

## Diabetes research in Mexico: a map of 13 years of public funding

La investigación en diabetes en México: un mapa de 13 años de financiamiento público

Pesquisa em diabetes no México: um mapa de 13 anos de financiamiento público

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### Abstract

*In Mexico, diabetes represents a serious public health problem and a high-cost disease for the health system. Health research is essential for generating new knowledge to combat such a serious issue, however, there is not enough information on how to generate and use it. This paper examines the public funding of 303 diabetes research projects, granted by the National Council of Science and Technology in Mexico between 2002 and 2014. The projects were systematized and classified according to their type of research, discipline or subject, and aim of knowledge. Considering these information, an econometric model that links the funding with the characteristics of the projects was prepared. The results show that the funding is focused on the basic and biomedical areas, particularly on genetic research, and also that diabetes research resources have increased over time, not steadily, but rather cyclically. In diabetes research projects there is a high level of concentration at several dimensions: research areas, topics, objects, institutions conducting research, and regions. The analysis of the resource allocation suggests that Mexico needs a stronger and oriented diabetes research agenda, including in its bases discussions about balance between basic and applied research, and about oriented research towards practical implementations. The importance of promoting health systems research to improve diabetes care is also discussed, as well as implementing mechanisms to assess the impact of diabetes research in short, medium and long term, as part of Mexico's science and technology policy.*

*Diabetes Mellitus; Research; Research Financing; Government Financing*

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## Introduction

Health research is considered critical for improving health field <sup>1,2,3,4</sup>. It can strengthen health system capabilities <sup>5,6</sup>, quality and efficiency of medical care <sup>7,8</sup>, proposing and creating new solutions, in addition to be an important input to guide public policies <sup>7,8,9,10</sup>.

In the last two decades, health research has become more important. Its public and private financial support have increased in most countries <sup>2,11</sup> with greater interest in innovation and technological advancement <sup>11</sup>. Different important social actors, such as governments, international health organizations, research communities and other partners, have agreed to develop and strengthen national health research systems. They have also been encouraging improvement to creation and use of research to reach health goals.

However, to have such systems widely acknowledged is challenging. In Latin American – low- and middle-income countries – health research systems are mostly incipient or still in development <sup>11,12</sup>. To change this scenario, it is necessary to build local capability in research and innovation <sup>11,13</sup>, promoting research agendas based on national health priorities <sup>14</sup> and converting solutions or evidence into policy, practice, and/or products <sup>11</sup>.

Available funding is one of the factors that determines the national health research agenda of the countries. Although the set of public and private investments reflect the importance of health research for each society <sup>3,15</sup>, public funds are very important for certain fields of knowledge and for countries where the expenditure in Research and Development (R&D) is provided by governments. In the health field, great dependence on public funds for the development of academic research <sup>2</sup> can be verified, especially when it is directed towards clinical or public health. In Mexico, R&D spending has historically been mainly public, and its trend has been increasing. In the last 5 years, between 60 and over 70% of the GERD (gross domestic expenditure on R&D) was made with public funds allocated as part of Science, Technology and Innovation (STI) policies. Public funding also has an important role in other Latin American countries, such as Brazil and Argentina <sup>16</sup>, allowing us to discuss some common problems between them and the Mexican case.

At the same time, as available funds have been growing, studies on funding to health research have increased in several countries and regions <sup>2,14,17,18,19</sup>. Two topics usually mentioned are: (i) analysis of the national health research agenda and its relation with health priorities; and (ii) the question of how to drive the implementation of research results to improve health. Some studies focus on national and global health problems <sup>3,15</sup>, which need to be analyzed as specific cases.

This paper describes and analyzes the characteristics of research projects on diabetes mellitus with public funding in Mexico, specifically, the projects on diabetes supported by the National Council of Science and Technology (*Consejo Nacional de Ciencia y Tecnología* – CONACYT), from 2002 to 2014, since they shed light on the relations between national STI policies and health research. Such funding possibilities determines – to a great extent – what is being researched and promotes certain viewpoints about health problems. Consequently, those projects have strong influence on converting solutions or evidence into specific health benefits. This funding scheme reflects a national agenda on diabetes and allows us to observe some features of the Mexican health research system.

The article briefly describes essential features of the STI policy funding in Mexico led by CONACYT. The importance of diabetes research as one of the most serious public health problems in the country is discussed below along with some debates on health research. Subsequently, the methodology and results of the funded projects analysis are described. The discussion addresses three main problems: (i) the disciplinary domain of basic biomedical research, which limits other perspectives on health problems; (ii) the obstacles to take advantage of diabetes research, with a still imprecise agenda to promote applied research; and (iii) institutional asymmetry in the allocation of resources, which may inhibit the development of local research capacities. In conclusion, this discussion reflects on the importance of achieving a research agenda that responds more directly to health needs and that incorporates processes to evaluate the results of diabetes research.

### **Mexican national science & technology system: institutions and funds for health research**

The dependency on public funding for developing STI activities – including health research – is important to understand the available public mechanisms. The main Mexican agency for STI policy (CONACYT) was created in 1970, hence the institutionalization of STI policy can be dated back to this year. CONACYT has been responsible for promoting STI activities and became a mediator between the Mexican government, that pursued its STI-related goals, and the academic community, which sought to fulfill their own interests and needs<sup>19</sup>. CONACYT has responsibilities as both a policy-maker and funding organization, as well as many similar agencies that were created in the 1970s and 1980s in Latin America.

