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Public policies and networks for the development of 4.0 technologies in Chile[1]

Políticas públicas y redes para el desarrollo de las tecnologías 4.0 en Chile

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ABSTRACT

This article analyzes public policies and networks for the development of 4.0 technologies in Chile, based on the study of the FONDEF-IDEA project portfolio, from 2012 to 2017. Through a syntactic analysis of the titles, objectives and summaries, specific initiatives were selected which have direct or indirect application of 4.0 technologies, on an initial basis of 530 public initiatives. The different specializations and the social network were analyzed. Our conclusion is that we do not observe at the public policy level in Chile a strategy that stimulates the decentralized development of these new technologies. There is a high centrality in the network of sensor applications in copper mining, monitoring and the conversion of data to information, there is still an important gap to be covered by public policies. In our opinion, it is urgent to have a technological development strategy that narrows the gap with the countries that are already in the lead.

Keywords
Technological change; technology policy; social capital; Chile

RESUMEN

Este artículo analiza las políticas públicas y las redes para el desarrollo de las tecnologías 4.0 en Chile, a partir del estudio de la cartera de proyectos FONDEF-IDEA, desde 2012 a 2017. Mediante un análisis sintáctico de los títulos, objetivos y resúmenes se seleccionaron las iniciativas específicas que tienen directa o indirecta aplicación de las tecnologías 4.0, sobre una base inicial de 530 iniciativas públicas. Se analizaron las diferentes especializaciones sectoriales y la red social. Nuestra conclusión es que todavía no observamos al nivel de políticas públicas en Chile una estrategia que estimule el desarrollo descentralizado de estas nuevas tecnologías. Se comprueba una alta centralidad en la red de las aplicaciones de sensores en la minería del cobre, del monitoreo y la conversión del dato a la información, existiendo todavía una importante brecha a ser cubierta por las políticas públicas. A nuestro juicio es urgente contar con una estrategia de desarrollo tecnológico que acorte la brecha con los países que se encuentran en una etapa más avanzada.

Palabras clave
Cambio tecnológico; política tecnológica; capital social; Chile

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Introduction

The intrusion of 4.0 technologies shall have a significant change on value chains (Tirole, 2017), which will enable the birth of new business models and generate new demands on workmanship, whether because of new skills required such as the likely fall of the unemployment rate (Nedelkoska & Quintini, 2018).

In this context, the State ought to assume an active role by means of the creation of new companies based on 4.0 technology-centered business models, on the creation of conditions aimed to stimulate technological adoption in small and medium size existing production organizations and adaptation of the educational system in its different instruction levels intended to maximize exploitation of new technological opportunities.

This paper is aimed to analyze a technologically-oriented public policy instrument by considering the articulation degree among different public and private actors around these new technologies. Our main conclusion is that in the case of Chile, no technological development is noticed that would enable the assumption of the challenges posed by the fourth industrial revolution.

It has been found that only 10.4% of the FONDEF-IDEA 2012-2017 projects is linked to 4.0 technologies, which is an evidence of the absence of a public policy that would decidedly encourage strategic development in this sector. It has also been found that these public initiatives are strongly concentrated on the national capital; therefore, regional institutions are mostly fortunate in having these projects assigned. A strong investment of mining sensors is evidenced and this economic sector explains 55% of the total Chilean exports.

A theoretical review shows that we are positioned in a “creative dispersion” phase, where we shall see the birth of new technologies in the medium term, as well as the merger of others and reposition from new applications and developments. From available information a set of 4.0 technologies is identified with a relevant diffusive capacity because they may be found in various economic sectors. These technologies imply an interesting opportunity for public investment, allowing strategic targeting on some technologies, thus maximizing the diffusive impact on the rest of the economy.

The structure of this work is organized as follows: first off, a literature review is performed intended to deepen into the definition of 4.0 technologies, different investigations are inquired where the relevance of networks is proven for innovating companies. Then, the results of the previous analysis on the databases are shown, the relevance of 4.0 technologies is identified on the total initiatives assigned, institutional and regional distribution is presented. In a fourth chapter, methodology is presented and developed into two axes: analysis of words, by using the free DBA Miner Lite software, and the survey of social networks by using the UCINET free software.

The technological network is seen in the field study and some elements of its architecture are identified: cluster and centrality from different indicators. Finally, conclusions are presented where we shall see the urgency of having a technological development strategy in a proactive manner and that would give way to new application environments that would maximize the diffusive impact of 4.0 technologies.

Theoretical review

Below is a literature review from two axes: First off, 4.0 technologies are defined by presenting its main features, configurations and the technological map. Then, some surveys are reviewed where diffusion of these technologies has been addressed.

4.0 emerging technological fields

Since the 4.0 industry was defined by the German government as a strategic target, there has been an explosion of new inventions and developments, thus generating "diffusive borderlines" in this new field of technological advance. In a first literature review, Hermann, Pentek & Otto (2015) identified six basic principles across these new technologies:

1) Modularity, flexibly adapting to requirement changes.

2) Service-oriented, moving across several companies by means of Internet of Things (IoT).

3) Real time capacity, which implies having instant data and analysis.

4) Decentralization, having equipment that can capture data, generate information, make decisions and physically implement solutions in every section of the production process.

5) Virtualization, where a copy of the physical world may ease communication with other people.

6) Interoperability, where, by means of Internet of Things and Internet of Service (IoS), there is instant communication among several sections of the process, which may be extended outside a private company.

These principles are not specific to the industry, usually understood as the manufacturing industry, but they answer to a new approach to doing things and that are present in several fields, such as agriculture, retail, education, health sector, among others.

Therefore, it is appropriate to speak of 4.0 technology applications, such as those that enable a decentralized operation, working within a circle among physical-digital-physical (PDP) systems (Coitteleer & Sniderman, 2017). They specifically are systems used to capture information of the physical world to then create a digital register allocated to a network which presents it in real time and that, by means of algorithms, solutions are generated returning from the digital to the physical field, thus closing the circle.

In essence, we are at a “new working methodology”, which is supported by 4.0 technologies and which performs in the so called “5 Cs” of technological implementation architecture (Lee, Bagheri & Kao, 2015).

- *Intelligent connection:* This implies incorporating sensors throughout the whole process to obtain a basic monitoring condition (BMC). In this level, there is a network of plug-and-play sensors, free communication, ERP, MES, SCM, CMN, among others.

