Papers in Evolutionary Economic Geography

14.17

Innovation and Regional Growth in Mexico: 2000-2010

Andrés Rodríguez-Pose and Edna MaríaVillarreal Peralta

Utrecht University
Urban & Regional research centre Utrecht

Innovation and Regional Growth in Mexico: 2000-2010

by

Andrés Rodríguez-Pose [a] and **Edna MaríaVillarreal Peralta** [b]

[a] London School of Economics, London, UK

[b] Scientific and Technological Advisory Forum FCCyT, Mexico City, Mexico

Corresponding author:
Andrés Rodríguez-Pose
Department of Geography and Environment
London School of Economics
Houghton St
London WC2A 2AE, UK
Tel: +44-(0)20-7955 7971
Fax: +44-(0)20-7955 7412
<http://personal.lse.ac.uk/RODRIGU1>

Innovation and Regional Growth in Mexico: 2000-2010

Abstract: This paper looks at the factors driving regional growth in Mexico, paying special attention to the potentially growth-enhancing role of innovation and innovation policy. The analysis combines innovation variables with indicators linked to the formation of adequate social conditions for innovation (the *social filter*), and spillovers for 31 Mexican states and the Mexico City capital district (the *Distrito Federal*) during the period 2000-2010. The results indicate that regional economic growth across Mexican states stems from direct investment in R&D in areas with favorable social filters and which can benefit not only from knowledge spillovers, but also from being surrounded by rich neighbors with good social conditions. The results stress that, although Mexican innovation policy has been relatively well targeted in order to generate greater economic growth, its relatively modest size may have undermined the attainment of its main objectives.

Keywords: economic growth, innovation, social economic conditions, regional convergence, Mexico

JEL Codes: R11, R12, O32, O33

1. Introduction.

In recent years empirical analyses looking at the factors driving regional growth or regional innovation across the world have tended to award particular importance to the returns of regional R&D efforts in different socioeconomic and local wealth contexts (Rodríguez-Pose and Crescenzi 2008; Navarro et al. 2009; Usai 2011 and Dettori et al. 2012). Most studies dealing with this topic have come out with much more complex and nuanced results about how innovation affects growth than the traditional approaches based on the linear innovation model. As a general rule, the studies considering R&D in combination with local wealth and socio-economic conditions find that regional economic growth and innovation is highly mediated by how local social economic conditions and, in particular, a good endowment of human capital, shape the returns of R&D investment (Rodríguez-Pose and Crescenzi 2008; Usai 2011). Spillovers have also been brought into the fray as key determinants of regional growth. In contrast to earlier analyses which tended to focus just on knowledge spillovers (e.g. Jaffe et al. 1993; Audretsch and Feldman 1996) or academic knowledge spillovers (e.g. Jaffe 1989; Anselin et al. 1997), more recent scholarly work has adopted a broader conception of spillovers, introducing not only knowledge, but also socioeconomic spillovers (e.g. Crescenzi et al. 2007, 2012; Crescenzi and Rodríguez-Pose 2013). .

Yet, most economic development policies applied in the developing world still ignore the fact that local economic conditions play an important role in the returns to investment in R&D and are still heavily based on the linear model. The assumption is simple: increasing R&D investment in any given territory will lead to greater innovation, and innovation, in turn, will result in greater economic growth. This assumption has however already been challenged by the literature in developed countries (e.g. Usai 2011). In most emerging countries, whose territories are farther away from the technological frontier and where, due to weaknesses in local socioeconomic conditions, the capacity to absorb R&D investment is limited, innovation efforts based on greater investment in R&D are even less likely to have growth-enhancing effects. If, however, included in more comprehensive territorial policies tackling simultaneously deficiencies in human capital, the production structure, and/or institutions, innovation policies may yield greater returns.

