFO) was used, and the data was analysed using Data Envelopment Analysis (DEA). DEA allows a quantitative assessment of the technology transfer efficiency, as a ratio between inputs and outputs. In the present study we found that almost all universities considered perform efficiently. Only one university showed an overall performance of 84%. The results indicate homogeneity in performance across the universities that participated in the survey.

The role of the economical context was analysed using clustering analysis. The Gross Domestic Product (GDP) and Development Indexes were clustered along the parameters of technology transfer. The universities were grouped into two clusters, with three braches. The clusters mirror the economical context where the universities are located. Universities in the countries capital (that concentrates most economical resources) clustered together. The other universities form one single cluster, divided into two branches. One branch aggregates universities located in two economically relevant regions (II and V), together with the University of Concepción (located in Bío Bío). All other universities clustered together in the second branch.

Overall, the efficiency of university technology transfer offices appears to be high and homogenous. Considering that the commonality that the analysed universities share stands from the funding, it can be concluded that the financial program allowed to bridge

the gap in technology transfer management among universities, by installing Best Technology Transfer Practices. For further studies, a longitudinal assessment may contribute to confirm or discard these findings. To enhance the scope of this study, the inclusion of additional universities would contribute to pinpoint the actual role of the financial program in the technology transfer management.

III. INTRODUCCIÓN

Durante siglos universidades e instituciones de educación superior han tenido como función principal la formación de capital humano e investigación. Sin embargo, durante las últimas décadas una nueva función ha venido perfilándose, la transferencia de resultados de investigación a la sociedad, bien sea con interés comercial o social.

La investigación científica sea esta básica o aplicada es financiada en sus inicios casi en su mayoría por el sector público, dadas las incertidumbres relacionadas con la generación de productos comerciales, las grandes demandas de inversión y los ciclos más largos de financiamiento necesarios (Hsu *et. al.*, 2015). Con el objetivo de asistir y estimular la transferencia a la sociedad de los resultados de investigación, universidades e instituciones públicas de investigación han establecido oficinas de transferencia tecnológica. Al interior de las universidades estas unidades o departamentos se conocen como Oficinas de Transferencia y Licenciamiento (OTL), Oficina de Transferencia Tecnológica (OTT), Oficina de Transferencia de Resultados de Investigación (OTRIs), entre otros. El objetivo principal de estas unidades al interior de la universidad es facilitar el proceso de transferencia de conocimiento de las universidades e institutos de investigación al sector público (Siegel & Wright, 2015) . En la literatura científica se ha discutido ampliamente las labores de estas unidades, entre estas se encuentran: 1. Alentar al interior de la comunidad universitaria la divulgación de resultados de investigación con potencialidad comercial, 2. Gestionar el portafolio de propiedad intelectual de la institución, 3. Identificar posibles clientes y/o inversionistas con los cuales negociar licencias, 4. Gestionar la movilización y creación de fondos de protección y explotación de propiedad intelectual, y finalmente 5. Actuar como intermediarios entre investigadores, empresas y la dirección/administración universitaria (Weckowska, 2015).

Las labores de las oficinas de transferencia tecnológicas han recibido mucha atención por parte de investigadores, en donde se ha evaluado su validez (Fitzgerald & Cunningham, 2016), su visibilidad al interior y exterior de la universidad (Huyghe *et al*.,

2016) y a nivel cuantitativo y cualitativo la eficiencia (Berbegal-Mirabent *et al.,* 2013; Curi *et al.*, 2012; Huelsbeck *et al.*, 2013; Kim *et al.*, 2008; Phan & Siegel, 2006). Por mucho tiempo, las medidas de evaluación de la eficiencia del proceso de transferencia universitaria se relacionaron con la generación de ingresos económico por la explotación de los títulos de propiedad intelectual e industrial de la universidad. No obstante, se ha llegado a un consenso general que estas medidas de evaluación son sesgadas e insuficientes para medir la complejidad del proceso de transferencia (Phan & Siegel, 2006; Siegel & Wright, 2015) . El uso de modelos econométricos (Curi *et al.*, 2012; Huelsbeck *et al*., 2013; Kim *et al.*, 2008) y en particular análisis no paramétricos como el análisis envolvente de datos (DEA - Data Envelopment Analysis) son bastante populares para medir eficiencia en transferencia, puesto que DEA permite medir la eficiencia como la relación de inputs/outputs, y es capaz de manejar una diversasidad de inputs/outputs, no solo de carácter monetario (Berbegal-Mirabent *et al.*, 2013; Curi *et al*., 2012; Holi *et al.*, 2008; Kim *et al.*, 2008; Phan & Siegel, 2006).

Transferencia Tecnológica en Chile

En el año 2005 el gobierno chileno creó la comisión asesora presidencial "Consejo de Innovación para la Competitividad" (República de Chile, 2005) con el objetivo de asesorar a la Presidencia de la República en la identificación, formulación y ejecución de políticas y acciones que fortalezcan la innovación, competitividad y el desarrollo en Chile. El diagnóstico del ecosistema de innovación chileno, definió que las actividades de transferencia de conocimientos de universidades e institutos de investigación durante el periodo de 1996 a 2007 había sido bastante limitado (Babish *et al.*, 2009). Al mismo tiempo, se encontró que durante el mismo periodo (1996 a 2007) las agencias estatales de financiamiento (CONICYT, CORFO, FIA) invirtieron US$ 951.212 millones de dólares en Investigación y Desarrollo (I + D) en universidades chilenas, US$ 941.122 millones de dólares en otras organizaciones e instituciones de investigación chilenas. Esto representa una inversión promedio en el período de US$ 157.686 millones de dólares por año. Adicionalmente, durante los últimos años la inversión en I + D ha aumentado constantemente y se estima que en el 2007 las universidades e institutos de investigación chilenos recibían aproximadamente US$ 216 millones de dólares en I + D por año. Como resultado, esta financiación está generando un flujo constante de resultados de

investigación que requiere una gestión eficaz de la propiedad intelectual (Babish *et al.,* 2009). La transferencia tecnológica y la construcción de capacidades en esta área se identificó como esencial para aumentar la competitividad en Chile (Babish *et al.*, 2009; The World Bank, 2009), es por esta razón que la Corporación de Fomento de la Producción (CORFO) implementó el Programa Nacional de Oficinas de Transferencia y Licenciamiento (OTL) en el marco del eje estratégico de capacidades tecnológicas (CORFO, 2015). El eje estratégico de capacidades tecnológicas tiene como objetivo "fortalecer las capacidades de innovación, gestión de la propiedad intelectual, comercialización y transferencia tecnológica en los actores del sistema nacional de innovación".

Los instrumentos de financiamiento del Programa OTL han permitido la formación o legitimación de OTLs al interior de las universidades chilenas, generando de este modo un reconocimiento, haciendo más visibles las OTLs al interior de la universidad. Además la gerencia de capacidades tecnológicas ha apoyado el desarrollo de políticas, procedimientos, reglamentos y regulaciones de propiedad intelectual y conflicto de intereses, la creación de sistemas de información, y ha permitido ampliar las capacidades en recursos humanos mediante el apoyo financiero para la contratación y capacitación (CORFO, 2018). Todas estas medidas han permitido la instalación de un conjunto de "buenas prácticas" de transferencia tecnológica. Por último para medir el impacto del programa, se creó la Encuesta de Gestión Tecnológica, dicha encuesta es la piedra angular de este estudio, para analizar la eficiencia de las oficinas de transferencia tecnológica en Chile.

IV. OBJETIVO

Determinar cuantitativamente el desempeño de las oficinas de transferencia tecnológica universitarias parte del instrumento gubernamental OTL (Oficinas de Transferencia y Licenciamiento) de CORFO.