Today, there are two main programs/instruments to fund scientific research, with annual calls:

(1) Sectoral funds: since 2002, these funds have been operating along with some Ministries or other government organizations to promote the development and consolidation of STI capabilities according to the strategic needs of each participating sector. There are 31 funds in operation and among those related to basic and applied health science are the “Sectoral Basic Research Fund (FOSIB)” (CONACYT and the Public Education Ministry – SEP), and “Sectoral Fund for Health and Social Security Research (FOSISS)” (CONACYT, the Health Ministry and the largest public healthcare institutions).

(2) Problem-oriented scientific development projects fund (FPDCAPN): a new program oriented to stimulate scientific research related to a set of national problems. It proposes national or regional innovative solutions to obtain results or products that could have a social impact or that derive from practical applications using high technology, with the potential to be used for the development of the country. Diseases of national importance are some of the problems included in this call.

Both are competitive funds, with annual calls and addressed to public and private higher education institutions, centers, laboratories, public and private companies and other actors from the National Registry of Scientific and Technological Institutions and Companies (RENIECYT).

For many years in México basic science funding was the only option for research financial resources<sup>17,19</sup>. As a result, it functioned as an umbrella for different types of research, ranging from very fundamental basic orientation to the most applied ones. The initial model to foster science and technology in Mexico was the linear model<sup>19,20</sup> – starting from basic knowledge and sequential steps to its application. In recent decades, there has been an explicit effort to overcome this linear model through promotion of research oriented towards technological development and innovation outcomes. Since 2003, sectoral funds have been oriented to promote more applied research project developments. Recently, in 2013, a problem-oriented fund was set up, seeking to promote scientific development directed to national problems. This new and interesting program still receives a very modest amount of resources. FOSIB remained as the main funding source for science. Despite the efforts to promote applied research, most resources are still destined to basic scientific research; hence it is normal to find a bias towards this kind of activity.

Summarizing, because of the funding scheme, most of scientific research resources in Mexico tend to be in basic science areas. At first sight, government’s strategy seems only to fund fundamental research. On the other hand, by allocating few resources to applied research financing, it pressures the basic science funds, leading to resource allocation in more applied areas. Thus, policy orientation becomes limited to simply devote a certain amount of resources to scientific research, without specific orientation<sup>19,21</sup>. The intention to fund more applied research is a priority of CONACYT’s policy, but the calls have marks of basic research.

### **Diabetes mellitus: a disease of national importance**

One of the strategies to guide research to solve national problems has been the definition and prioritization of these problems. CONACYT, considering the feedback of national researchers community<sup>22</sup>, has defined the main areas of interest for the development of the country. In the health field, one of these problems is research on diseases of national importance, as diabetes mellitus, obesity and other chronic diseases.

Diabetes mellitus – specially type 2 – represents a serious public health issue in Mexico. In 2016, Diabetes mellitus type 2 was declared a national emergency, being one of the leading mortality causes

of the country <sup>23,24</sup>. It is also one of the leading causes of premature death and disability, with high cost for the Mexican health system <sup>24,25,26,27</sup>.

Mexico is the sixth highest diabetes-populated country worldwide <sup>25,28</sup>, with the highest diabetes-mortality rate in Latin America (14% of total deaths) <sup>25</sup>. After age-adjustments, diabetes prevalence in Mexico is 10.4%, similar to other Latin American countries, such as Chile (11.4%), Uruguay (11.1%), Argentina (10.2%) and Cuba (10.2%). Diabetes mortality in Mexico is between 5 and 7 times higher than in the mentioned countries (89.8 per 100,000, in 2014) <sup>29</sup>.

In 2011, the expenditure on diabetes mellitus in the country, including direct and indirect costs, was USD 7.729 billion <sup>26</sup>, which represented 0.74% of Mexican GDP (gross domestic product). Diabetes accounted for almost a sixth of the total expenditure on disease prevention and care, and its budget is higher than the allocated to social development (0.71% of GDP) or federal spending on science and technology (0.44% of GDP) for that year <sup>26</sup>. The provision of such amount of resources is considered an unsustainable issue for the Mexican health system <sup>24</sup>.

### **Diabetes health research: shedding some light on the current situation**

In Mexico, scientific capabilities on diabetes and its complications can certainly be seen, developing a wide generation of knowledge <sup>30,31</sup> that results from high-level scientific and technological research conducted in universities, National Institutes of Health (NIH), Public Research Centers (PRC), and pharmaceutical industrial laboratories. However, some problems need to be discussed around the value and input of diabetes research for Mexican society.

First, diabetes is a health problem that needs specific research agenda <sup>11</sup>. In terms of etiology and treatment, current evidence on diabetes shows it as a complex health problem, not only biological, but socially determined. Considering the strong evidence of the genetic vulnerability and many risk factors for diabetes (such as obesity or sedentary habits) in the Mexican population <sup>31</sup>, the unequal distribution of the disease and its lethality shows relation with health inequalities <sup>32,33</sup>, limitations of health services <sup>34,35</sup> and cultural, economic or other difficulties in adopting healthy lifestyles <sup>36</sup>. Regarding this, diabetes requires multiple approaches to be defeated – the full spectrum of health research may contribute to its prevention, diagnosis, and treatment. Specifically, Mexico has received OECD (Organization for Economic Co-operation and Development) recommendations about the need of strengthening research in health systems and primary care to improve diabetes attention <sup>37</sup>. Health services are responsible for greater implementation of research solutions <sup>38</sup> and other research outcomes that can be tested or evaluated <sup>4</sup>.