The studies analyzing the territorial returns of innovation policies at a subnational level in the developing world are few and far between. The few available exceptions apply to China (Li 2009) or to China and India (Crescenzi et al. 2012a, two countries which are increasingly catching up in terms of knowledge generation and which have become much more active in innovation policies. In these countries the territorial dimension of knowledge and knowledge policies is also of paramount importance as the level of internal disparities in knowledge generation is significantly higher than that observed in developed countries (Crescenzi and Rodríguez-Pose 2013).

Beyond China and India, the territorial analysis of innovation policies remains a black box. Despite the fact that innovation policies have become more and more popular in recent years and that territorial knowledge gaps are highly significant, there are virtually no studies dealing with the differential geographical returns of innovation policies in Latin America. In this paper we contribute to narrowing this gap in the literature by looking at how, through the use of an integrated approach, innovation and innovation policies have contributed to shape regional economic growth in Mexico in the period between 2000 and 2010.

The choice of Mexico is not random. There are three key reasons that make Mexico an excellent case study in order to address the question of how knowledge affects economic growth in emerging countries. First of all, Mexico is one of the largest emerging countries. According to IMF data, Mexico is the 11th largest economy in the world and the largest emerging country outside the BRICs (Brazil, Russia, India, and China). Second, as in the case of many of the leading emerging countries, in recent years Mexico has adopted a more ambitious and comprehensive innovation policy aimed at both getting closer to the technological frontier and generating greater economic growth (Capdevielle and Dutrénit 2012). While this policy contains some elements of the regional innovation systems approach, it is by far still dominated by the linear approach and characterized by increases in investment in R&D as the main policy tool. And finally Mexican states have been the object of closer scrutiny by academics in order to unveil the factors behind their uneven territorial development, although the majority of the studies have not gone beyond the discussion of regional convergence vs. divergence (e.g. Juan-Ramón and Rivera-Bátiz 1996; Esquivel 1999; Sánchez-Reaza and Rodríguez-Pose 2002; Chiquiar 2005; Carrión-i-Silvestre and Germán-Soto 2007), or have focused on one specific aspect behind economic growth (e.g. Lederman and Maloney 2003).

While analyzing the link between innovation policies and regional growth in Mexico is not new, most of the studies examining this relationship have tended to be qualitative and/or focus on specific case studies (e.g. Cimoli 2001; Rózga 2002 and 2009; Villavicencio and López de Alba 2010). In this paper we propose a different approach which involves quantitative techniques by estimating a panel regression model combining variables derived from linear model, innovation systems, and knowledge spillover approaches for states in Mexico and the Federal District between 2000 and 2010.

The results of the analysis underline that, although innovation policies in Mexico have attained some of the expected results at a regional level, they seem to have favored wealthier states to a much greater extent than those farther away from the technological frontier. The returns of investment in R&D are also strongly mediated by the socioeconomic conditions of each state, which act as powerful facilitators of the transformation of R&D investment and to economic growth. Finally, knowledge and social economic spillovers from neighboring states have an important influence on regional growth across Mexico.

The rest of the paper is structured as follows. In section 2 we review the evolution of science and technology (S&T) and innovation policies in Mexico. In section 3, we look at theories linking innovation to economic growth, in light of the innovative policies undertaken in Mexico. Section 4 describes the current situation of S&T in Mexico, paying special attention to the regional dimension of the policy. Section 5 introduces the empirical model, while the results of the analysis are presented and discussed in section 6. The final section includes the conclusions and some preliminary policy implications.

2. S&T and innovation policy in Mexico.

Mexico is a country where S&T and innovation policies have until recently tended to play second fiddle to other policies. Since their inception, they have generally been considered as subsidiary to growth and development policies and designed and implemented top-down in a highly centralized way.

During the long phase of the import substitution industrialization (ISI) model (1930s-1980s), S&T innovation policies contributed to try to enhance the industrial base of the country and its productivity by means of facilitating the import of technology and foreign direct investment (FDI) as the key instruments of a technological development policy.