A. Objetivos específicos:

i. Identificar la estructura y complejidad educativa de las universidades chilenas que han implementado OTLs en el marco del programa de CORFO.

ii. Determinar de manera cuantitativa la eficiencia de las OTs en la conversión de inputs a outputs de transferencia tecnológica.

iii. Realizar un análisis de agrupamientos de universidades de acuerdo a su similitud en inputs y outputs de transferencia tecnológica.

iv. Determinar la influencia del contexto económico de las universidades en la gestión de transferencia tecnológica.

V. ARTÍCULO

Measuring University Technology Transfer Efficiency in Chilean Universities

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Summary

This study focused on analysing the performance of Chilean University Technology Transfer Offices. In Chile, a national funding program has been established to enhance the countries capacities in technology transfer and innovation. To assess technology transfer efficiency Data Envelopment Analysis was used. Furthermore, universities were clustered according to technology transfer indicators and economical indicators. Our analyses showed that almost all universities analysed are efficiently translating inputs into outputs. We concluded that the funding policies contributed to install good indicators in technology transfer, minimizing the implications of economical environment where the universities are located. We suggest enhancing the scope of our findings by conducting a longitudinal study and by including universities with technology transfer offices that are not part of the funding program.

Keywords

University Technology Transfer, Data Envelopment Analysis (DEA), Performance, Chile

Introduction

The transfer of university research findings to the commercial sector has seen a steep increase during the last decades. The Bayh-Dole Act in the USA in 1980 is taken as the ground-breaking beginning of university technology transfer (Bremer, 1998; Phan & Siegel, 2006). Currently, almost all universities in the USA and Europe have established Technology Transfer Offices (henceforth TTOs). In the USA, the Association of University Technology Managers (AUTM - https://www.autm.net) conducts yearly surveys to monitor and report technology transfer activities in USA and Canada (Holi *et al*., 2008; Rosli & Rossi, 2015). The last report summarize the contribution of academic licensors to industry from $320 billion to $1.33 trillion, in 2009 U.S. dollars from 1996 to 2015 (Pressman *et al*., 2017). In Europe, the Association of European Science and Technology Transfer Professionals (ASTP - https://www.astp-proton.eu/) founded 2000 strives to promote technology transfer between universities and industries, and generate yearly surveys on

knowledge transfer activities performed in the different member countries. Individual countries in Europe organize data collection exercises too. In the UK a comprehensive survey (Higher Education Business and Community Interaction survey, henceforth HE-BCI) currently managed by the Higher Education Statistics Agency is distributed yearly to all universities in the country; the results are used to allocate third stream funds to universities. The Australian government runs a biannual survey of universities and public research institutes (Rosli & Rossi, 2015).

Literature about TTOs span from structure (Markman *et al.*, 2008), mission (Fitzgerald & Cunningham, 2016), governance (Geuna & Muscio, 2009; Schoen *et al.*, 2014), role in commercialization (Bellucci & Pennacchio, 2016; Fini *et al.*, 2011; Siegel *et al*., 2007), best practices (Comacchio & Bonesso, 2012; Resende *et al.*, 2013), legitimacy (Huyghe *et al*., 2016) and performance (Berbegal-Mirabent *et al*., 2013; Hsu *et al*., 2015; Huelsbeck *et al*., 2013; Kim *et al*., 2008; Vinig & Lips, 2015).

Among all fields of research, rating technology transfer efficiently attracted increasing attention in the academic literature (Berbegal-Mirabent *et al*., 2013; Curi *et al.*, 2012; Frederick & Granieri, 2015; Hsu *et al*., 2015; Huelsbeck *et al*., 2013; Kim *et al*., 2008; Phan & Siegel, 2006; Vinig & Lips, 2015). Recently, a consensus has been reached that technology transfer efficiency transcends the economical indicators of revenues generated by the commercialization of intellectual property rights. To this end, empirical analysis of technology transfer performance have made use of econometric approaches such as Data Envelopment Analysis (DEA) (Berbegal-Mirabent *et al*., 2013; Curi *et al*., 2012; Kim *et al*., 2008; Park *et al.*, 2017), regression models (Huelsbeck *et al*., 2013) and stochastic frontier estimation (Siegel *et.al*, 2003).

In our study we used DEA to measure performance of university technology transfer offices in Chile. We examined sixteen Chilean University Technology Transfer Offcies (UTTOs), taking the data from the Innovation Survey carried out by CORFO (Chilean Economic Development Agency) in 2016. We used the following technology transfer outputs: invention disclosures, intellectual property rights applications, published peer-review articles, contracted research (university – industry partnerships) and license agreements; and the following inputs: R+D budget, Applied R+D budget, total number of Full-time Equivalents (FTE) worked by TTO staff. Additional such as number of

students, FTEs worked by professors and Income were retrieved from the National Rectors Council Database (http://www.consejoderectores.cl).

The UTTOs were clustered according to technology transfer inputs and outputs. To determine the implication of the local economical context, universities were clustered using regional indicators such as GDP (Chilean Central Bank - http://www.bcentral.cl) and Development Index (https://www.idere.cl).

The results of our study show an efficiency score of one for almost all universities. This result suggests a homogeneous performance across the Chilean UTT system. Our conclusion is that the national funding policy undertook by CORFO successfully contributed to form technology transfer units that operate similarly, reaching an uniform production frontier. This in turns contributes to bridge the gaps that university size, organizational structure, human and financial resources or geographical context has in performance.

Methods

Sample:

The data used in this study comes from six different sources, and are publicly available, with the exception of the Innovation Survey carried out by the Chilean Economic Development Agency (CORFO), The Innovation Survey 2016 records the activities in the field of technology transfer carried out by nineteen universities. The survey records activities in four areas: research and development, intellectual property rights, commercialization and connected areas (TTO human resources and contract research).

Information regarding university structure (degrees, students and Full-Time Equivalent FTE hours worked by professors) was extracted from the universities website and/or the University Rectors Council (http://www.consejoderectores.cl). Information regarding university accreditation was collected from the National Accreditation Agency (www.cnachile.cl/). The year of first institutional patent was collected from the National Intellectual Property Institute Database – INAPI

(www.inapi.cl/) and Economical Data was retrieved from the Central Bank (http://www.bcentral.cl/) and the IDERE website (www.idere.cl).

For three of the nineteen universities we could not retrieve all the necessary data and we were forced to exclude them for our analyses.

Efficiency Analysis:

We used the non-parametric technique DEA (Data Envelopment Analysis) to assess university technology transfer performance. Efficiency is defined as the ratio of the weighted sum of outputs to a weighted sum of inputs (see Equation 1). The weights are calculated by means of mathematical programing and Constants Returns to Scale (CRS) are assumed. The rations are calculated for each so called Decision Making Units (DMUs), in our case University Technology Transfer Offices (UTTOs). In mathematical terms, the efficiency score ($\boldsymbol{\theta}o$) for a group of DMUs (j=1….n) is computed from the selected outputs (y_{rj},r=1,….,s) and inputs (x_{ij}, i=1,….,m) using the following programming formula (from Johnes (2004) cited in (Huguenin, 2012)):

$$Maximize\ \boldsymbol{\theta}o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} V_i x_{io}}$$

$$subject\ to\ \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad \text{Eq. (1)}$$

$$u_r, v_i \geq 0\ for\ all\ r\ and\ i$$

To solve the linear programing problems for each DMU we used the R package rDEA (Simm & Besstremyannaya, 2016).