Second, an important global debate about the gap between research and implementation can be considered. Achievements in health research are not often seen in the implementation <sup>1,4,39</sup> of therapeutic and/or preventive actions, including public health measures leading to developing health service, clinical practice, and medical care innovative processes. In Mexico, evidence suggests that the relationship between scientific research and its implementation is still insufficient <sup>21,40</sup>, if compared to other Latin American countries <sup>41</sup>. As for the health field, linking experiences between research and health policies and programs development <sup>8,42,43</sup> can be seen; however, a lot still needs to be done to bridge the gap between knowledge generated in Mexico and its practical implementation <sup>19,44,45</sup>. All this considering, in Mexico, the lack of evaluation on the use of health research, which is a necessary condition to identify the most relevant measures to take advantage of Mexico's potential of using available knowledge <sup>26</sup>. Converting results or evidence into practice in the health field is an important goal <sup>46,47</sup>.

Finally, a problem observed in the Mexican Innovation System is the asymmetry in resource distribution, in terms of scientific institutions <sup>21</sup>, which implies different scientific and technological capacities. Mexico is a large and diverse country, and its health problems have different characteristics depending on the geographical region, culture or ethnic group. Universities and research centers located geographically in areas of higher prevalence and/or diabetes mortality, should be encouraged to develop local capabilities <sup>11</sup> to contribute to a solution of the National System of Health Research (NSHR) problem and strengthen.

## Methods

This paper uses public information of projects approved by three main national research funds of CONACYT financing health issues: FOSISS, FOSIB, and the FPDCAPN – each of these funds have an annual call to submit research projects. To simplify international and longitudinal comparison, all amounts of projects in nominal Mexican pesos were converted into constant US dollars, in purchasing power parity, using 2011 as reference year – in order to make this reading easier, hereinafter referred to as “dollars” to sum up this transformation.

Three hundred and three (303) diabetes projects or projects including diabetes-related objectives were selected, approved between 2002 and 2014. FOSISS and FOSIB are the two funds with the largest number of projects, because FPDCAPN started in 2013 (Table 1). While FOSISS is the only specific call for health research and provides the highest funding, FOSIB assigns a significant part of the funds for health research problems.

As for the 303 projects, information on the geographical location of the funded institutions was completed, as well as project characteristics.

### Classification criteria

The project classification purpose was pointing out how resources are allocated and what type of studies are most likely to be funded by CONACYT. Therefore, an initial classification resulted in a typology on research distinguishing three typical categories: basic biomedical, clinical, and public health research<sup>18,48</sup>. A greater disaggregation of them allowed detecting relevant aspects of diabetes funding research. Consequently, two types of research were found: basic biomedical and public health. In the first case, a specific basic research (ex vivo and animal models) category was developed based on human research but focused on the development of basic knowledge in the biological level, not constituting clinical interventions. As for public health, health system research was classified specifically, separating it from population, descriptive and/or analytical studies. Types of research are described in Box 1.

At a second level of classification, Research Topics and sub-topics were categorized. These topics relate to disciplines (Genetics, Cell and Molecular Biology and Biochemistry, Pharmacology, Pathophysiology, Nutrition) and research objects (Risk and Health Determinants, Health Care Models).

Finally, a classification was developed that refers to the implementation or use purposes of research results, which was called “Knowledge Application Objects” (Box 2).

In these projects, phytopharmaceutical is the only category related to pharmacological development, since CONACYT does not finance directly – or uses these calls for – other pharmacological studies in public research centers and universities. Most of the drug research in Mexico is conducted by private funds.

Basic and applied research, and technological development classification, as the one referred to in the *Frascati Manual*<sup>49</sup>, were not deliberately used because we believe that a more specific system is required to discriminate between health projects – classifications of the OECD manuals are oriented towards categorizing science, technology, and innovation activities at the aggregate level rather than by certain areas of implementation. Thus, if the classification of the *Frascati Manual* had been followed, it would not have been possible to detect the different areas, topics or objects of the diabetes research projects.

### Analysis methods

Two methods were used for data analysis. Firstly, a descriptive analysis of the 2002-2014 funding evolution was conducted, as well as the composition of the funding that had been granted per fund. This descriptive analysis was implemented in the following dimensions: types and topics of research, application objects of research projects, research institutions, and conditions in which research is conducted. Secondly, by linear regression models with ordinary least squares (OLS) methods, an exploratory analysis of the significant econometric relations between the funding amounts and the dimensions were included in the descriptive analysis – the purpose of this second empirical

**Table 1**

Number of diabetes research projects approved and amount of funding, according to the National Council of Science and Technology (CONACYT) fund, Mexico, 2002-2014.

Fund	Diabetes research		Amount of funding	
	Number	%	Amount (USD millions PPP 2011 year)	%
FOSIB	126	41.6	21.8	36.4
FOSISS	150	49.5	33.4	55.6
FPDCAPN	27	8.9	4.8	8.0
<b>Total</b>	<b>303</b>	<b>100.0</b>	<b>60.0</b>	<b>100.0</b>

FOSIB: sectoral basic research fund; FOSSIS: sectoral fund for health and social security research; FPDCAPN: problem-oriented scientific development projects fund.

Source: elaboration based on information of the CONACYT projects, 2002-2014.

**Box 1**

Types of research classification.

Type of research	Description
Basic	Studies not conducted in living humans, but in animal models, tissues, or ex vivo organs.
Biomedical	Studies in living humans, not involving interventions, but the development of basic knowledge on pathological (genesis, evolution) or biological (i.e. genetic expression studies) processes.
Clinical	Patient-centered research on pathology diagnosis, treatment, and evolution, including preclinical and clinical research.
Public health	Studies on the distribution and determinants of conditions or events (particularly diseases) related to health and the implementation of such studies for diseases and other health problems control. Includes epidemiological surveillance and descriptive studies, as well as analytical studies on health determinants and risk factors. Researched at population level.
Health systems	Studies about the care of health problems by service providers, assessing technical, operational, financial, and administrative aspects related to the provision of health services.

Source: own elaboration.

approximation was assessing the most relevant interactions between the different dimensions to better understand the determinants of CONACYT funding towards diabetes research.