Within this framework, the Mexican federal government created a basic S&T infrastructure and invested in the training and skills of human resources in S&T with the aim of providing large public enterprises with the right skills to enhance their productivity. The key landmarks in the strategy were the creation of a number of research institutes and councils, such as the Mexican Institute for Petroleum (IMP) in 1965, the all-powerful National Council for Science and Technology (CONACYT) in 1970, the National Institute for Nuclear Research (ININ) in 1979, and the Mexican Institute for Water Technology (IMTA) in 1986, among others. This policy of creating research centers and institutes was mainly targeted at generating innovation and improving the productivity in what were deemed to key sectors of the Mexican economy (Cimoli et al. 2005).

The demise of the ISI system during the 1980s was associated to an overall decline in the relevance of S&T innovation policies in Mexico. Existing S&T infrastructures remained relatively underused during the decade. Moreover, the top-down, supply-side policy which had dominated until then generated a mismatch between public sector supply and private sector demand, while, at the same time, failed to stimulate the participation of the private sector in the innovation process (Capdevielle et al. 2000; Capdevielle and Flores 2004; Lemarchand 2010; OECD/CEPAL 2011). Innovation levels in the Mexican economy thus remained relatively low and the exhaustion of the Mexican ISI model also resulted in the demise of the traditional S&T and innovation policies.

The change in the Mexican economic model in the late 1980s led to radical changes in the approach to S&T and innovation. In the space of just a few years, between 1986 and 1994, Mexico changed its economic policy in a radical way. It went from import substitution to becoming one of the most open countries in Latin America. The opening of the economy was accompanied by a reduction of the size of the state, the privatization of a large number of public enterprises, and the adoption of a less interventionist stance in the overall economy. Industrial policies became less prominent, with the role of the state increasingly becoming limited to the provision of public goods and services (gas, electricity, education, and social security), the control of monetary policy, as well as the implementation of horizontal policies aimed at tackling poverty (Villavicencio 2008 and 2011).

This economic transformation brought about important changes in the perception of S&T and innovation in public policies, moving from a supply-side approach to S&T to a system targeted at addressing market failures and encouraging the participation of the private sector (Capdevielle and Flores 2004; Villavicencio 2008 and 2011; OECD/CEPAL 2011). This new model put technological demand at its core, emphasizing the need to create an adequate environment for the transfer of science and technology to Mexican firms. This implied a certain commercialization of knowledge and technology as a way to better address the needs of Mexican firms. The ultimate aim was, again, improving productivity, the quality of production, and the competitiveness of the Mexican economic fabric.

However, despite the change in orientation of the policy, the results left a lot to be desired. Significant improvements in the allocation of resources to R&D and innovation were not matched by a significant increase in the participation of the private sector in innovation. The overall innovative capacity of the Mexican economy remained rather limited.

The disappointing results led to a comprehensive review of Mexican S&T and innovation policies at the beginning of the 21st century. The review resulted in a radical reform of the policy based on two pillars: a) an increase of the resources devoted to R&D, but also b) a greater emphasis on the role of innovation to the relative detriment of S&T. The 2001-2004 Development and Technological Innovation program and the 2007-2012 National Development Plan represented excellent examples of this shift in the S&T innovation policy. In these programs greater allocation of funds for R&D were matched by a raft of measures aimed at fostering and facilitating the intervention of Mexican firms in the innovation process. The ultimate aim of these programs was to reduce the technological gap between Mexican firms and those in countries closer to the technological frontier.