- *Data conversion to information:* In this level, there are Business Intelligence (BI) tools, that allow capturing data gathered by the sensors and that are stored in a data warehouse, to then match these data by means of Olap Cubes or Big Data applications.

- *Cyber level:* This tool enables grouping and comparing information obtained from Cyber-Physical Systems (CPS) to direct them to the decision-making process.

- *Cognition level:* This is where decisions are made and prioritized by means of the necessary graphic representation aimed to transfer knowledge to users.

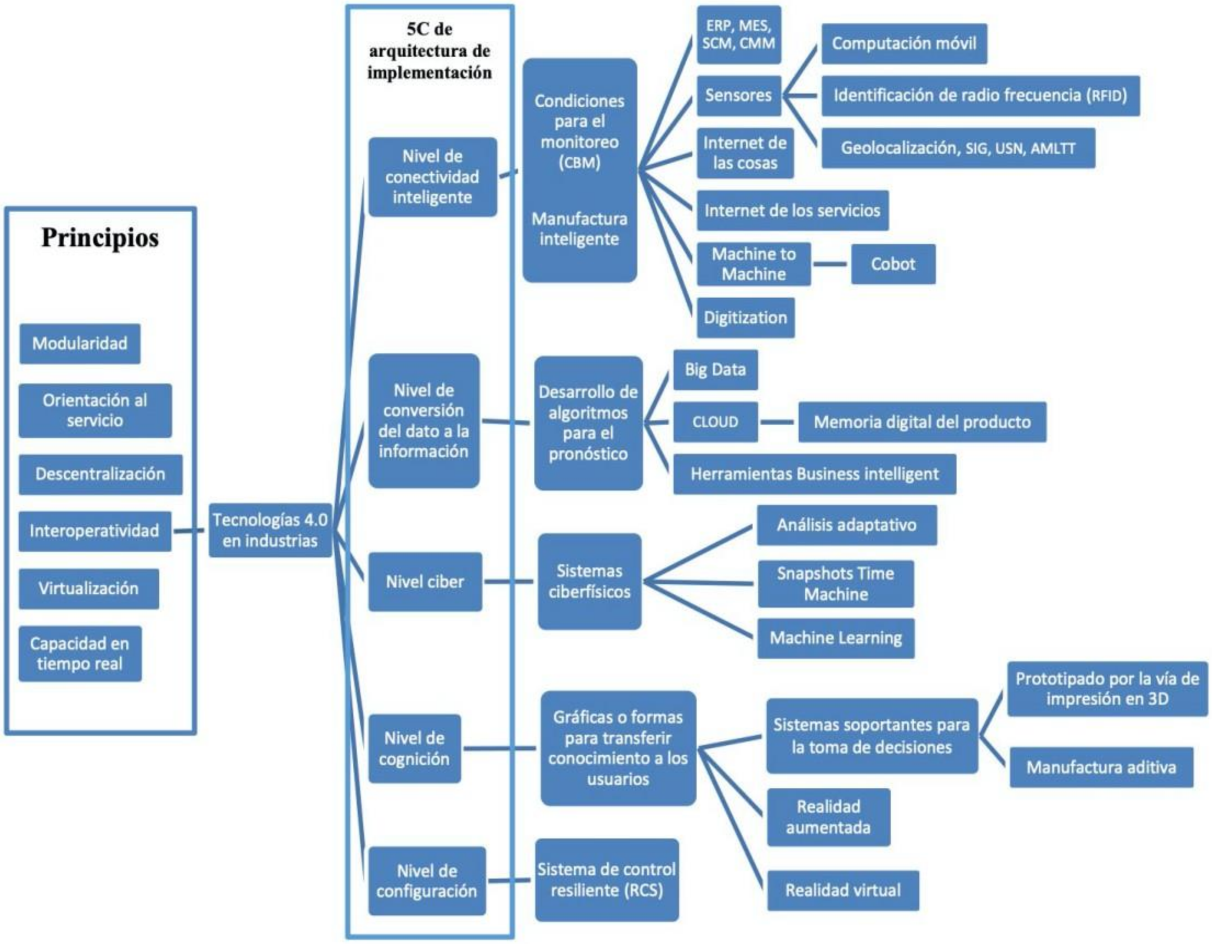
- *Configuration level:* This stage is working as a resilience control system to be applied to corrective or preventive decisions.

The technological map on figure 1 is built by means of performing a literature review and by synthesizing ideas developed by Hermann, Pentek & Otto (2015), Dallasega, Erwin & Linder (2018), Qin, Liu & Grosvenor (2016), Lee, Bagheri & Kao (2015) and Lasi *et al.* (2014). In this sense, significant changes may be foreseen over the next years, which would currently place us in a “creative dispersion” stage, definitely making the classification of 4.0 technologies difficult.

In this context, the World Economic Forum has extensively disseminated the fourth industrial revolution (Schwab, 2016) with the development of new technologies which allow digitalization of and sensing different links in the value chain (Tirole, 2017). At this challenge, public policies have been rather orthodox. Calderon & Catells (2016) propose that for the case of Chile, there still is a "neoliberal mindset" permeating the Ministry of Economy, which leaves technological upgrade in the hands of the market and, therefore, it is inefficient in accordance with the sector and socially unequal from the territorial point of view.

Chile has an historical opportunity in the recently enacted Law 21.105 which, for the first time, has created the Ministry of Science, Technology, Knowledge and Innovation, so that, from recognizing certain specific territorial and technological bets, a set of initiatives is generated that would serve as inputs for productive upgrading that would be accelerated by the fourth industrial revolution.

Figure 1. Concept map synthesis of 4.0 technologies



Source: developed by the author.

Methodological proposal: Participatory Communication Workshop and ICT.

Below are some surveys reviewed related to intensively knowledgeable companies with innovation networks. In principle, Malerba & McKelvey (2020), from Schumpeterian and evolutionary approaches and innovation systems, suggest that an intensively knowledgeable entrepreneur does not perform in isolation from an innovative environment. From a survey on 4,004 companies of the European Union, 2,454 of which were intensively knowledgeable, it is proven that there is a positive value on this kind of companies for accessing eternal knowledge sources, especially, for participating in diverse national, regional and sectorial innovation networks.