The dimensions of the research that we have already defined are not independent. It is, therefore, important to explore the main interactions among them. Regarding this, a preliminary exploratory analysis was conducted to determine the most relevant dimensions for public funding of diabetes research. A series of binary variables was developed to classify the projects pursuant to the different dimensions. For each classification category, a variable was created: with the value of 1 when the project has relevant attribute, and, if not, with the value of 0. The description of the variables included in the models is in Box 3.

**Results**

In real terms, during the period analyzed, public funding for diabetes research was increased inconsistently. During 2002, the funding for diabetes research was USD 0.61 million, while in 2014 it amounted to USD 8.40 million. The largest funding was granted in 2010 (USD 9.58 million).

**Box 2**

Knowledge application objects.

Knowledge application objects	Description
Studies	Research focused on knowing the nature of health-disease processes, whose main purpose is to generate new knowledge.
Technique	Research focused on the development or improvement of medical practice application criteria or forms. Includes the definition or modification of critical values on pathological processes, and research on genetic biomarkers.
Phytopharmaceuticals	Development and characterization of the healing properties of plants for the treatment of pathologies.
Medical device	Objects, medical equipment or materials useful in the treatment of diseases.
Evaluations	Research aimed at verifying the technical or economic efficiency of the system or the health care strategies.
Interventions	Alternative proposals or modifications to treatments or care models to be implemented into a population.

Source: own elaboration.

**Box 3**

Variables.

Variables	Description
Funding amount	Number of actual millions of MXN – the year 2002 as reference – with which each research project was funded by the various mechanisms of CONACYT.
Type of research	Classifies the projects according to their research: Basic, Biomedical, Clinical, Public health, or Health systems. By collinearity, Basic research is considered a reference; therefore, the results of this dimension may be interpreted as deviations against this type of research.
Research topic	Discriminates the projects according to Biology and biochemistry, Genetics, Risks and determinants, Pharmacology, Pathophysiology, Nutrition, or Health care models. The reference research topic to be used for avoiding collinearity is Genetics.
Knowledge application objects	Dimension that categorizes the projects according to their final result. The categories considered are: Studies, Techniques, Phytopharmaceuticals, Medical device, Evaluations, or Interventions. In this case, collinearity will be avoided using the variable “Interventions” as the basis of deviation.
Research institution	Indicates the research institution that received the funding. Five institutions have been considered: The Mexican Social Security Institute (IMSS), the National Institute of Public Health (INSP), the Center for Research and Advanced Studies (CINVESTAV), the National Autonomous University of Mexico (UNAM), and the Metropolitan Autonomous University (UAM).
Research region	Considering the high concentration on Mexico City and the State of Morelos, projects are classified by sorting out the institutions that are not located in the states gathering most of the projects. Therefore, the variable created is called “NoCDMX-NoMorelos”.
Starting year of research	Figure 1 indicates a 2004-2010 positive promotion of research; therefore, it will be measured if the projects funded during these years are distinct from the others.
Call	Points out if the projects belong to FOSIB or FOSISS. The FPDCAPN was not used as a variable since there are very few projects thus funded.

CONACYT: National Council of Science and Technology; FOSIB: sectoral basic research fund; FOSISS: sectoral fund for health and social security research; FPDCAPN: problem-oriented scientific development projects fund.

Source: own elaboration.

### Types of research and topics

In terms of the issues and disciplines addressed by diabetes research within the period analyzed, 60% of the funds is focused on basic and biomedical research projects (Figure 1). The FOSISS is the main funding mechanism for clinical research, public health, and health systems. Nevertheless, the health systems category is the one receiving the least amount of resources, and public health research consists especially of epidemiological research on risk.

As for diabetes research funded by CONACYT (Figure 2), a clear prevalence of topics such as (Cell and Molecular) Biology & Biochemistry (36% of total funding) and Genetics (21% of total funding) is observed.

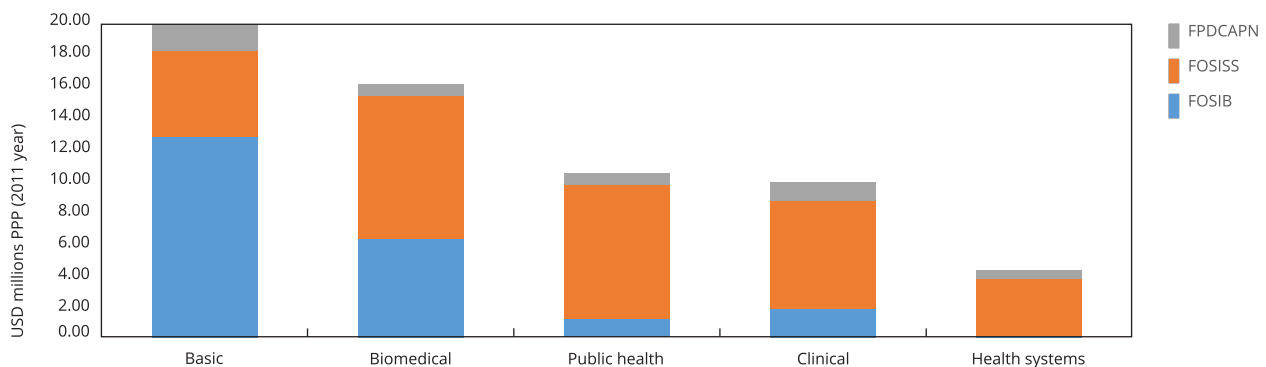
As for research objects, the evolution of diabetes research funding in Mexico shows an increasing tendency of supporting research projects that generate studies, which typically do not involve treatment of diseases. Secondly, there are projects focused on developing techniques, but with a considerable gap throughout the period (except for 2010).