3. S&T and innovation policies in Mexico in light of innovation theories.

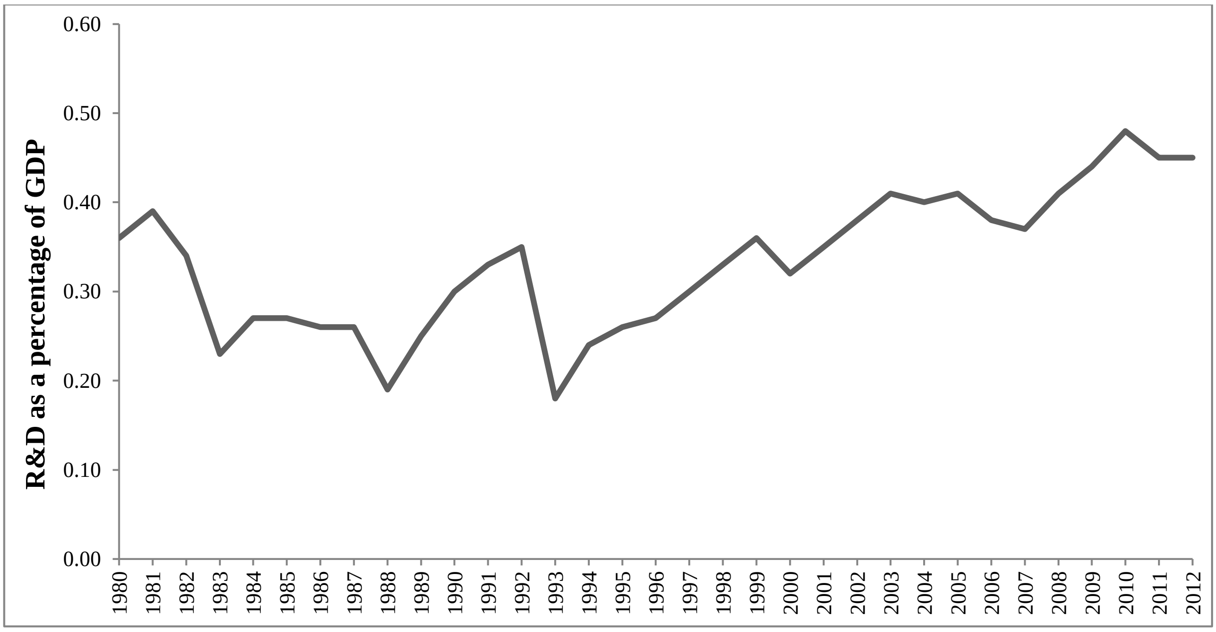
Changes over time in Mexican S&T and innovation policies have, to a large extent, mirrored changes in the theories of innovation. S&T and innovation policies during the ISI period and, to a lesser extent, after the reform of the system in the late 1980s, followed closely the linear vision of innovation which dominated until the 1980s. This perception – based fundamentally on Bush (1945) – posits that greater investment in R&D leads to greater innovation and innovation, in turn, results in greater economic growth. Hence, by investing in S&T infrastructure and pumping resources into the system, Mexican decision-makers were expecting a science push (Schumpeter 1934): supply-side intervention would help generate its own demand by firms and enhance the overall capacity of Mexican economy to innovate.

Greater investment in R&D was also believed to help fill the technology gap between Mexico and the rest of the world (Fagerberg 1988). In an economy characterized by S&T agents too distant from the technological frontier, greater public investment in R&D and the creation of public research centers and institutes was regarded as a way not only to bring the Mexican innovation system closer to the frontier, but also to generate knowledge spillovers and promote the absorption of knowledge by assimilation and imitation (Cimoli 1988 and 2001; Dosi et al. 1990; Verspagen 1991; Lemos et. al. 2006).

However, the catch-up in terms of innovation never truly materialized (Cimoli 2001; Lederman and Maloney 2006) and Mexican firms across the country remained, to a large extent, firmly anchored at the bottom of the innovation scale, producing goods and services of relatively low quality for a captive national market.