Accordingly, the work of Vowles, Thirkell & Sinha (2011) analyzes the factors to determine the adoption of radical innovations in 220 companies of New Zealand, specifically, on the adoption of B2B platforms. Among the conclusions, emphasis is made on the relevance of networks for an entrepreneur to adopt more radical innovations.

On the other hand, Horrillo-Tello & Llados-Masllorens (2018), as they perform an analysis of structural equations for the different regions of the European Union, conclude that the innovative institutional environment facilitates the adoption of new 4.0 technologies in the different territories. Whereas, Huggins, Prokop & Thompson (2019) make an empirical insight on the centrality of the universities on innovation networks, by studying the architecture and strategic position of the different nodes to explain innovating environments.

Likewise, Falabella & Gatica (2017) analyze the technological networks of Chile in a dynamic mode by comparing the network configuration around the investigation and development of information and communication technologies (ICTs). In this sense, there is a link between the development of ICTs and the diffusion level of 4.0 industries. Nhamo, Nhemachena & Nhamo (2020) analyze the basis of ITCs of 212 countries and conclude that a low ITCs capacity foresees slow dissemination of 4.0 industries.

Another dimension on the analysis is the study of technological fields. The work of Cortes-Sanchez (2019) stands out, whereby, from the analysis on a scientific publication base (Scopus) linked to economy, business, and management, confirms that the topic of the 4.0 industry is not yet under development in Latin-America, in spite of the fact that this is a relevant investigation field in developed countries. This work addresses the distribution of publications per institution, the evolution and generation of networks from co-quotations.

Maresova *et al.* (2018) analyzed indexed publications (Wos, Scopus) and observed that the topic of the 4.0 industry had not been deeply addressed. There are topics arising as the development of new business models, the reconversion of manpower and the settling national accounts aimed to measure the activity.

From the case review we may conclude:

- Network analysis allows us to identify the elements to determine innovation spaces.
- The development of technological fields must be analyzed, whether from a dynamic point of view, such as the likely intersections or coincidences of different technologies.

From these two axes, the purpose of this work is to identify the extent to which 4.0 technologies are disseminated in national technological networks. Our hypothesis is that there is no focalized strategy in Chile to develop 4.0 technologies; so far, it is centered in aspects linked to monitoring and converting data-information for the mining sector. The above gives rise to gaps to be bridged by more active public policy, acting with decentralized criteria, in an uncertain context of a “creative dispersion”.

This survey only analyzes the visible part of the global investment on technological development, by tangentially considering private investment. Such companies with sufficient scale economies, aimed to support internal R+D laboratories, or private organizations based on science (see Pavitt, 1984; Bogliacino & Pianta, 2016), are directly engaged by the FONDEF-IDEA projects because these public policy instruments request financial resources and they are valued as a counterpart.

Analysis of results

We worked on a global basis of FONDEF-IDEA projects of the National Commission of Science and Technology (CONICYT, by its acronym in Spanish), which reports to the Ministry of Education of the Government of Chile. The basis contains a total of 530 projects between the years of 2012 and 2017. In order to identify the projects linked to 4.0 technologies, a list of concepts was created (attachment 1) from the concept map shown above (figure 1).

In principle, a “syntactic search” was performed reaching 20 matching projects.[2] With this result, and taking into consideration that we are before an emerging technological field, a “thorough review” was performed to more broadly collect such initiatives using 4.0 technologies. This review is done project by project with the aid of the DBA-Miner Lite software (Provalis Research, s/f).

From the thorough search there were 35 projects detected (see table 1), with some development of the 4.0 type. By taking both searches into consideration (syntactic and exhaustive) we have reached a basis of 55 technological development initiatives, which represent a 10.4% of the total. The annual average growth rate of projects is 30%, from 7.3% of the total assigned initiatives to 14%. From these data, a first conclusion is reached. The Chilean State, through its public policy to foster technological development and from the results obtained between 2012 and 2017, does not show any clear preference to support these technologies.

Table 1. Projects related to technologies 4.0

Years	Projects analyzed	Syntactic detection	Detection by thorough search	Totals	Percentage of projects 4.0 over total	Growth rate in the field (%)
2017	74	2	8	10	14	-44
2016	139	7	11	18	13	100
2015	98	5	4	9	9	13
2014	88	4	4	8	9	33
2013	76	1	5	6	8	50
2012	55	1	3	4	7	n/a
Total	**530**	**20**	**35**	**55**	**10.4**	n/a
					Average growth rate	**30**

Source: made from FONDEF-IDEA projects list.
Note: n/a = not applicable.

Below is an exploratory analysis performed to identify the main areas and the most frequently assigned institutions.

With regards the areas of development

The development areas field is defined in each project and is an indirect indicator of specialization (table 2).

Table 2. Distribution of projects related to technologies 4.0 (by area)

Areas by classification	No. of projects by area	Percentage by no. of projects	Total amount invested (M$)	Percentage by total invested	Average by project
Senior citizens	1	1.8	$ 149 986	1.9	$ 149 986
Farming	2	3.6	$ 260 891	3.2	$ 130 446
Education and Social Sciences	7	12.7	$ 1 051 040	13	$ 150 149
Energy and Water	3	5.5	$ 544 879	6.8	$ 181 626
Infrastructure	1	1.8	$ 118 362	1.5	$ 118 362
Manufacture	2	3.6	$ 264 229	3.3	$ 132 115
Mining	14	25.5	$ 2 055 815	25.5	$ 146 844
Fishing and Agriculture	3	5.5	$ 420 629	5.2	$ 140 210
Healthcare	2	3.6	$ 253 424	3.1	$ 126 712
Information and Communications Technology	20	36.4	$ 2 952 449	36.6	$ 147 622
Total	**55**	**100**	**$ 8 071 704**	**100**	**$ 1 424 072**
Average by project					**$ 146 758**

Source: developed by the author.

The following conclusions were reached from the analysis of the project portfolio distribution:

- The main development area is centered on ICTs, which explains 36.4% of the initiatives. 4.0 technologies result in the context of ICTs with a "concentric" technological development, as a condition precedent for further development in other sectors, and which was also noted by Nhamo, Nhemachena & Nhamo (2020); nonetheless, in view of the nature of these technologies, it is our opinion that current classification criteria used by CONICYT ought to change to separate this group, therefore, facilitating delivery of information for making decisions.