The analysis by geographical location was conducted considering the different regions of Mexico, revealing a very high funding concentration in the Central region of Mexico (Figure 3). Mexico City accounts for 59% of all funds approved for diabetes research granted by the analyzed calls, followed by Morelos (15%), Querétaro (5%), and Sonora (4%). During the period of the study, they were funded by 57 institutions, 4 of which (located in Mexico City and Morelos) accounted for 52% of the total funding granted within 2002-2014. From the perspective of the number of projects funded, these 4 institutions represented 45.54% of the total amount.

The strong prevalence of Mexico City regarding other states eventually remains constant. It has even increased throughout the period of analysis when comparing funding to projects in the Central region and the rest of Mexico regions.

**Figure 1**

Amount of cumulative funding for diabetes projects according to type of research and fund. Mexico, 2002-2014 (N = 303).



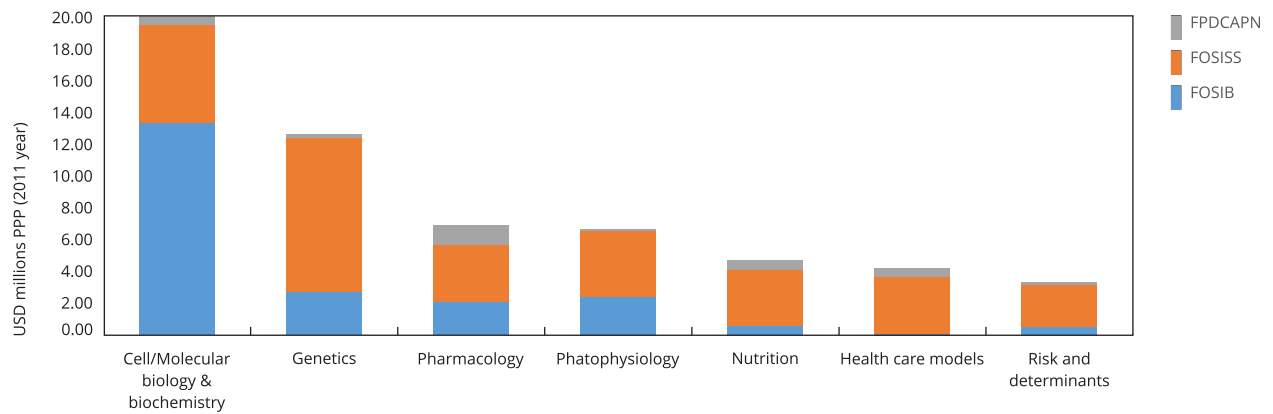
FOSIB: sectoral basic research fund; FOSISS: sectoral fund for health and social security research; FPDAPN: problem-oriented scientific development projects fund.

Source: elaboration based on information of the National Council of Science and Technology (CONACYT) projects 2002-2014.



**Figure 2**

Amount of cumulative funding for diabetes projects according to research topic and fund. Mexico, 2002-2014 (N = 303).

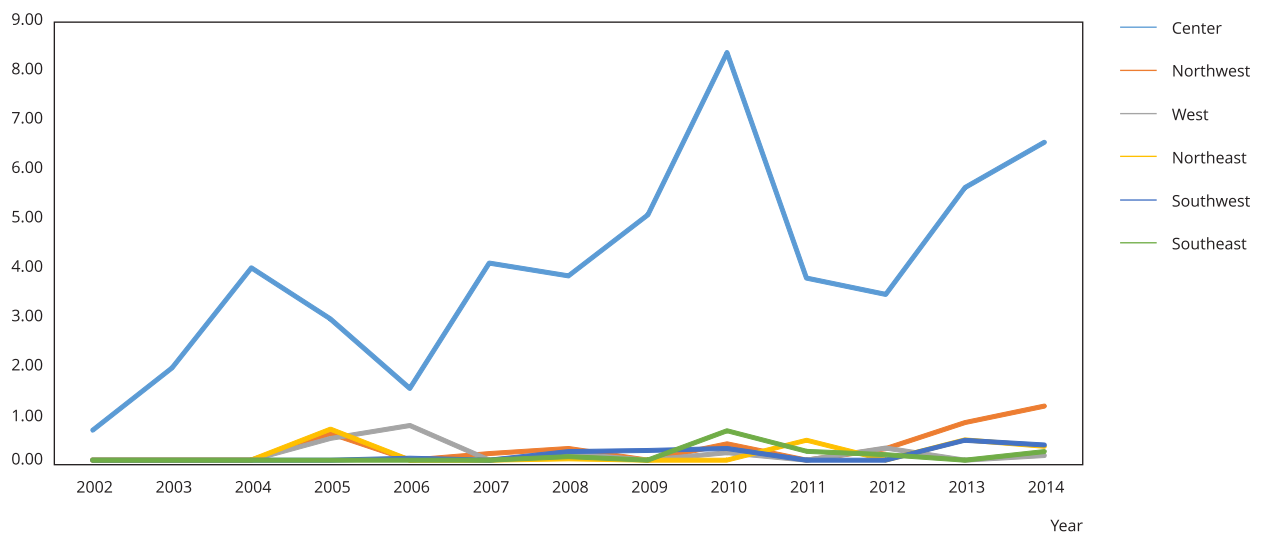


FOSIB: sectoral basic research fund; FOSISS: sectoral fund for health and social security research; FPDCAPN: problem-oriented scientific development projects fund.

Source: elaboration based on information of the National Council of Science and Technology (CONACYT) projects 2002-2014.

**Figure 3**

Annual funding amount for diabetes projects by region. Mexico, 2002-2014 (N = 303).