The opening of the economy to trade also brought increased competition and a greater need to improve the productivity and innovative capacity of firms in a more open environment. This process led – without really parting with the linear approach to innovation policy, which remained at the center of the Mexican innovation strategy – to a significant change in S&T and innovation policies in Mexico. First, the amount of resources devoted to R&D increased significantly (see Figure 1), albeit from very low levels. Second, complementing the increase in resources, the concept of national innovation system developed by Freeman (1979) and Nelson (1993) started seeping in into Mexican policy. This approach looks at innovation as the result of the creation of networks of multiple agents involving stakeholders and organizations in the public and private sectors, whose activities and interactions are at the root of the generation, diffusion, and assimilation of new technologies. Greater attention to the formation of a national system of innovation brought to the fore the need to enhance the interaction of the three key actors in the Mexican system, along the lines of a triple helix model (Etzkowitz and Leydesdorff 2000). This involved creating the institutional conditions for the knowledge generated by universities and public and private research centers to be easily transferred to firms and for firms to transform that knowledge into production. It also involved a greater feedback and interaction by firms to universities and research centers. The state, through its innovation centers and institutes and development agencies, represented the third pillar of the system, setting the bases for the facilitation of the interaction between all agents in the system and the transfer of knowledge (OECD 2008, 2009a, 2009b).

Figure 1. R&D intensity of the Mexican economy, 1980-2010.



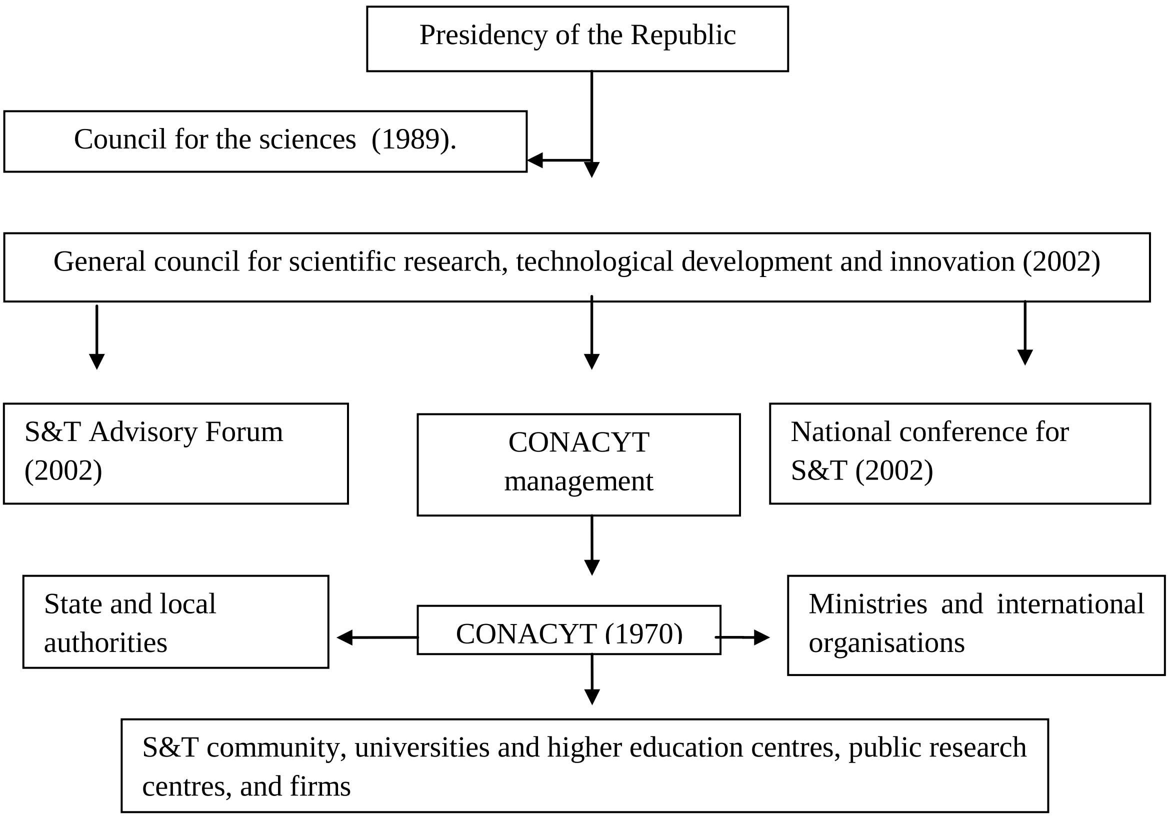
Source: Own elaboration based on CONACYT (2011) data.