- Mining applications are in the second area, which is consistent with the relevance of this activity in the national export basket. This sector explains 25.5% of the whole projects with a public investment of $2.055 million pesos in the six years under analysis.

- Projects dedicated to the education area stand out in the third place, which explain 12.7% of the total. This development is consistent with the greater social attention generated in the area of education from the 2011 student movement.

- The manufacturing sector only explains 2% of development projects with 4.0 technologies. This reveals that the "4.0 Industry" concept, per se, does not allow that the true impact of these technologies be included.

- Finally, there is a single project on the "senior citizen" line. This area of technological application should grow with time from the change in demographics currently undergoing in the country.

Regarding favored institutions

Regarding the main beneficiary institution, it follows that 15 universities are distributed in the 55 projects. From a first review, we may ascertain:

- A high concentration of projects in the universities of Chile (29.1%), the '*Pontificia Universidad Catolica* of Chile' (12.7%), and 'of Santiago' (10.9%). These three institutions explain 52% of the projects linked to 4.0 technologies, in the period 2012 and 2017 (table 3). This may have three explanations:
    - The existence of "depending trajectories", where the assignment of new projects arises from technological advantages obtained from previous initiatives in a specific field.
    - The likely "differentials of confidence" produced in some key actors. We have to consider that the FONDEF-IDEA projects require fresh and valued leverage resources from the companies.
    - The existence of a "discretional strategic support" which is the product of the influence of a pressure group and that may operate on some initiatives so that they become winners in the evaluation processes.

- 61% of institutional resources are invested in universities of the Metropolitan Area (Santiago de Chile, National Capital). The remaining 39% is distributed in the other regions in the country. Geographical concentration is explained by the elements not in the project: depending trajectories, differential of confidence, and strategic support which furthermore favor geographical concentration, with an accrual effect in time.

This centralism causes the loss of positive technological externalities and, therefore, of eventual synergies because it makes a geographic separation of the research work from locating productive processes, thus generating tension between geographical proximity and cognitive and technological proximity (Carrincazeaux, Lung & Vicente, 2008; Boix *et al*., 2015; Gong & Hassink, 2017). This is a limiting element of the Chilean growth model, and therefore, this prevents it from taking a more intensive advantage of the different interactive learning processes originating in the geographical proximity of the research and production activities.

Table 3. Distribution of projects related to technologies 4.0

Recipient institution	No. of projects by institution	Percentage by institution	Total amount invested (M$)	Percentage by total invested
Pontificia Universidad Católica de Chile	7	12.7	$ 986 942	12.2
Universidad Austral de Chile	1	1.8	$ 149 997	1.9
Universidad Católica del Maule	1	1.8	$ 115 000	1.4
Universidad Católica del Norte	3	5.5	$ 489 154	6.1
Universidad de Chile	16	29.1	$ 2 398 612	29.7
Universidad de Concepción	5	9.1	$ 733 980	9.1
Universidad de la Frontera	3	5.5	$ 445 747	5.5
Universidad de la Serena	1	1.8	$ 148 501	1.8
Universidad de los Andes	2	3.6	$ 399 514	4.9
Universidad de Santiago de Chile	6	10.9	$ 853 308	10.6
Universidad de Talca	1	1.8	$ 67 816	0.8
Universidad de Valparaíso	2	3.6	$ 253 216	3.1
Universidad del Bío-Bío	1	1.8	$ 149 229	1.9
Universidad Santo Tomas	2	3.6	$ 266 196	3.4
Universidad Técnica Federico Santa María	4	7.3	$ 614 492	7.6
Total	**55**	**100**	**$ 8 071 704**	**100**

Source: developed by the author.

Methodology

The purpose of this work is to identify the extent to which 4.0 technologies are incorporated to national technological networks. With this purpose there are two axes of analysis:

- First axis: identification of technologies and sectors of application for each FONDEF-IDEA project assigned between 2012 and 2017. With this purpose, words are analyzed using the free DBA Miner Lite software which facilitates codification and selective text search.

- Second axis: analysis of technological networks, from a codification generated previously by using the UCINET software, aimed to identify likely technology conglomerates, centrality, and strong and weak links.

Below are the methodological instruments for each axis of analysis:

- It is associated to identification of a frequency of occurrence of 4.0 technologies, whether in the title, objectives or the summary of the different FONDEF-IDEA projects, using the Minter Lite DBA software. [3] It must be mentioned that a project may have various 4.0 technologies and that it has to be present in parallel to several sectors of application; therefore, the number of technologies and sectors mentioned exceed the total number of project under analysis.

  For practical purposes, the following steps were created:

  a) A list of 4.0 technologies to be found was generated from the literature review (attachment 1).

  b) The projects were thoroughly analyzed with the purpose of codifying the relevant paragraphs to each technology and sector of application.

  c) The results from the search were downloaded to a co-occurrence matrix of codes into an Excel template.

- With these background facts, the distribution of sectors of application is analyzed as well as the actual emergence of 4.0 technologies in the project portfolio at hand. A vision of the network generated around 4.0 technologies is presented, based on the 55 projects previously analyzed. For this purpose, the free software specialized in the analysis of social networks UCINET was used.[4] From the co-occurrence matrix, generated in the previous point, a symmetric matrix was built that connects various institutions and technologies.

- In principle, the centrality degree is calculated from two indicators that are usually used in network analysis (Hanneman & Riddle, 2005; Borgatti & Everett, 1997):
  - *Degree:* This is the normalized centrality degree of each vector. Normalization of this ratio is produced when this number is divided by the maximum possible value, expressed as a percentage. *Degree*= (C(vi)/C.Max). Where vi, vii, …, vn are the vertexes; C(vi): the contact number of the vertex or node I and C.Max: the maximum number of possible contact.
  - *Betweeness:* This is the normalized degree of intermediation each vertex may have. In essence this is the proportion of every "geodesic trail" which connect the j vertex and the k vertex, which go through the i vertex, *Betweenness*=Σgikj/gij. Where gii is the number of geodesic trails from i to j and giki is the number of those trails going through k.
- Secondly, the strongest ties or links are identified from the number of projects in the ratio technological area and institution. The foregoing may be specifically viewed in figure 2.
- Thirdly, subgroups are determined, which consist of a set of nodes that are more closely linked among each other. According to Borgatti & Everett (1997), in order to identify these subgroups, the UCINET software applies a "partition of the input diagram" routine by using a combination optimization algorithm called Taboo Search.