Clustering Analysis:

All analyzed universities were clustered regarding technology transfer inputs and outputs using a hierarchical cluster method (agglomeration method). The cluster analysis is based on the distance matrix between vectors, calculated using Euclidean distance. The vectors were standardized to have zero mean and standard deviation of one before calculating the distance matrix. To extend further the reach of the cluster analysis, universities were re-clustered including data from the

economical context where universities are located. The agglomeration method used to compute the clusters was Ward's method that minimizes the total whitin-cluster variance. Unless other specified, all calculations were performed using the statistical software R (Team, 2013).

Results

University Characteristics:

In this study we evaluated the knowledge transfer performance of a subset of Chilean Universities. Chile has 61 registered universities in the national register of higher education institution (Ministry of Education, http://www.mifuturo.cl). In Fig. 1 the geographical distribution of all universities along Chile and the universities considered in this study is shown. The sixteen universities selected are part of an instrument designed by the Chilean government to strengthen the knowledge (and technology) transfer capacities of the country. The instrument is managed by CORFO (Chilean Economic Development Agency). As can be seen in Fig. 1 the Chilean capital concentrates 60% of the universities in the country (36 from 61). Nevertheless, our study considered only 4 universities located in Santiago, accounting for 25% of the universities studied. Chile is politically divided into 15 regions, and our study compiled information from 7 regions. The coverage for universities located outside the national capital ranged between 50 – 100 percentage. In Chile some of the universities are public while others are privately owned. Nevertheless in our study we did not analysed the relationship (if any) of university ownership and knowledge-transfer capacity.

We classified our 16 universities by disciplinary fields. According to Berbegal-Mirabent *et al.*, 2013 the fields of research that produce more results that can be transfer are science, engineering and medicine. While analysing university structure, we found that ten universities offer undergraduate degrees in all three fields (SEM), while from the remaining six, four lack medicine (SE_) and two lack science degrees (_EM). We grouped the six universities as a single category named XEX. In Fig. 2 depicted using boxplots are accreditation years, year of first institutional patent, total number of students and degrees offered (undergraduate to postgraduate degrees) and number of Full-Time Equivalent hours worked by professors and employees in the respective UTTO. At first glance is apparent that SEM universities are more heterogeneous, showing a wider distribution of values.

Accreditation years ranged from four to seven with a median of six years. XEX universities show a more compact distribution with a median of five accreditation years. The first institutional patent shows an even wider range in SEM universities, while XEX universities registered the first institutional patent during the last eighteen years. The median year is similar in both SEM and XEX universities. The total number of students ranged from around 7000 to 18000 in XEX universities, and 9000 to 40000 in SEM universities, indicating that SEM universities are conceivably more complex in structure. The large range of degrees offered and the number of FTE hours worked by professors confirm this view. Strikingly, despite all the differences in university structure, the median FTE hours worked by UTTO employees are almost identical in SEM and XEX universities, indicating that universities with large differences in size and complexity are devoting a similar amount of human capital in performing technology transfer duties. The complete summary statistics is provided in Table 1.

Efficiency Analysis:

In this study we reasoned the more meaningful inputs and outputs involved in technology transfer. We selected inputs related to human capital (number of students, FTE worked by professors and UTTO employees). Similar to Berbegal-Mirabent *et al* (2013) and Curi *et al* (Berbegal-Mirabent *et al*., 2013; Curi *et al*., 2012) we consider that labour force is critical for universities to fulfil all duties that rely nowadays on these institutions (namely teaching, research and transference). To have a more accurate estimation on labour intensity involved in technology transfer, we have chosen worked hours over number of professors and UTTO staff. Other inputs selected as crucial for universities attempting to transfer their technologies to market is capital, for that reason we considered three particular aspects regarding capital: Total Income, R+D Budget and Applied R+D Budget. R+D and applied R+D Budget according to OECD's Frascati Manual Definitions (OECD, 2015).

Technology transfer outputs considered in this study included: number of academic papers published in the indexed ISI Web of Knowledge during the recorded year. The selection of this output responds to the widely accepted criteria that papers submitted for publication in peer review journals is a criteria to assess research performance, and is an standard measurement used by

governmental agencies when evaluating research projects for funding (Holi *et al*., 2008; Rosli & Rossi, 2015; Vinig & Lips, 2015). The second output relates to invention disclosures, that are an approximation of the number of research results that may eventually result in technologies to license (Bremer, 1998; Huelsbeck *et al*., 2013; Markman *et al*., 2008). The third output considers the summary of all kinds of IP rights that can be registered and subsequently licensed. We included patents, utility models, industrial designs, plant breeders' rights, copyrights and trademarks applications in Chile and abroad, as well as granted rights in the recorded period. The fourth output relates to contract research (research arising from collaborative interactions among university researchers and the private sector, where research meets the needs of the external partner – (Holi *et al*., 2008; Rosli & Rossi, 2015). Finally, we considered research commercialization outputs (licenses and university start-ups). The descriptive statistics for the selected inputs and outputs not included in Table 1 are presented in Table 2. As described previously, the analysis of technology transfer inputs and outputs in SEM and XEX universities showed that SEM universities show a wider distribution, have on average more resources (both human and capital) and produce on average more outputs, as indicated by the standard deviation, the mean and the minimum and maximal values.

We calculated an Efficiency score for each group of universities separately using Data Envelopment Analysis (DEA). The performance of similar organizations is calculated relative to an efficiency frontier. Units located on the production frontier serve as benchmarks to inefficient units (Huguenin, 2012; Phan & Siegel, 2006; Simm & Besstremyannaya, 2016). DEA has been used to measure technology transfer performance of Spanish and French universities (Curi *et al.*, 2012; Berbegal-Mirabent *et al.*, 2013). The efficiency is calculated as a weighted ratio of outputs over inputs and the scores range from 0 to 1, where values lower than 1 indicate inefficient DMUs. As can be seen in Table 3, the six XEX universities reach a score of 1, while nine out of ten SEM universities also attained a score of 1. The most likely explanation for such homogenous performance is the large number of factors (inputs and outputs) relative to the number of DMUs.

Regarding the university with the lowest score (0.834), our DEA analysis assumes constant returns to scale (CRS) to define the efficiency frontier and the scores are input oriented. Particularly for the UCN the benchmarked DMUs are UACH, UDEC, USACH and UCH. Table 4 indicates how inputs

can be proportionally reduced without a reduction in outputs. Overall the benchmarked UTTOs will need only 42% of the inputs the UCN has to produce similar outputs. The last two columns in Table 4 indicate that UCN is particularly inefficiency in translating the allocated Budget for R+D (the benchmarked units would use 3%) and the Budget for Applied R+D Budget (17%).

Our efficiency analysis shows that almost all SEM universities and all XEX universities make an efficient use of the inputs, indicating homogeneity in performance across UTTOs. Nevertheless, our results do not rule out the possibility that the entire system analyzed may be under performing. Nor can it be concluded that Chilean UTTOs are efficient when compared to institutions abroad.

Strikingly, our results are different that the ones described by Curi (Curi *et al.*, 2012) in French universities or by Berbegal-Mirabent in Spanish universities (Berbegal-Mirabent *et al.*, 2013). For both countries using an output oriented approach efficiency was on average 0.12 for Spanish universities and 0.51 for French universities. The divergent results found by us in comparison to other similar studies highlight the need to increase the size of the sample to achieve more reliable conclusions.

Our results indicates homogenous performance across universities, nevertheless the entire system may be under performing. Similar scores only indicate that Chilean universities perform very well against each others. A similar study across the Australian University System, measuring research and teaching inputs/outputs found that the high scores where reflecting an overall low production frontier (Abbott & Doucouliagos, 2003).