In parallel to the formation of a national system of innovation, limited but increasing interest was also awarded to the formation of subnational systems (Cooke and Morgan 1999). The specific characteristics of each territory came into the innovation policy equation for the first time and some slight differentiation across Mexican states was allowed in the policy.

Finally, greater attention was also given to the need to generate knowledge spillovers (Griliches 1979 and 1992; Jaffe 1986; Audretsch and Feldman 1996 and 2004). The perception was that Mexico had not only been unable to create a significant amount of new knowledge, but also that the geographical diffusion of this knowledge had been highly imperfect. Hence, the policy was also aimed at enhancing the diffusion of knowledge from the center where this knowledge was either generated or first assimilated in Mexico to neighboring geographical areas.

All these factors put together led to the formation of a national system of innovation, which has been described by the National Council for Science and Technology (CONACYT 2011). The system combines both vertical and horizontal linkages, with stakeholders in the public sector adopting a prominent role (Figure 2).

Figure 2. Structure of the national system of S&T and innovation in Mexico.



Source: own elaboration with CONACYT information.

On the vertical axis the system is very hierarchical. It has the Presidency of the Republic at its apex, with the president being advised by a General Council for Scientific Research, Technological Development and Innovation and, in a more indirect way, by a Council for the Sciences. CONACYT sits at the center of the system and provides the basic connection between the state, on the one hand, and the S&T community, universities and higher education centers, public research centers, and firms, on the other (Figure 1). CONACYT is also responsible for the horizontal coordination, linking the effort done by different ministries in S&T and innovation with that of the different states and municipalities across Mexico. Finally, a Scientific and Technological Advisory Forum and a National Conference for S&T bring together the key Mexican S&T stakeholders with the aim of providing guidelines for new policy development.

CONACYT is also the main coordinator of the national policies of S&T innovation, setting the key objectives of the policy and administering a significant percentage of the funds channeled to S&T and innovation.

The question is whether this change in policy, which has become evident since 2000, has had an impact on Mexican innovation and, more importantly, whether the change has contributed to the ultimate stated goals of the S&T and innovation policy in Mexico, which are those of enhancing productivity and economic growth. In the next sections we address this question by first looking at the geography of S&T in Mexico, followed by an analysis of how the different factors that shape innovation in the country have affected the economic performance of Mexican states over the period 2000-2010.

4. The geography of S&T Mexico.

Despite the significant revamp of S&T and innovation policies since 2000, the Mexican innovation system is still far away from the leading systems of the world in virtually all dimensions of innovation (FCCyT 2006; Sanz Menéndez et al. 2007; OECD 2009a;