Source: elaboration based on information of the National Council of Science and Technology (CONACYT) projects 2002-2014.

### **Relationship among the dimensions of diabetes research with CONACYT funding in Mexico**

Results from the regression series of OLS are shown in Table 2, from which the following evidence of the diabetes research is extracted:

- (1) Evidence of a high funding concentration is verified, which can be seen in five dimensions: (i) Institutional: being part of the Mexican Social Security Institute (Instituto Mexicano del Seguro Social – IMSS), the National Institute of Public Health (Instituto Nacional de Salud Pública – INSP), and the Center for Research and Advanced Studies of the National Polytechnic Institute (Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional – CINVESTAV) has a significant and positive effect for obtaining CONACYT funds; (ii) Region: not developing research activities in Mexico City and in Morelos is also significantly and negatively associated with obtaining such funds; (iii) and (iv) Type and Topic of Research: conducting any type of research not related to basic science or to genetics has a negative and significant association with obtaining the funding; (v) Objects: research on techniques is the one showing a positive and significant relation with the funding. This is a surprising result regarding the importance of studies in funding distribution. Nevertheless, this positive correlation may be explained with the techniques, since such a project receives, on average, more resources than a project to conduct a study. On the other hand, a large part of the projects with new technical criteria is about genetics and search for risk biomarkers.
- (2) This also implies an interesting fact connected to research promotion in 2004 and 2010. In contrast to all regressions made, a positive and significant effect of 2004 and 2010 is observed. The foregoing shows that – beyond the characteristics inherent in research – funding depends on public policy decisions about priority topics at a given time.

### **Discussion**

Diabetes research funded by CONACYT between 2002 and 2014 shows a positive and growing trend, which is congruent with the increase on R&D expenditure of the country<sup>16</sup>. However, such tendency implies a high level of concentration at several dimensions: institutions conducting research (mainly IMSS, INSP, and CINVESTAV), regions (Mexico City, Morelos, and Sonora), research areas (basic and biomedical), research topics (biology, biochemistry, and genetics), and research objects (studies and techniques). This concentration shows the need to build a specific agenda for research in diabetes, to leverage on its contribution to resolve such a complex disease.

CONACYT funding increase for diabetes projects between 2002-2014 was not continuous – it was actually concentrated into two specific years, 2004 and 2010. While the growing trend of funding is a positive sign, allowing generation of new knowledge, funding uncertainty has a negative effect on the construction of scientific and technological capacities. For example, the budget variability does not help a long-term planning and may hinder efforts to create STI infrastructure or to create results in its insufficient implementation<sup>50</sup>. The lack of continuity to maintain the same level of resources has a greater negative effect in countries with a high dependence on public funds<sup>2</sup>, such as Mexico, which also shows an absence of a long-term agenda of CONACYT for diabetes research.

For research type, a high concentration of basic and biomedical research in diabetes-related projects is observed. Clinical or health system research receive proportionally less funding within the analysis period, especially the latter. On one hand, this happens because one of the calls is specifically intended for basic science (FOSIB), but the analysis of its composition indicates that other types of projects have been selected. However, FOSISS has the same characteristic: an important proportion of approved projects are related to basic and biomedical research, reflecting the historical orientation of research funding in Mexico<sup>17,19</sup>, focused on basic sciences and with a linear view-based research conception<sup>19,20</sup>, which does not always consider the necessity of implementation of its results.

Concentration of biomedical and basic research has been analyzed in previous national and international studies: these are the research areas that often receive most institutional resources in the world<sup>14,18,51</sup>. The reason of this funding concentration may be the greater scientific prestige<sup>51</sup> of these fields of health research. However, the low proportion of expenditure on health services research makes it difficult to implement the OECD recommendations on diabetes in Mexico<sup>37</sup>.

**Table 2**

Models of relationships between the dimensions of diabetes research in Mexico with the National Council of Science and Technology (CONACYT) funding, 2002-2014 (N = 303).

	Model: type of research & region	Model: research topic & region	Model: knowledge application objects & region	Model: research institution	Model: research topic & research institution	Model: research type & research institution
Type of research						
Biomedical	-0.221 * (0.099) [-2.22]	-	-	-	-	-0.198 * (0.100) [-1.99]
Clinical	-0.308 * (0.121) [-2.56]	-	-	-	-	-0.317 * (0.125) [-2.54]
Public health	-0.22 ** (0.119) [-1.85]	-	-	-	-	-0.311 * (0.128) [-2.42]
Health systems	-0.322 ** (0.168) [-1.92]	-	-	-	-	0.175 *** (-2.500) [0.013]
Research topic						
Biology & biochemistry	-	-0.247 * (0.112) [-2.20]	-	-	-0.255 * (0.111) [-2.30]	-
Risk & determinants	-	-0.400 * (0.169) [-2.37]	-	-	-0.467 *** (0.172) [-2.72]	-
Pharmacology	-	-0.266 ** (0.141) [-1.89]	-	-	-0.297 * (0.138) [-2.15]	-
Pathophysiology	-	-0.243 ** (0.143) [-1.69]	-	-	-0.237 ** (0.142) [-1.67]	-
Nutrition	-	-0.343 * (0.154) [-2.23]	-	-	-0.450 *** (0.155) [-2.91]	-
Health care models	-	-0.343 * (0.172) [-2.00]	-	-	-0.452 *** (0.173) [-2.62]	-
Knowledge application objects						
Studies	-	-	-0.053 (0.130) [-0.40]	-	-	-
Technique	-	-	0.245 ** (0.147) [1.66]	-	-	-
Phytopharmaceuticals	-	-	0.070 (0.203) [0.34]	-	-	-
Medical device	-	-	-0.041 (0.198) [-0.21]	-	-	-
Evaluations	-	-	-0.303 (0.207) [-1.47]	-	-	-