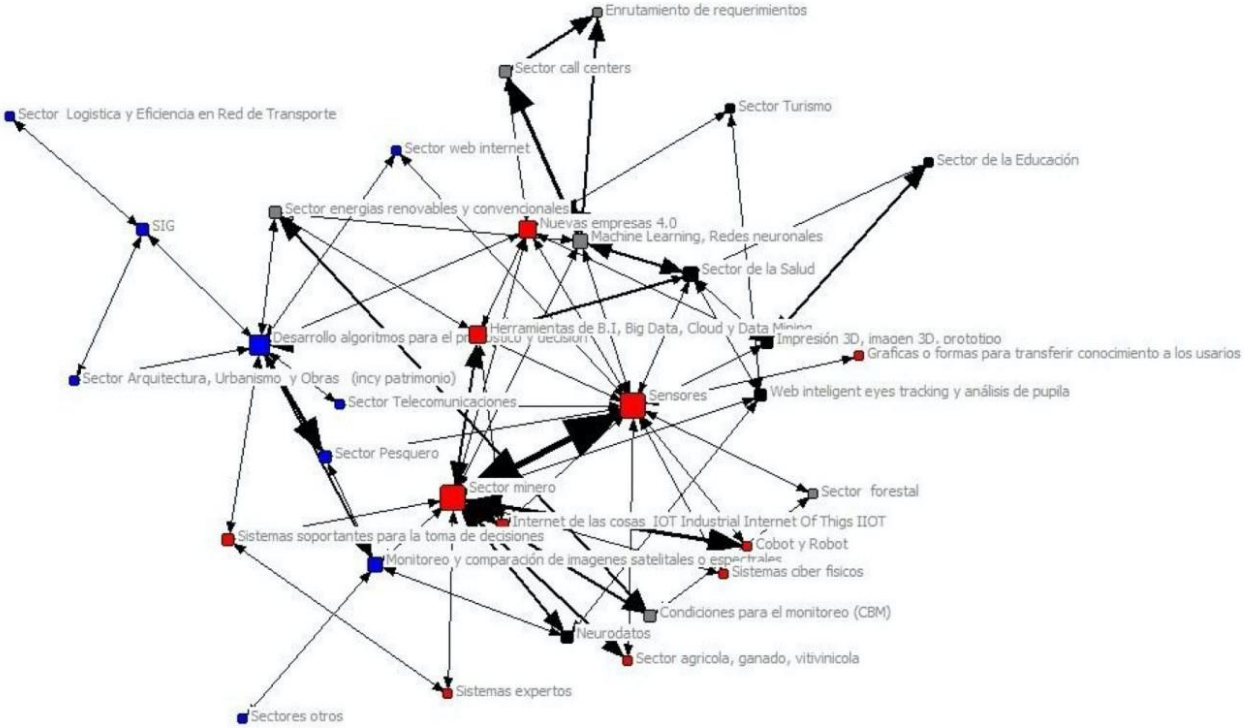
Finally, the analysis of occurrence and the network of actors do not allow any interference in the final success of every project under analysis. The foregoing, certainly is a limitation for this report, as it shall be cured in a second stage in the research, once the initiatives under analysis have become mature. It must be mentioned that 67% of the projects under analysis has been under development since 2015; therefore, not enough time has elapsed to reach concrete results from each initiative (new companies, patents, new applications, etcetera).

Analysis and results

Sectors, technological applications and networks from the contents of the projects.

Below is an analysis of words using the DBA Miner Lite software from a thorough review of the FONDEF-IDEA projects (2012-2017), and in a second item, subgroups are identified as well as its diffusive weight into the 4.0 technological network.

Figure 2. Network of technological links



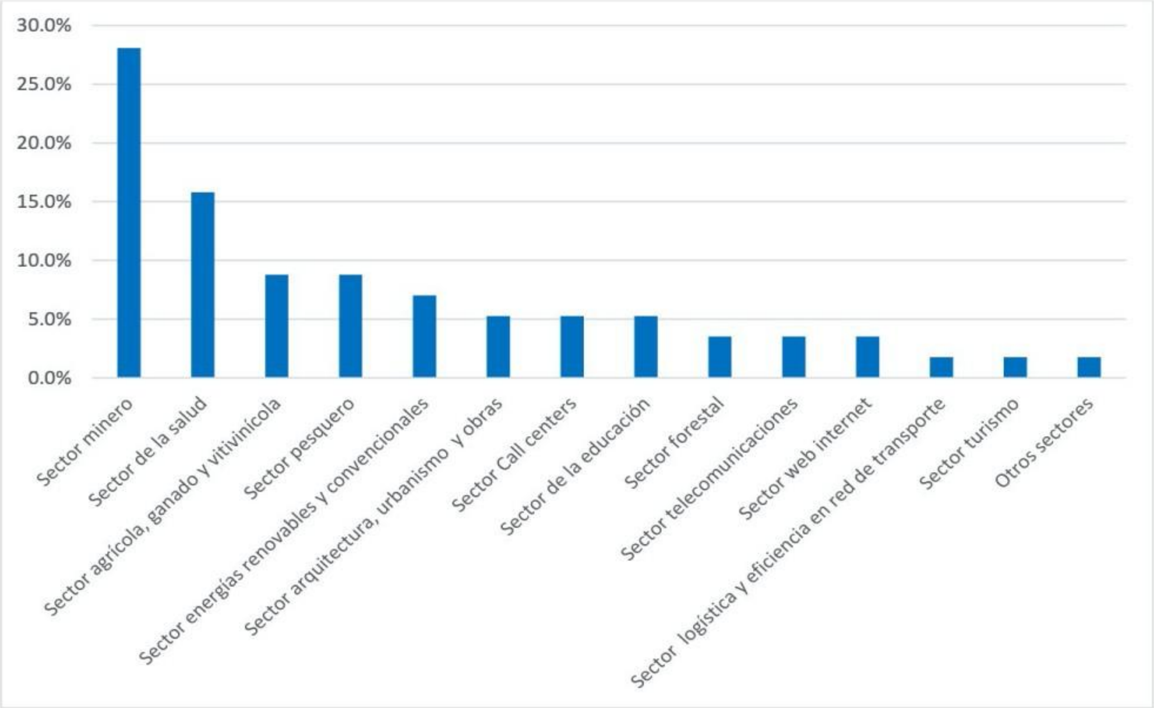
Source: developed by the author using UCINET.