Clustering Analysis:

We analysed the internal structure of the technology transfer firstly clustering universities according to inputs and outputs. For the cluster analysis we used the Euclidean distance of the standardized variables. The results are depicted as a dendrogram in Fig. 3. The results of the cluster analysis show two different groups of universities. The first cluster grouped eleven universities in two distinct leaves. On the one hand the UCN, the university with the lowest efficiency score, and on the other hand almost all regional universities. The second cluster groups the four universities located in

Santiago and notably, the University of Concepcion (UDEC), located in the eight region, around 500 km away from the countries capital.

In order to assess the relevance of the economic environment where universities are located, we collected some economic data. Firstly, the Regional Development Index (IDERE from the Spanish "índice de desarrollo regional"), calculated using 29 indicators, grouped into six dimensions: i. education, ii. health, iii. economical welfare, iv. economic activity, v. security and vi. communication and connectivity. And secondly, the regional GDP and GDP by activity (agriculture/livestock and forestry, fishery, mining, manufacturing industry, electricity, gas, water and water management, construction, wholesale and retail trade, hotels and restaurants, transport, information and communication, financial and business services, dwelling services and real state, personal services, public administration). The clustering results are shown in Fig. 4. When the regional dimension is considered, universities are clustered in two groups with three separated branches. The universities located in Santiago retain the same cluster structure (Cluster 1). Strikingly UDEC, which co-clustered with the universities in Santiago in Fig. 3 when only technology transfer inputs and outputs are considered, co-clustered here in the second cluster, together with the universities from the V and II region. The second cluster is form entirely by regional universities, dividing the universities located in economically weaker regions from those located in economically powerful regions (see Fig. 5a and 5b). The first branch of the cluster groups the universities from the regions VII, VIII (2 from 3), IX and XIV, that as can be seen in Fig. 5a and 5b have lower GDP; while the second branch groups the universities from the V region, and outside the main group the UDEC and the UCN, from the VIII and II Region respectively.

Conclusions:

In our study we found that Chilean universities do not show substantial difference in performance. Almost all universities scored and efficiency score of one. Considering the reduce sample of universities analysed, it is likely that DEA failed to discriminate efficient DMUs and all appeared efficient due to the large number of factors considered (inputs and outputs) compared with the number of DMUs under analysis. Nevertheless, we suggest that the homogenous performance of almost all universities may rely on the underlying funding for UTTOs by CORFO. The national

funding instrument ensures that the implementation of technology transfer policies within universities follow similar structures.

One of the most remarkably findings in our analysis is that the University of Concepcion located in the VIII Region shares characteristics in technology transfer with universities located in Santiago (see Fig. 3), that are characterized by a very different economical context (see Fig. 5a and 5b). Moreover, when the economical dimension is considered, The UDEC is more similar to universities located in stronger economical regions (II and V) than universities located in the same region. Both results point to strong indicators of technology transfer inputs and outputs and a very efficient use of resources.

We found exclusively one university with an efficiency score lower than one. The benchmarked scores allowed us to determine that the UCN is using less efficiently the inputs related to R+D budget (both pure and applied R+D). According to the benchmarked values, the UCN should expand the use of the inputs by 68% to operate efficiently, keeping the outputs fixed. As enunciated above, is particularly imperative to improve the efficient use of R+D Budget.

Although we have not consider qualitative factors in our analysis, we consider that Chile universities have used the advantage to learn from other models of university technology transfer worldwide, as the AUTM (Association of University Technology Managers) or ASTP-Proton (Association of European Science and Technology Transfer Professionals) to adapt the best technology transfer practices under the surveillance of CORFO, by means of the national funding strategy. Unlike Germany or Spain, the mechanisms implemented in Chile to organize university technology transfer allowed to minimize the impact of factors identified to play a role in TTO performance, such as TTO and university organizational structure (Huelsbeck *et al*., 2013) and regional context (Berbegal-Mirabent *et al*., 2013).

Our preliminary study pretends to be a guideline to undertake more in-deep analysis of the outreach of the policies envisaged to improve Chilean knowledge and technology transfer. Our study is rather limited by the number of data available and the absence of longitudinal studies that would allow to measure the performance over time and broader the perspectives and conclusions.

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Author contributions

Conceptualization, J.L.G.P.; Research, J.L.G.P., Writing–Original Draft, J.L.G.P.; Writing–Review & Editing, J.L.G.P. and P.V.; Supervision, P.V.

Competing interests:

The authors declare no competing financial interests.

References

Abbott M, Doucouliagos C. **2003**. The efficiency of Australian universities: A data envelopment analysis. *Economics of Education Review* **22**: 89–97.

Bellucci A, Pennacchio L. **2016**. University knowledge and firm innovation: evidence from European countries. *Journal of Technology Transfer* **41**: 730–752.

Berbegal-Mirabent J, Lafuente E, Solé F. **2013**. The pursuit of knowledge transfer activities : An ef fi ciency analysis of Spanish universities. *Journal of Business Research* **66**: 2051–2059.

Bremer H. **1998**. *University Technology Transfer: Evolution and Revolutions*. Council on Governamental Relations.

Comacchio A, Bonesso S. **2012**. Performance Evaluation for Knowledge Transfer Organizations : Best European Practices and a Conceptual Framework. Intech Open Access Publisher, Rijeka, Croatia.

Curi C, Daraio C, Llerena P. **2012**. University Technology Transfer: How (in-)efficient are French Universities? *Cambridge Journal of Economics* **36**: 629–654.

Fini R, Grimaldi R, Santoni S, Sobrero M. **2011**. Complements or substitutes? the role of universities and local context in supporting the creation of academic spin-offs. *Research Policy* **40**: 1113–1127.

Fitzgerald C, Cunningham JA. **2016**. Inside the university technology transfer office: mission statement analysis. *Journal of Technology Transfer* **41**: 1235–1246.

Frederick P, Granieri M. **2015**. Development of a Holistic Tool to Identify Barriers to Success for Technology Transfer Offices Transfer Offices. In: Financing Knowledge Transfer in Europe (FinKT).

Geuna A, Muscio A. **2009**. The governance of university knowledge transfer: A critical review of

the literature. *Minerva* **47**: 93–114.

Holi MT, Wickramasinghe R, Van Leeuwen M. **2008**. Metrics for the evaluation of knowledge transfer activities at universities. *Cambridge: Library House* **5**: 1–33.

Hsu DWL, Shen YC, Yuan BJC, Chou CJ. **2015**. Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technological Forecasting and Social Change* **92**: 25–39.

Huelsbeck M, Lehmann E, Starnecker A. **2013**. Performance of technology transfer offices in Germany. The Journal of Technology Transfer. *The Journal of Technology Transfer* **38**: 199–215.

Huguenin J-M. **2012**. *Data Envelopment Analysis (DEA) - A pedagogical guide for decision makers in the public sector*. Lausanne. Institut de hautes études en administration publique.

Huyghe A, Knockaert M, Piva E, Wright M. **2016**. Are researchers deliberately bypassing the technology transfer office? An analysis of TTO awareness. *Small Business Economics* **47**: 589–607.

Kim J, Anderson T, Daim T. **2008**. Assessing University Technology Transfer: a Measure of Efficiency Patterns. *International Journal of Innovation and Technology Management* **5**: 495–526.

Markman GD, Siegel DS, Wright M. **2008**. Research and technology commercialization. *Journal of Management Studies* **45**: 1401–1423.

OECD. **2015**. *Frascati Manual 2015*. Paris. OECD Publishing.

Park J, Kim J, Sung S-I. **2017**. Performance Evaluation of Research and Business Development: A Case Study of Korean Public Organizations. *Sustainability* **9**: 2297.

Phan PH, Siegel DS. **2006**. *The Effectiveness of University Technology Transfer*. Foundations and Trends® in Entrepreneurship. **2**: 77–144.