(continues)

Table 2 (continued)

	Model: type of research & region	Model: research topic & region	Model: knowledge application objects & region	Model: research institution	Model: research topic & research institution	Model: research type & research institution
Research institution						
IMSS	-	-	-	0.200 ** (0.116) [1.72]	0.192 ** (0.113) [1.70]	0.240 * (0.113) [2.13]
INSP	-	-	-	0.303 * (0.131) [2.30]	0.418 *** (0.132) [3.17]	0.405 *** (0.135) [3.01]
CINVESTAV	-	-	-	0.422 * (0.183) [2.31]	0.377 * (0.180) [2.10]	0.344 ** (0.180) [1.91]
UNAM	-	-	-	0.124 (0.119) [1.04]	0.118 (0.113) [1.05]	0.037 (0.116) [0.32]
UAM	-	-	-	0.500 (0.459) [1.09]	0.523 (0.452) [1.16]	0.384 (0.455) [0.84]
Research region						
NoCDMX-NoMorelos	-0.150 ** (0.083) [-1.81]	-0.140 ** (0.084) [-1.66]	-0.183 * (0.082) [-2.23]	-	-	-
Morelos	-	-	-	-	-	-
Querétaro	-	-	-	-	-	-
Sonora	-	-	-	-	-	-
Jalisco	-	-	-	-	-	-
Starting year						
2004	0.430 * (0.178) [2.41]	0.425 * (0.179) [2.37]	0.470 *** (0.178) [2.65]	0.405 * (0.181) [2.24]	0.451 * (0.180) [2.51]	0.457 * (0.180) [2.54]
2010	0.204 ** (0.109) [1.87]	0.213 ** (0.109) [1.94]	0.201 ** (0.109) [1.84]	0.209 ** (0.110) [1.91]	0.241 * (0.108) [2.23]	0.233 * (0.108) [2.16]
Fund						
FOSIB	-	-	-0.163 ** (0.086) [-1.90]	-0.070 (0.140) [-0.50]	-0.203 * (0.085) [-2.39]	-0.300 *** (0.089) [-3.38]
FOSISS	0.316 *** (0.085) [3.74]	0.202 * (0.080) [2.51]	-	0.140 (0.141) [0.99]	-	-

(continues)

Table 2 (continued)

	Model: type of research & region	Model: research topic & region	Model: knowledge application objects & region	Model: research institution	Model: research topic & research institution	Model: research type & research institution
Model data	[3.74]	[2.51]	-	[0.99]	-	-
n	303	303	303	303	303	303
R2	0.0977	0.1002	0.1049	0.1013	0.14	0.1284
Prob > F	0.0002	0.0005	0.0001	0.0005	0.0001	0.0001

CINVESTAV: Center for Research and Advanced Studies of the National Polytechnic Institute; FOSIB: sectoral basic research fund; FOSSIS: sectoral fund for health and social security research; IMSS: Mexican Social Security Institute; INSP: National Institute of Public Health; NoCDMX-NoMorelos: Mexico City and Morelos; UAM: Metropolitan Autonomous University; UNAM: National Autonomous University of Mexico.

Source: own elaboration.

Notes: (i) dependent variable: amount of financing; (ii) standard errors in parentheses (); (iii) Z-values in brackets [].

Levels of significance: \* 5%; \*\* 10%; \*\*\* 1%.

Health services research is considered “*the main tool available to evaluate the clinical benefit of technology*”<sup>2</sup> (p. 1338) and increasing its relevance and corresponding funds remains an unmet challenge.

From a public health point of view, promoting research on the social determinants of diabetes and how health inequalities can be addressed<sup>33,52</sup> is also important. The emphasis on biomedical and basic research can reduce the opportunity of selecting social research projects on diabetes. Social research do not have the same prestige as scientific research in health science field comparing to Genetics, however it generates social and collective strategies to deal with diabetes, which is very important. Besides, fundamental knowledge – as a unique starting point for health knowledge – is oriented to individual patients (it has not a population scope) and is strongly associated with pharmaceutical research<sup>53</sup>. We do not neglect the importance of pharmaceutical research, nonetheless, in the case of diabetes, drug-therapy treatment is only one component of patient’s needs. In any case, CONACYT public funds for diabetes might be considered as investments in low cost drug-therapy or other interventions to reduce health inequalities. With right incentives, it is possible to promote biomedical and basic research oriented to our social and economic conditions<sup>44</sup>.

We consider necessary the applicability level of projects to build a stronger diabetes research agenda. Research project objects may be an indicator of the applicability level of their results in diabetes treatment. For instance, an increased probability that knowledge may be changing and that research results may be used can be observed when, regarding this research, an adaptation or transformation is made from a technical standard, when necessary public health actions are determined, or when medical devices are developed for its clinical implementation. On the contrary, the wait may be much longer in order to identify the influence of research focused on the study of specific phenomena, whose purpose is to increase the stock of knowledge, without necessarily addressing to its implementation. The emphasis on non-implemented studies production reduce the possibility of converting research results to specific solutions for tackling diabetes. Implementation time of generated knowledge is uncertain and, considering the few existing calculations, at least a 15-year time period is estimated to obtain results<sup>54,55</sup>. On the other hand, when research is supported with an specific orientation, the potential beneficiaries of knowledge that may foster the adoption and acceptance processes of health innovations are considered.

From the institutional funds distribution point of view, high levels of research concentration may have differential effects on the use of knowledge to address diabetes in Mexico. While considered an efficient mechanism to create more and better knowledge, institutional and regional concentration of funds also hinders the capability building process of peripheral and geographical institutions and areas, consequently hampering the possibility of creating more useful knowledge to population’s local conditions. Maintaining the strength of large institutions is important, however, favor local initiatives

and capabilities<sup>11</sup> is necessary, which contributes to generate specific knowledge and to stimulate the implementation of local solutions adapted to the communities<sup>11</sup>.