In respect to the distribution of sectors of application

A first result consists of the distribution of sectors of application that may be deducted from reading the projects, in this respect we found (chart 1):

1) From the total sectors of application, 27% of cases are linked to copper mining. It must be mentioned that the State defined a priority line in this sector for FONDEF-IDEA projects, from national strategic axes. Further on, the reader shall see that part of the mining technologies developed may be applied to other national economic items, which comprises an opportunity to take advantage of positive technological externalities, from the input-product ratio to the whole network of suppliers of this sector.

Chart 1. Percentage distribution of sectors of application of 4.0 technologies.



Source: developed by the author.

2) The health sector is in the second place, where there is a set of applications linked to education of medical sciences. This is an emerging sector, especially in view of 3D printing applications, the analysis of neuronal networks, among others.

3) There are two sectors in the third place: farming, cattle breeding and winegrowing, and the fishing sector, where both blocks have five initiatives, where sensor applications, internet of things and development of algorithms stand out for forecasting and decision making.

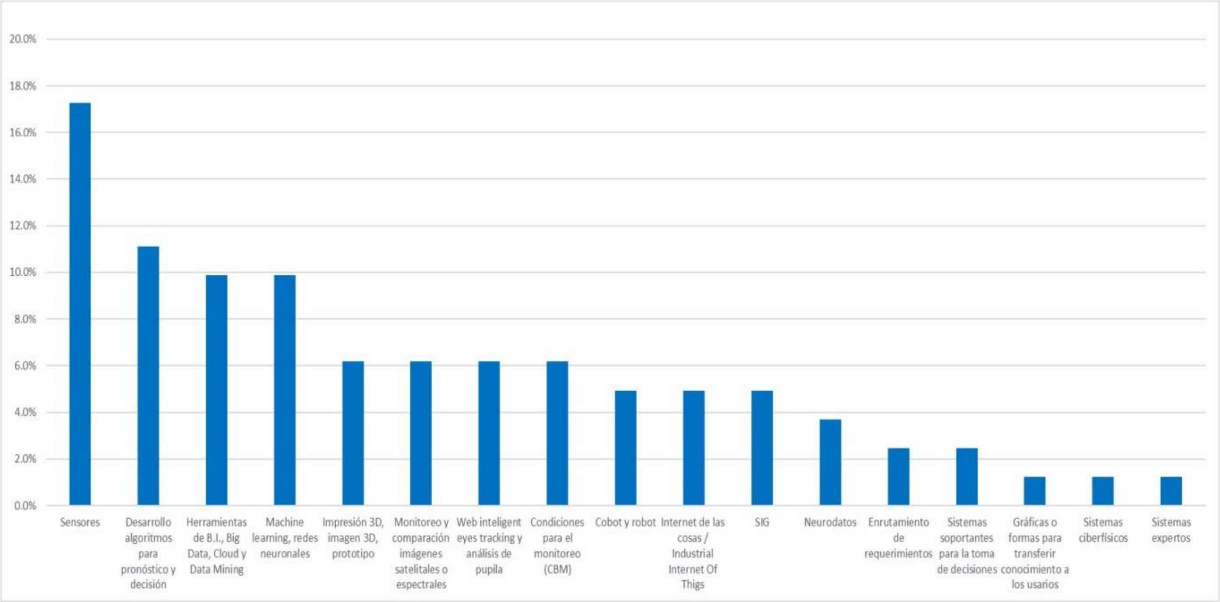
4) In the first four areas of application we have 61% of the total sectors mentioned in the FONDEF-IDEA projects portfolio.

5) In the other ten sectors of application, we have 32% explained of the projects portfolio. The following sectors are in this block: forestry, tourism, telecommunications, among others.

In respect to the main technologies

From the results, the main sectors of application for each 4.0 technology are synthetically presented in excess of 6-0% (chart 2).

Chart 2. Percentage distribution of 4.0 technologies



Source: developed by the author.

- The most important development of 4.0 technologies are applications regarding sensors, which explain 17.3% of the total occurrences.
- A second developed technology is algorithms for forecasting and decision-making which is mentioned nine times and which represents 11.1% of the total under analysis.
- The third 4.0 technology is the tools of Business Intelligence (BI), Big Data, Cloud and Data Mining, which explain 9.9% of the total.
- The machine learning systems and neuronal networks are in the fourth place, which represent 9.0% of the total, with eight occurrences.
- There is 3D printing, 3D images and prototype development in the sixth block. This field occurs five times and represents 6.2% of the total occurrences in the block of projects under analysis.

- Monitoring and comparing satellite or spectral images are at the same level, weighing 6.2% of the total occurrences.

- Also, at the same level of importance, is web intelligent Eye Tracking and pupil analysis, with a weight of 6.2% on the total.

- Condition Base Monitoring (CBM) represents 6.2%

Below is a supplementary vision of the analysis of occurrences. The network analysis is shown identifying proximity levels and different intensities of links into the technological network.

Architecture of the technological network: subgroups, centrality and weak links

The network vision is not centered in a specific node, but in the current global configuration. It analyzes the elements of the network architecture with the identification of the different subgroups, centralities and weak links.

Table 4 shows four relationship subgroups of the sector of application-technologies, with a correct proportion rate of 80%, which is an evidence of the advantage of the conglomeration algorithm. This table also shows centrality measures in parenthesis for each technology and sector of application, which identify the diffusive potentiality of each subgroup. Also, in order to better identify the relationships, figure 2 shows subgroups and centrality of the technological network of 4.0 industries.

Below are the following results:

- A first subgroup is visualized dominated by the renewable and conventional energies sector, as well as call centers and the forestry sector. There is a stronger linkage in this group with machine learning technologies and neuronal networks, everything associated to monitoring and routing of requirements is also interesting. The sum of all centralization measures of the subgroup is located in the last position (Σ *Degree* = 25), which represents 17% of the total network. The intermediation degree (Σ Betweeness = 92.5) reveals that there is a low strategic weight in this subgroup. Its existence explains 13% of the total geodesic trails of the network. As table 4 and figure 2 are analyzed, it is evidenced that the nodes in this subgroup (marked in grey color) are surrounding the network and there is a low interrelation level inside.