Pressman L, Planting M, Yuskavage R, Okubo S, Moylan C, Bond J, Moylan C, Bond J. **2017**. *The Economic Contribution of University / Nonprofit Inventions in the United States : 1996-2015 Prepared for the Biotechnology Innovation Organization and*.

Resende DN, Gibson D, Jarrett J. **2013**. BTP - Best Transfer Practices. A tool for qualitative analysis of tech-transfer offices: A cross cultural analysis. *Technovation* **33**: 2–12.

Rosli A, Rossi F. **2015**. Monitoring the knowledge transfer performance of universities: An international comparison of models and indicators. *Studies in Higher Education* **40**: 1970–1991.

Schoen A, van Pottelsberghe de la Potterie B, Henkel J. **2014**. Governance typology of universities' technology transfer processes. *Journal of Technology Transfer* **39**: 435–453.

Siegel DS, Veugelers R, Wright M. **2007**. Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. *Oxford Review of Economic Policy* **23**: 640–660.

Siegel DS, Waldman D, Link A. **2003**. Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Research Policy* **32**: 27–48.

Simm J, Besstremyannaya G. **2016**. rDEA: Robust Data Envelopment Analysis (DEA) for R.

Team RC. **2013**. R: A Language and Environment for Statistical Computing.

Vinig T, Lips D. **2015**. Measuring the performance of university technology transfer using meta data approach: the case of Dutch universities. *Journal of Technology Transfer* **40**: 1034–1049.

Tables

Table 1: Descriptive Statistics

Structure[1]	Variable	Students	Undergraduates	Master	Doctorate	Post-title	Degrees	FTE Lectures	FTE TTO	Accreditation	First Patent
SEM	Mean	22811.70	88.90	53.60	14.90	47.00	204.40	1174.00	311.00	5.70	2000.00
	Median	19898.00	72.00	39.00	10.50	47.50	179.50	1001.50	233.50	6.00	2006.00
	St.Dev.	12228.55	44.05	33.77	13.11	25.30	77.95	679.28	281.06	1.16	16.08
	Min	9124.00	48.00	24.00	0.00	5.00	122.00	376.00	71.00	4.00	1968.00
	Max	43096.00	196.00	130.00	39.00	90.00	331.00	2256.00	1004.00	7.00	2017.00
XEX	Mean	12430.00	59.50	24.17	6.33	15.67	105.70	496.00	254.67	5.17	2008.00
	Median	11951.00	55.00	22.50	6.00	8.50	112.00	438.00	239.50	5.00	2008.00
	St.Dev.	4026.40	26.44	12.25	5.05	18.76	32.57	114.31	85.01	0.75	6.50
	Min	6852.00	31.00	11.00	1000.00	4.00	54.00	389.00	169.00	4.00	2000.00
	Max	18184.00	107.00	44.00	15000.00	53.00	135.00	647.00	409.00	6.00	2016.00

[1]Universities were divided in two groups. SEM= Universities with Science, Engineering AND Medicine undergraduate degrees. xEx= Universities with Science/Engineering or Medicine/Engineering undergraduate degr

Table 2: Descriptive Statistics for the selected inputs and outputs

Structure[1]	Variable	Income	Budget R+D	Budget Applied R + D	Disclosures	PI[2]	ISI	Contract Research[3]	Commercialization[4]
SEM	Mean	195243324.0	15743.0	3690.0	26.4	64.3	818.6	7.7	20.5
	Median	97950753.0	6599.0	2186.0	23.0	17.0	461.0	3.5	9.0
	St.Dev.	189079196.0	24490.4	4415.8	16.7	75.2	833.7	7.8	27.2
	Min	58784494.0	0.0	48.0	4.0	4.0	82.0	0.0	3.0
	Max	574029293.0	78789.0	14286.0	47.0	206.0	2399.0	23.0	92.0
XEX	Mean	81667310.0	5498.0	1384.8	12.2	16.7	260.2	3.2	7.5
	Median	77561390.0	4122.0	577.5	12.0	20.0	233.5	2.5	7.5
	St.Dev.	32712163.0	4862.9	2165.9	6.6	6.7	170.4	2.9	6.8
	Min	43538258.0	809.0	181.0	5.0	5.0	66.0	0.0	0.0
	Max	126554977.0	12498.0	5753.0	24.0	22.0	483.0	7.0	17.0
		INPUTS			**OUTPUTS**				

[1]Universities were divided in two groups. SEM= Universities with Science, Engineering AND Medicine undergraduate degrees. xEx= Universities with Science/Engineering or Medicine/Engineering undergraduate degrees. [2]Summarises the following industrial property: patents, PCT patents, utility models, industrial designs and plant varieties applications and granted in Chile and abroad; and the following intellectual property: copyright, trademarks and software licenses. [3]Number of research contracts. [4]Summarises number of university start-ups and licenses.

Table 3: Technology Transfer Efficiency for Chilean UTTOs

UNIVERSITY	EFFICIENCY[1]
UACH	1.000
UCN	0.838
UV	1.000
UAB	1.000
UDEC	1.000
UFRO	1.000
USACH	1.000
PUC	1.000
UCSC	1.000
UCH	1.000

UNIVERSITY	EFFICIENCY[2]
UCT	1.000
UBB	1.000
UTFSM	1.000
UCM	1.000
UTALCA	1.000
PUCV	1.000

[1]SEM= Universities with Science, Engineering AND Medicine undergraduate degrees.

[2] XEX= Universities with Science/Engineering or Medicine/Engineering undergraduate degrees

DEA scores were calculated using Constant Returns to Scale (CRS) and an input orientation.

Table 4: Benchmarked DMUs for UCN

INPUTS	UACH	UDEC	USACH	UCH	TOTAL	UCN	Total Sum	%
Students	0.3738	0.0250	0.0144	0.0264	0.4249	10984	7624.3	69
FTE Professor	0.3738	0.0250	0.0144	0.0264	0.4249	553	477.6	86
FTE TTO	0.3738	0.0250	0.0144	0.0264	0.4249	92	78	85
Income	0.3738	0.0250	0.0144	0.0264	0.4249	58784494	50801743	86
R+D Budget	0.3738	0.0250	0.0144	0.0264	0.4249	78789	2643	3
Applied R+D Budget	0.3738	0.0250	0.0144	0.0264	0.4249	8231	1419	17

Columns two to five show the vector of DEA scores in the input-oriented model for the most efficient DMUs. Total refers to the total amount by which UCN is overusing the inputs in relation to the efficient DMUs. UCN refers to input values. The last two columns (Total Sum, %) refer to the corresponding amount by which the inputs could be reduced in absolute numbers and in percentage.