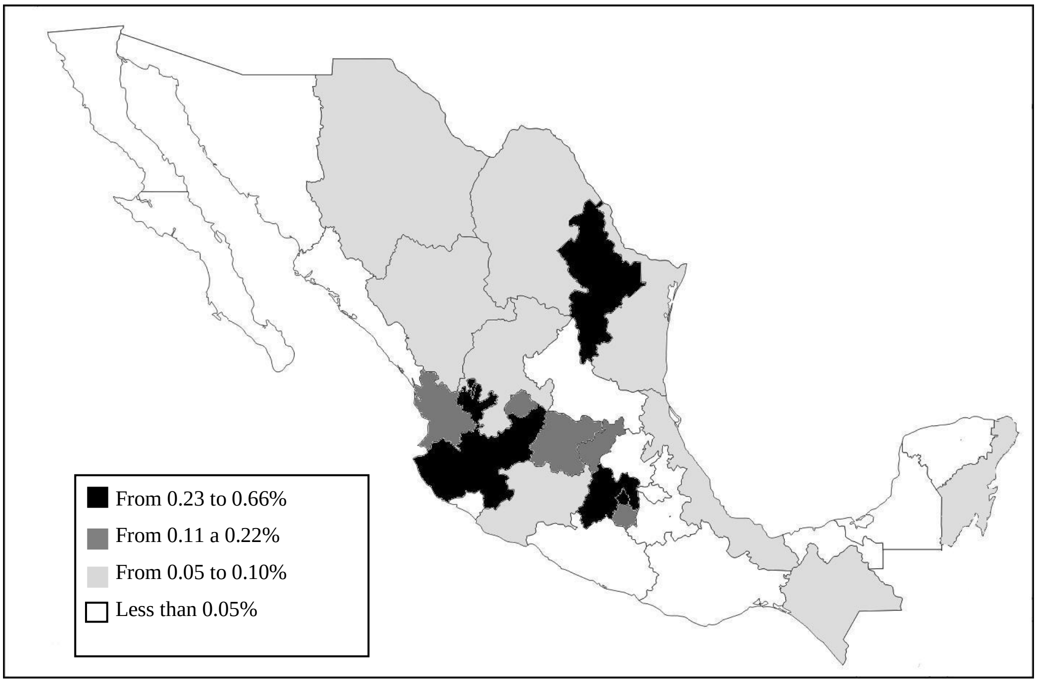
Capdevielle and Dutrénit 2012). If we simply look at the R&D input into the system – the ‘indicator’ for the linear system of innovation – Mexico, at 0.44% of GDP in 2010 according to the OECD, lingers well below the OECD median of 2.4% of GDP. This percentage puts Mexico second from bottom in the OECD ranking, only surpassing Chile. It is also below other Latin American countries, such as Argentina or Brazil, but above Colombia. The R&D effort has been more or less evenly spread between the public and private sector, with resources from the public sector representing 0.2% of GDP and those from the private sector the remaining 0.24%. A large percentage of the public investment in R&D is earmarked for basic, rather than for applied, research.

A second factor which stands out is that the necessary interaction between all the key stakeholders is far from ideal. In spite of the efforts to create a genuine system of innovation, public and private institutions involved in the generation of S&T and innovation are still, by and large, operating independently from one another, without the necessary collaboration in order to maximize the returns of R&D investment (Capdevielle and Dutrénit 2012).

The system also presents some important bottlenecks. Although the decentralization of the Mexican S&T system has proceeded apace, the majority of the activities – from the design to their implementation and promotion of S&T and innovation – are still very much concentrated in the hands of CONACYT. This often leads to some confusion, undermining the capacity of the whole system to achieve its goals (FCCyT 2006).

From a geographical point of view, there are also major differences in terms of the capacity of Mexican states to generate innovation. Eight Mexican states – Mexico State, the Federal District, Veracruz, Jalisco, Puebla, Guanajuato, Chiapas, and Nuevo León – concentrate 50% of the overall R&D expenditure in the country. As seen in Figure 3, R&D is heavily concentrated in the traditional industrial hubs of the country. Only the Federal District, the state of Mexico, Jalisco, and Nuevo León have levels of R&D expenditure which exceed 0.23% of GDP. In a country which 0.44% of GDP is devoted to R&D, these figures point to an extremely high polarization of both R&D expenditure and GDP. Aguascalientes, Guanajuato, Morelos, Nayarit, and Querétaro form a second-tier of states in terms of current expenditure. All these states have levels of expenditure in R&D which exceed 0.1% of GDP (Figure 3). Put together these results point to the existence of a geographically limited key axis of innovation in Mexico which expands from the Mexico City agglomeration in the center of the country to Guadalajara in the West. A secondary pole can be found in the North, around the city of Monterrey.