Discussions on basic and applied research, types of research needed, and importance of strengthening the scientific and technological capacities of research institutions can enrich a national diabetes research agenda.

## Conclusions

The descriptive and econometric analysis of research projects on diabetes funded by CONACYT for 13 years allows us to reconstruct some signs of the diabetes research agenda. This is an important input to strengthen the NSHR and maximize the potential of scientific research.

Based on the results obtained herein, some problems that have to be addressed to strengthen diabetes scientific-technological agenda in Mexico may be outlined: (i) developing a long-term strategy and commitment for attaining a stable diabetes research funding; (ii) designing resource allocation actions, so that peripheral institutions and other regions are more likely to develop diabetes research activities; and (iii) addressing funding towards diverse research areas, subjects, and objects. To achieve a balance between types of research, methodologies and subjects, basic and applied research, minimal proportions for every category can be defined. The closeness to the creation of possible solutions or implementation might be one of the criteria for evaluation of research proposal. The work for tackling diabetes in a shorter period should be a goal in the Mexican diabetes research agenda.

Knowledge creation and transfer contributing to solve a complex problem, such as diabetes, accounts for a major challenge because of the disciplinary and fragmented nature of health knowledge and the pitfall to conveying research results to the multiple components of the health system, including the public-policy level. Regarding this, to integrate the assessment phase, based on structured models consistent with the purposes of public policies and on promoting research processes, is essential, since it allows identifying areas of opportunity and taking corrective actions to attain knowledge implementation.

## Contributors

S. Rojas-Rajs is responsible for the general conception of this paper, the study design, and the classification and analysis of diabetes research projects. She wrote and critically reviewed this paper, approved this version and agreed to be accountable on the aspects of the work that requires further study. J. M. Natera performed the econometric analysis and participated in the study design and data analysis. He wrote and critically reviewed this paper, approved this version and agreed to be accountable on the aspects of the work that requires further study. O. S. Medina Gómez participated in data classification, analysis and validation. He also wrote and critically reviewed this paper, approved this version and agreed to be accountable on the aspects of the work that requires further study.

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## Resumen

En México la diabetes es un grave problema de salud pública y es una enfermedad de alto costo para el sistema de salud. La investigación en salud es esencial para generar nuevo conocimiento para combatir este problema, pero existe escasa información sobre su generación y uso. Este trabajo examina el financiamiento público de 303 proyectos de investigación sobre diabetes, otorgados por el Consejo Nacional de Ciencia y Tecnología en México, entre 2002 y 2014. Los proyectos fueron sistematizados y clasificados de acuerdo con el tipo de investigación, disciplina o temática, y objetivo de generación de conocimiento. Con estos datos, se elaboró un modelo econométrico que relaciona el financiamiento con las características de los proyectos. Los resultados muestran que el financiamiento está centrado en áreas básica y biomédica, particularmente en investigación genética, y que los recursos destinados a la investigación en diabetes se han incrementado en el tiempo pero no de manera constante, sino coyuntural. En los proyectos de investigación sobre diabetes hay un alto nivel de concentración en varias dimensiones: áreas de investigación, temáticas, objeto de estudio, instituciones que realizan la investigación, y regiones. El análisis de la asignación de recursos sugiere que México necesita una agenda de investigación en diabetes más fuerte y orientada, con fundamento en discusiones sobre el equilibrio entre investigación básica y aplicada, y sobre investigación orientada hacia implementaciones de tipo práctico. SE discute también la importancia de promover investigación sobre el sistema de salud para mejorar el cuidado a los pacientes con diabetes, así como la de implementar mecanismos para evaluar el impacto de la investigación en diabetes a corto, mediano y largo plazo, como parte de la política de ciencia y tecnología en México.

*Diabetes Mellitus; Investigación; Financiación de la Investigación; Financiación Gubernamental*

## Resumo

No México, o diabetes representa um grave problema de saúde pública e uma doença de custo elevado para o sistema de saúde. A pesquisa em saúde é essencial para gerar novos conhecimentos para combater o problema, mas não há informação suficiente para gerar e utilizá-los. O artigo examina o financiamento público de 303 projetos de pesquisa em diabetes, através do Conselho Nacional de Ciência e Tecnologia do México entre 2002 e 2014. Os projetos foram sistematizados e classificados de acordo com o tipo de pesquisa, disciplina ou assunto e o objetivo do conhecimento. Com base nessa informação, foi preparado um modelo econométrico que associa o financiamento às características dos projetos. Os resultados mostram que o financiamento está concentrado nas áreas de pesquisa básica e biomédica, principalmente em pesquisa genética, e que os recursos para pesquisa em diabetes aumentaram ao longo do tempo, não continuamente, mas ciclicamente. Os projetos de pesquisa em diabetes mostram uma forte concentração em diversas dimensões: área de pesquisa, tema, objeto, instituição que realiza a pesquisa e região do país. A análise da alocação de recursos sugere que o México precisa de uma agenda de pesquisa mais forte e orientada, com bases que incluam discussões sobre o equilíbrio entre pesquisa básica e aplicada, e para pesquisa voltada para implementações práticas. O artigo também discute a importância de promover pesquisas em sistemas de saúde para melhorar os cuidados em diabetes, além de implementar mecanismos para avaliar o impacto da pesquisa em diabetes no curto, médio e longo prazo como parte da política de ciência e tecnologia do país.

*Diabetes Mellitus; Pesquisa; Financiamento da Pesquisa; Financiamento Governamental*

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