Figures

Figure 1

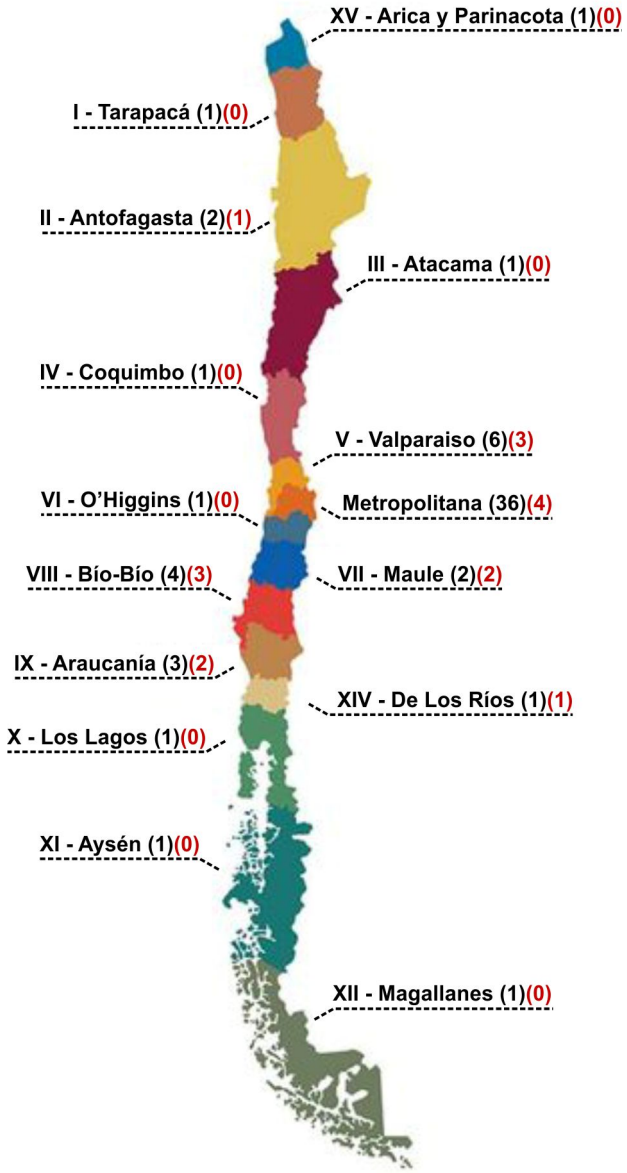

Fig. 1. Distribution of universities in Chile. Number of universities per region are shown in black. Universities included in this study are shown in red.

Figure 2

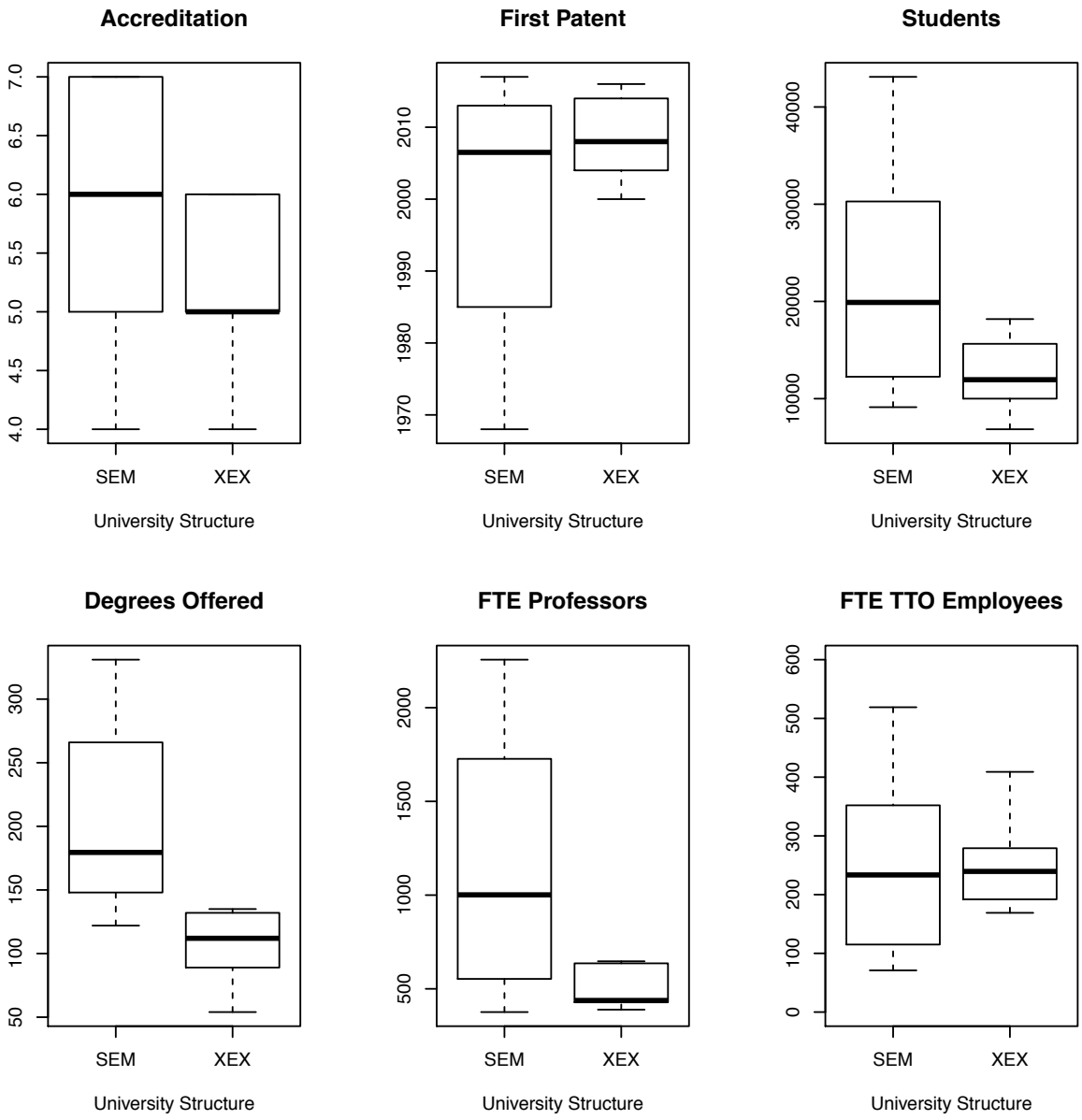

Fig. 2. Box-and-whisker plots showing descriptive statistics from SEM and XEX Universities Box and whisker plots shows mean, maximum and minimum values for accreditation years, first institutional patent year, number of students, number of degrees offered and FTE-worked hours by professors and employees in SEM (Science-Engineering-Medicine) universities or XEX (_-Engineering-Science / Medicine-Engineering-_) universities.

Figure 3

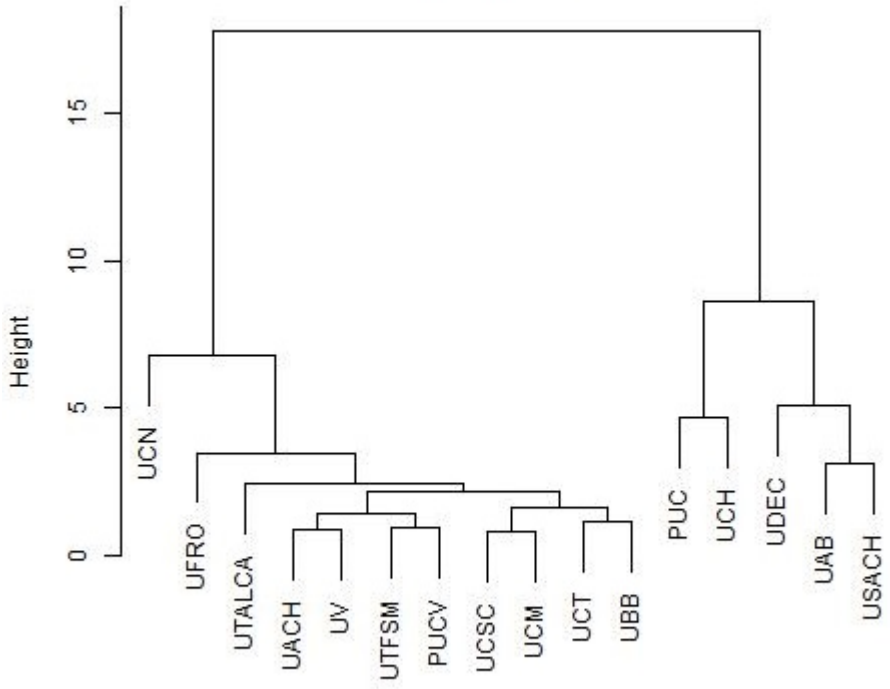

Fig. 3. Dendrogram of the hierarchical agglomerative cluster analysis. Distance matrix was computed using the standardise input and output technology transfer values. y-axis depicts the distance metric between clusters. At height ten universities grouped into two clustes. Cluster 1 (left) groups almost all universities located in regions outside the countries capital and is composed by two branches. Cluster 2 (right) groups all universities located in Santiago and UDEC located in Region VIII – Bío Bío