- The second subgroup is the most important in the 4.0 technologies network. The mining sector is in this conglomerate. The binomial mining-sensors is the core of the 4.0 technological network, 20% of the total contacts and 39.2% of the total geodesic trails of the network are explained between these two nodes. Meanwhile, the degree and the betweeness clearly place this subgroup at the center of the network (degree = 38% y betweeness = 45%). The tools of Business Intelligence, Big Data, Cloud and Data Mining, together with sensors, are at a second level of importance. It is clear in figure 2, that this subgroup is located in the center of the network from the spatial location of its nodes (red color). There are technological nodes which still lack intermediation potentiality. Specifically, Internet of Things, Cobot-Robot, Cyber Physical systems and expert systems fall in this condition (all of them with a B = 0). In spite of being at the center of the network, they do not have any diffusive capacity.

Table 4. Main dentification of subgroup based on the relation between sector of application and technologies

Subgroups	Sectors of application (Degree –D- and Betweenness – B-)	Technologies 4.0 (Degree –D- and Betweenness –B-)
Subgroup 1 **Σ D = 25 (17%);** **Σ B =9 2.5 (13%)**	• **Renewable and Conventional Energies Sector (D = 5; B = 20.7)** • Call center sector (D = 3; B = 0.0) • Forestry sector (D = 3; B = 2.0) Σ D = 11; Σ B = 22.7	• **Machine Learning and Neural Networks (D = 7; B = 62.3)** • Conditions for monitoring (D = 4; B = 7.5) • Routing of requirements (D = 3; B = 0.0) Σ D = 14; Σ B = 69.8
Subgroup 2 **Σ D = 56 (38%)** **Σ B = 320.5 (45%)**	• **Mining Sector (D = 15; B = 154.6)** • Agricultural, livestock and viticultural sector (D = 3; B = 0.0) Σ D = 18; Σ B = 154.6	• **Sensors (D =14; B = 120.8)** • BI, Big Data, Cloud and Data Mining tools (D =7; B =33.3) • The Internet of things (IoT), Industrial Internet of Things (IIoT) (D = 4; B = 0.0) • Supporting systems for decision (D = 4; B = 11.8) • Cobot and robot (D = 3; B = 0.0) • Cyber-physical systems (D = 3; B = 0.0) • Expert systems (D = 3; B = 0.0) Σ D = 38; Σ B = 165.9
Subgroup 3 **Σ D = 27 (18%)** **Σ B = 83.7 (11%)**	• **Healthcare Sector (D = 7; B = 39.0)** • Education sector (D = 3; B = 0.0) • Tourism sector (D = 2; B = 0.0) Σ D = 12; Σ B = 39.0	• **Web Intelligent Eye Tracking and Pupil Analysis (D = 5; B = 31.2)** • 3D printing, 3D image, prototype (D = 4; B = 9.2) • Neurodata (D = 4; B = 4.3) • Graphs or forms to transfer knowledge to users (D = 2; B = 0.0) Σ D = 15; Σ B= 44,7
Subgroup 4 **Σ D = 37 (25%)** **Σ B = 205.2 (29%)**	• **Fishing Sector (D = 4; B = 7.4)** • Architecture, urban planning and public works sector (D = 3; B = 0.0) • Telecommunications Sector (D = 3; B = 4.5) • Internet web sector (D = 3; B = 4.5) • Other sectors (D = 2; B = 0.0) • Logistics and transportation network efficiency (D = 2; B = 0.0) Σ D = 17; Σ B = 16.4	• **Algorithm development for prediction and decision (D = 10; B = 115.8)** • Monitoring and comparing of satellite or spectral images (D = 6; B = 44) • GIS (D = 4; B = 29.0) Σ D = 20; Σ B = 188.8
Σ total Degree = 145; Σ total Betweenness = 701.9		

Source: UCINET software results.

- The third subgroup is dominated by the health sector, as well as by the Intelligent Eyes Tracking and Pupil Analysis web. This is a low relevance conglomerate in the global technological network. It explains 18% of contacts resulting from the whole network. Thus, the intermediation level of the nodes in this conglomerate adds up 11% of the total network. The above is evidence of the low diffusive capacity. As figure 2 is reviewed we find that the nodes of this conglomerate (dyed in black color) are in peripheral zones. 3D printing, 3D images and prototypes with an interesting intermediation level also stand out in this figure.

- Finally, there is the fourth subgroup which is dominated by the fishing sector and by the development of logarithms for forecasting and decision-making. This cluster is the second most important in the global technological network. The contacts explain 25% of the total, in accordance to the degree. Whereas, if the intermediation is evaluated, we confirm that 29% of the total betweeness of the network is explained. Attention is attracted to the high diffusive capacity of the development of algorithms for forecasting and decision-making, from its intermediation level (betweeness = 115.8). Thus, the other 4.0 technologies in this conglomerate show an important diffusive capacity from its intermediation level, to wit: monitoring and image comparison (B = 44) and Geographic Information Systems (B = 9). Figure 2 shows that the nodes considered by this conglomerate (dyed in blue color) show centrality around the development of algorithms.

As proposed, the success rate of the conglomerate was 80%. Thus, there are 20% of cases where a node contact was away from its conglomerate assigned by the algorithm. In these cases, we are speaking of “weak links”, with which these nodes manage to connect with different clusters or subgroups. In this respect, Granovetter (1973) highlights the importance of these weak links because they are communication bridges that are not trapped by a specific subgroup, which increased the diffusive speed.

Table 5 shows the number of links for each “pair of subgroups” which escape from each cluster. The reader may find that the highest values are on the oblique line, this is explained by intra-subgroup links. The other combinations answer to “weak links” which enable that the learning process be diffused at a greater speed as it crosses or joins different sections of the technological network.

With this purpose, some links are shown in each intersection with greater diffusive potential.