Figure 4

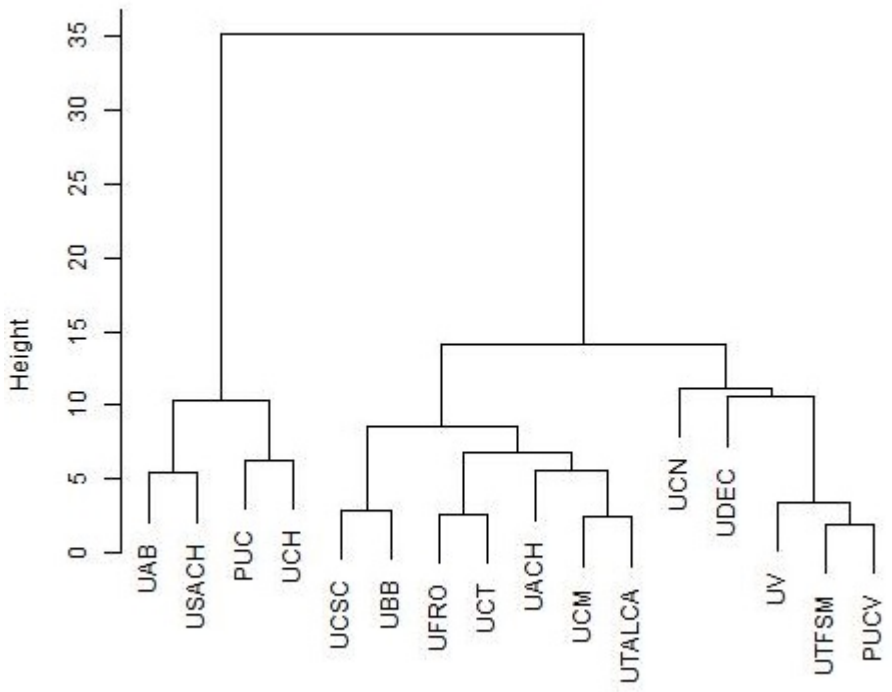

Fig. 4. Dendrogram of the hierarchical agglomerative cluster analysis. Distance matrix was computed using university (inputs and outputs) as well as economical data from each region. At height fifteen universities grouped into two clustes. Cluster 1 (left) groups all universities located in Santiago, and is composed by two branches. Cluster 2 (right) groups all universities located in regions and is composed by two branches.

Figure 5

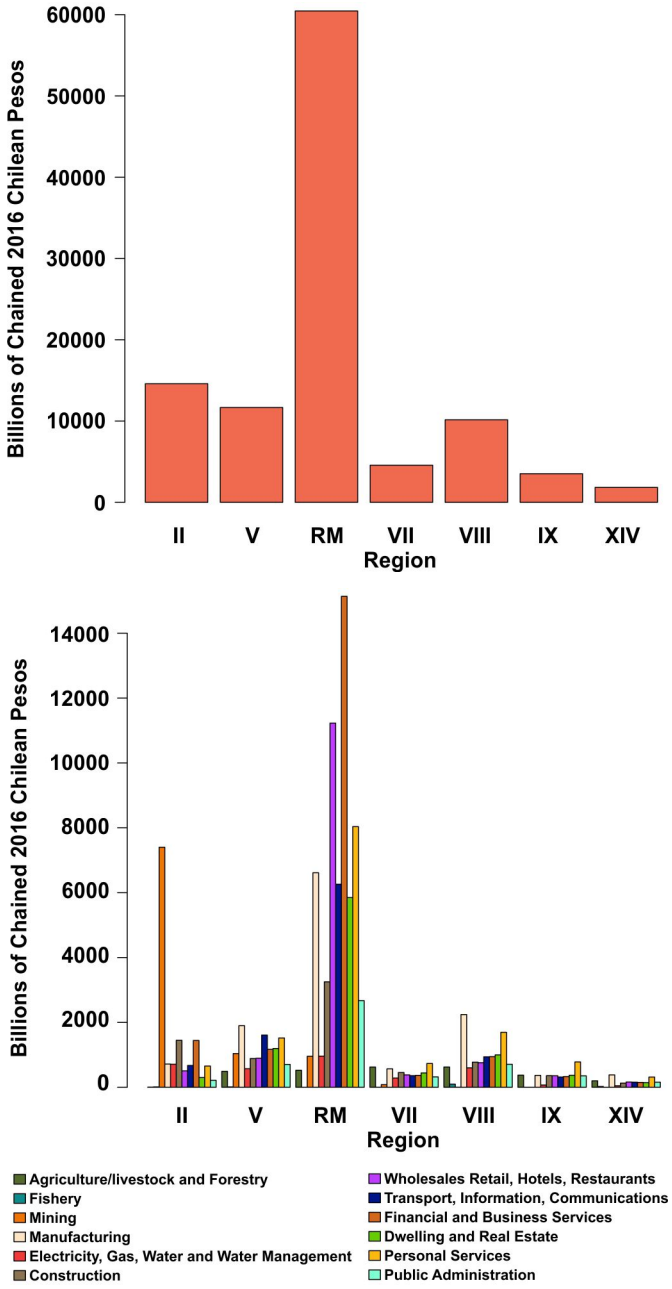

Fig. 5. Regional GDP in Chile. (a) Total GDP year 2016 per region. (b) Total GDP year 2016 per region and economical activity.

VI. CONCLUSIONES Y PERSPECTIVAS

Los principales hallazgos de nuestro análisis muestran que:

1. En materia de estadística descriptiva, luego de analizar las universidades de acuerdo a las áreas de estudio de medicina, ingeniería y ciencias naturales, se encontró que las universidades chilenas con estas tres áreas del conocimiento parecen ser estructural y organizacionalmente más complejas y diversas que universidades que presentan solo dos de tres áreas (medicina e ingeniería o ciencias e ingeniería). Esto se refleja en el rango de años de acreditación, número de estudiantes, ingresos y número de jornadas completas equivalentes de personal académico. No obstante, el número de jornadas completas equivalentes del personal de las OTLs, se encuentra dentro de los mismos rangos para ambos tipos de universidades, indicando que la complejidad y estructura de las OTLs en el set de universidades analizadas es equiparable.

2. Todas las universidades del Programa OTL tienen al menos dos áreas intensivas en generación de resultados con potencial comercial (medicina, ingeniería y ciencias naturales); mostrando un dinamismo universitario, aún en Chile, país que se caracteriza por tener un perfil bajo de innovación, enfocado en una economía de materias primas y extractiva, más que una economía de generación de valor, a través de la producción de nuevas tecnologías.

3. Se encontró que con la notable excepción de la universidad UCN, todas las otras universidades analizadas presentan un cociente de inputs y outputs de 1 (equivalente al 100%), indicando que están utilizando sus inputs de recursos humanos y económicos de manera eficiente, para traducirlos en outputs de transferencia tecnológica (divulgaciones

de investigación, publicaciones indexadas, títulos de propiedad intelectual e industrial, contratos de investigación y productos de comercialización). No obstante, la uniformidad en nuestro análisis también puede indicar que el bajo número de OTLs consideradas no permite realizar un buen cálculo de la frontera de eficiencia de producción.