Table 5. Identification of nodes which could not be conglomerated

	Subgroup 1 Dominated by the Renewable and Conventional Energies Sector Machine learning	**Subgroup 2 Dominated by the Mining sector and Sensors**	**Subgroup 3 Dominated by the Healthcare sector and Web Intelligent Eye Tracking**	**Subgroup 4 Dominated by the Fishing sector and the Algorithm development for prediction**
Subgroup 1 Dominated by the Renewable and Conventional Energies sector Machine learning	**32**			
Subgroup 2 Dominated by the Mining sector and Sensors	**6** Machine learning and conditions for monitoring (2)	**66**		
Subgroup 3 Dominated by the Healthcare sector and Web Intelligent Eye Tracking	**2** Machine learning and Healthcare sector (2)	**8** Neurodata and Mining (2) Healthcare sector and Machine learning (2)	**31**	
Subgroup 4 Dominated by the Fishing sector and Algorithm development for prediction	**1** Renewable energies and algorithms for prediction (1)	**7** BI tools and algorithms for prediction (2) Sensors and algorithms (3)	**1** Neurodata and image comparing (1)	**40**

Source: based on adjacency matrix.

Note: for practical purposes, the name of the subgroup is given by the sector and the technology that has a predominance in its centrality.

As specific technologies are reviewed that may go through the network the following stand out: machine learning, prognostic algorithm, neurodata, and sensing. For each case some application fields are presented from the database, which empirically evidence the width of the diffusion space:

- Machine learning
    - Routing messages in call center
    - Analysis of availability, reliability and maintainability of the equipment
    - Monitoring and automatic classification of vital signs.
    - Predicting the risk of leaving school and dropping out

- Prognostic algorithms
    - Patterns that enable characterization of brain diseases.
    - Inspection, diagnostic and predicting damages of steel bridges
    - Early alert for childhood social systems and programs.
    - Electric use control implemented by microcomputers
    - Vision system to generate images in spectrum bands
- Neurodata
    - Visual exploration analysis for an IT platform
    - Mining work control in high altitude work
- Sensors
    - Automated telemetric to gather data from sensor networks
    - Identification of a bottle of wine using radio frequency
    - Optoelectronic biosensor technology to perform optical detection and quantification of veterinary use antibiotic residues
    - Animal traceability by means of an individual identification device
    - Optical-digital device for the production of mytilidae (mussels) seeds in Chile.

This type of 4.0 technologies moving across the network likely are the focus of the strategic location of instruments of public policy, oriented to R+D and to dissemination of these results to the market, thus maximizing diffusive effects: this may be learned increasingly within the subgroup and in parallel and may give rise to substantial learning processes from cross networks.

Conclusions

A limitation to this work is that the final result of technological network links is not analyzed. Therefore, development of new businesses cannot be identified for each of the 55 projects. It must be reported that 67% of the projects under analysis have been developed since 2015; therefore, not enough time has elapsed for concrete results to develop each initiative.

We have confirmed that only 10.4% of the FONDEF-IDEA projects are directly or indirectly linked to 4.0 technologies. Therefore, there is no decided bet within public policies in Chile during the period under analysis (2012-2017) for the development of new 4.0 technological applications, and the opportunity is wasted to bridge technological gaps due to the efficiency of the borderlines of developed countries.

We are currently facing the expansion of new technologies in what may be dubbed as a "creative dispersion". Therefore, figure 1 (shown at the beginning of this article) will change as a function of the rise of new technologies, merger of other and reinterpretation of potentialities; because of this, the technological network shall have a significant change in the years to come.

In the period under analysis, we confirmed a high centrality of the mining-sensor binomial. In this sense, this is a key for the national economic development and the network of suppliers of the mining conglomerate generates crossed-relations with other sectors of the economy, in terms of their input-product relations, aimed to facilitate dissemination of the technologies to the rest of the production system.

In respect to the technological network, it is confirmed that 20% of links cannot be easily grouped together inside the current technological network. These developments of the type: machine learning, prognostic algorithm, neurodata and sensing, cannot be completely cloistered in any specific subgroup, therefore, they may cross the network and increase positive technological externalities at the focalization of public instruments.

In this sense, focalization of public policies in these "pivoting" technologies, mentioned above, and which join the different groups of the network together, give way to an interesting possibility to maximize the efficiency of public resources when "productive upgrading" is undertaken, closer to an active State in the economic area.

Finally, we have noted there is a "bottleneck" as a result of the high territorial concentration of these development projects in the national capital, where 52% of initiatives are led by three institutions in Santiago, which explains 62% of the investment amounts. This centralism is harming the generation of knowledge from the geographical proximity with production processes located near regional areas where they are exploiting natural resources.

The technological network makes emphasis on the generation of monitoring conditions and on the conversion of data to information (specifically, on aspects linked to the development of prognostics to make decision). In this context, the rise of new 4.0 companies is essential. Furthermore, having an accurate public policy to foster new business models is key, as they are the spearhead for global production upgrading. These new companies may be "specialized suppliers" or "science-based sectors", thus facilitating the dissemination of 4.0 technologies to the rest of the national economy, which translates into job creation.

Chile needs a strategy of technological development acting with a decentralized and inclusive logic, so that the fourth industrial revolution turns into an opportunity to bridge the gap between developed countries.

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Annexed 1. Word list

1) Integrated manufacturing
2) Intelligent manufacturing
3) Cloud computing
4) Cyber-physical system
5) Internet del servicio (IoS)
6) Industrial internet
7) Predictive analytics
8) Manufacturing platform
9) Intelligent robots
10) Automated simulations
11) Internet of things (IoT)
12) Cloud computing
13) Additive manufacturing (AM)
14) Augmented reality (AR)
15) Big data analytic
16) Industry 4.0
17) Smart manufacturing
18) Simulations
19) Prototype
20) 3-D printing
21) Augmented reality
22) Robotic
23) Cyber security
24) Artificial intelligence
25) Inteligencia artificial distribuida
26) Machine learning
27) Deep learning
28) Redes neuronales
29) Colonias de hormiga
30) Sistemas expertos
31) Sistemas colaborativos
32) Sistemas autoorganizados
33) Fábrica virtual
34) Data analytic
35) Ingeniería de datos
36) Modelos predictivos
37) Mantenimiento 4.0
38) Sistemas multiagentes
39) Manufactura integrada
40) Sensores inalámbricos
41) Redes de sensores
42) Robótica colaborativa
43) Sistemas holónicos
44) ERP
45) MES
46) Decision support systems
47) Intelligent machines

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[3] Available at https://provalisresearch.com/es/products/software-de-analisis-cualitativo/freeware/ #.XpPBd8hKhPY

[4] Available at http://www.analytictech.com/archive/ucinet.html