4. Al agrupar las universidades de acuerdo a los inputs y outputs del proceso de transferencia tecnológica, se encontró que las universidades en Santiago al igual que la UDEC forman un grupo independiente, más similar entre sí que las universidades de otras regiones. Así mismo, la universidad UCN se separa en las agrupaciones de todas las universidades analizadas. De manera interesante, al incluir la dimensión del contexto económico regional, con indicadores de Producto Interno Bruto e Índices de Desarrollo Regional, los agrupamientos muestran dos grandes grupos, por un lado las universidades situadas en Santiago, y por el otro las universidades regionales, divididas a su vez en dos grupos muy característicos. Las universidades ubicadas en las regiones con mejores indicadores económicos (II y V) forman un grupo, sorprendentemente junto con la UDEC (ubicada en la región VIII). Todas las otras universidades de regiones se agrupan en la otra rama del árbol generado.

De manera general, la implementación y monitoreo de la gestión tecnológica a nivel nacional, en el marco del programa OTL ha permitido que las universidades chilenas establezcan prácticas estandarizadas de transferencia tecnológica, minimizando así los efectos que pueden tener en la gestión de la transferencia universitaria aspectos tales como la disponibilidad de recursos humanos y financieros, u otros aspectos externos, como la influencia del contexto económico regional.

Futuras áreas de investigación para ampliar los alcances de este estudio serían el análisis longitudinal de datos de transferencia tecnológica, así como incluir otras universidades que no estén al alero del programa de financiamiento CORFO, para de esta manera determinar de manera inequívoca que la alta eficiencia medida se debe a la exitosa implementación de una política publica de formación de capacidades tecnológicas.

VII. BIBLIOGRAFÍA

Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: A data envelopment analysis. *Economics of Education Review*, ***22*****(1),** 89–97.

Babish, J. G., Garcia, R. L., Pearce, C. J., & Paau, A. S. (2009). *Establishment of Centers for Innovation, Technology Transfer and Entrepreneurship (CITE) in Chile*. Santiago de Chile.

Bellucci, A., & Pennacchio, L. (2016). University knowledge and firm innovation: evidence from European countries. *Journal of Technology Transfer*, ***41*****(4),** 730–752.

Berbegal-Mirabent, J., Lafuente, E., & Solé, F. (2013). The pursuit of knowledge transfer activities : An ef fi ciency analysis of Spanish universities. *Journal of Business Research*, ***66*****(66),** 2051–2059.

Bremer, H. (1998). *University Technology Transfer: Evolution and Revolutions*. Council on Governamental Relations.

República de Chile. (2005). Decreto No. 1408. Biblioteca del Congreso Nacional. Santiago de Chile, 24 de Diciembre de 2005.

Comacchio, A., & Bonesso, S. (2012). Performance Evaluation for Knowledge Transfer Organizations : Best European Practices and a Conceptual Framework. Intech Open Access Publisher, Rijeka, Croatia.

CORFO. GERENCIA DE CAPACIDADES TECNOLÓGICAS -RESOLUCIÓN EXENTA (2015). Chile.

CORFO. Gerencia de Capacidades Tecnológicas - Resolución Exenta (2018). Chile.

Curi, C., Daraio, C., & Llerena, P. (2012). University Technology Transfer: How (in-)efficient are French Universities? *Cambridge Journal of Economics*, ***36*****(3),** 629–654.

Fini, R., Grimaldi, R., Santoni, S., & Sobrero, M. (2011). Complements or substitutes? the role of universities and local context in supporting the creation of academic spin-offs. *Research Policy*, ***40*****(8),** 1113–1127.

Fitzgerald, C., & Cunningham, J. A. (2016). Inside the university technology transfer office: mission statement analysis. *Journal of Technology Transfer*, ***41*****(5),** 1235–1246.

Frederick, P., & Granieri, M. (2015). Development of a Holistic Tool to Identify Barriers to Success for Technology Transfer Offices Transfer Offices. In *Financing Knowledge Transfer in Europe (FinKT)*.

Geuna, A., & Muscio, A. (2009). The governance of university knowledge transfer: A critical review of the literature. *Minerva*, ***47*****(1),** 93–114.

Holi, M. T., Wickramasinghe, R., & Van Leeuwen, M. (2008). Metrics for the evaluation of knowledge transfer activities at universities. *Cambridge: Library House*, ***5***, 1–33.

Hsu, D. W. L., Shen, Y. C., Yuan, B. J. C., & Chou, C. J. (2015). Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technological Forecasting and Social Change*, ***92*****,** 25–39.

Huelsbeck, M., Lehmann, E., & Starnecker, A. (2013). Performance of technology transfer offices in Germany. The Journal of Technology Transfer. *The Journal of Technology Transfer*, ***38*****(3),** 199–215. https://doi.org/DOI: 10.1007/s10961-011-9243-6

Huguenin, J.-M. (2012). *Data Envelopment Analysis (DEA) - A pedagogical guide for decision makers in the public sector* (Vol. 41). Lausanne: idheap.

Huyghe, A., Knockaert, M., Piva, E., & Wright, M. (2016). Are researchers deliberately bypassing the technology transfer office? An analysis of TTO awareness. *Small Business Economics*, ***47*****(3),** 589–607.

Kim, J., Anderson, T., & Daim, T. (2008). Assessing University Technology Transfer: a Measure of Efficiency Patterns. *International Journal of Innovation and Technology Management*, ***5*****(4),** 495–526.

Markman, G. D., Siegel, D. S., & Wright, M. (2008). Research and technology commercialization. *Journal of Management Studies*, ***45*****(8),** 1401–1423.

OECD. (2015). *Frascati Manual 2015*. Paris: OECD Publishing.

Park, J., Kim, J., & Sung, S.-I. (2017). Performance Evaluation of Research and Business Development: A Case Study of Korean Public Organizations. *Sustainability*, ***9*****(12),** 2297.

Phan, P. H., & Siegel, D. S. (2006). *The Effectiveness of University Technology Transfer*. *Foundations and Trends® in Entrepreneurship* (Vol. 2).

Pressman, L., Planting, M., Yuskavage, R., Okubo, S., Moylan, C., Bond, J. (2017). *The Economic Contribution of University / Nonprofit Inventions in the United States : 1996-2015 Prepared for the Biotechnology Innovation Organization*

Resende, D. N., Gibson, D., & Jarrett, J. (2013). BTP - Best Transfer Practices. A tool for qualitative analysis of tech-transfer offices: A cross cultural analysis. *Technovation*, ***33*****(1),** 2–12.

Rosli, A., & Rossi, F. (2015). Monitoring the knowledge transfer performance of universities: An international comparison of models and indicators. *Studies in Higher Education*, ***40*****(10)**, 1970–1991.

Schoen, A., van Pottelsberghe de la Potterie, B., & Henkel, J. (2014). Governance typology of universities' technology transfer processes. *Journal of Technology Transfer*, ***39*****(3),** 435–453.

Siegel, D. S., Veugelers, R., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. *Oxford Review of Economic Policy*, ***23*****(4),** 640–660.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Research Policy*, ***32*****(1)**, 27–48.

Siegel, D. S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? *British Journal of Management*, ***26*****(4),** 582–595.

Simm, J., & Besstremyannaya, G. (2016). rDEA: Robust Data Envelopment Analysis (DEA) for R.

Team, R. C. (2013). R: A Language and Environment for Statistical Computing. Vienna, Austria.

The World Bank. (2009). *Fostering Technology Transfer and Commercialization*. Washington, DC.

Vinig, T., & Lips, D. (2015). Measuring the performance of university technology transfer using meta data approach: the case of Dutch universities. *Journal of Technology Transfer*, ***40*****(6),** 1034–1049.

Weckowska, D. M. (2015). Learning in university technology transfer offices: Transactions-focused and relations-focused approaches to commercialization of academic research. *Technovation*, ***41*****,** 62–74.