Figure 3. Geographical distribution of R&D expenditure as a percentage of GDP in 2010.



Source: own elaboration with CONACYT (2011) data.

By contrast, the rest of the country can be defined as an R&D desert. Some of the poorest states in Mexico, such as Oaxaca and Guerrero, have got levels of expenditure of R&D

which are below 0.05% of GDP. But these rates, which could be expected of the poorest states in the country, are reproduced in some middle income states, such as Yucatán in the South and Puebla in the Centre, and even expand to some northern states. Baja California and Sonora, two of the key hubs of the Mexican maquiladora industry and which benefit from their proximity to the US, also spend negligible amounts in R&D. This points to the presence of a maquiladora industry in these states which either implements process innovations or has hardly gone beyond a simple assembly stage. There is also little evidence in the literature of considerable knowledge spilling out from the Mexican technology hubs into the rest of the country (Albaladejo 2001; Aage 2003; Dutrénit 2009; De Fuentes and Dutrénit 2011). If anything knowledge spillovers in Mexico are associated with the presence of particular sectors, such as the automotive, aeronautics, and shoe-making sectors (Aage 2003; Dutrénit 2009). The poor endowments in terms of skills and competitive firms in many parts of the country also act as a powerful barrier to the diffusion of knowledge spillovers.

Overall, Mexican S&T and innovation policy has been generally anchored in the linear model of innovation, in which the public sector has established the main supply-side priorities in order to generate, strengthen, and promote S&T in Mexico. Recent efforts aimed at fostering the generation of a Mexican system of innovation and to stimulate the engagement of the private sector in the S&T innovation process are still incipient and far too limited to have generated a significant turnaround. Mexico remains far away from the technological frontier and its R&D effort is still not fully permeating into the production system. Mexico has the second lowest levels of productivity in the OECD (only above Chile) and deficiencies in a number of basic endowments for innovation may still hamper its capacity to transform S&T into innovation.

Given this panorama, it is necessary to examine which factors associated to S&T and innovation in Mexico are having the greatest impact in order to assess whether it is worth continuing with the current S&T effort and, especially, which S&T policies are likely to yield the greatest returns in the future.

5. Innovation and the sources of economic growth in Mexico: empirical model.

As seen in the previous sections, the S&T effort in Mexico has gone in three key directions. First and foremost, the policy has followed a linear view of innovation. Mexican decision-makers have for long adopted the belief that greater investment in R&D would lead to greater innovation and, eventually, to greater economic growth. Parallel to that, recent efforts towards the formation of a Mexican system of innovation, have been aimed at encouraging technological learning and diffusion, by means of improving the participation of firms in the process and their capacity to absorb knowledge and improving the overall skills of the labor force. Finally, the policy has also put emphasis on the diffusion of knowledge across the geography of Mexico.

We put the influence of these three dimensions of innovation policy to the test in a model aimed at explaining the determinants of regional growth in Mexico. This model follows Rodríguez-Pose and Crescenzi's (2008) method about how innovation shapes economic performance, combining approaches linked to R&D, systems of innovation, and knowledge spillovers. The model is also embedded in the tradition of endogenous growth catch-up models (Fagerberg 1988).

The model adopts the following form:

$$\frac{Y_{i,t}}{Y_{i,t-T}} = \alpha + \beta_1 log(y_{i,t-1}) + \beta_2 R\&D_{i,\,t} + \beta_3 SocFilter_{i,t} + \beta_4 Spill_{i,\,t} + \beta_5 ExtraSocFilter_{i,\,t} + \beta_6 ExtraGDPpc_{i,t}$$

$$+ ExtSocfilter_{i,t} + ExtPibpc_{i,t} + \varepsilon \qquad (1)$$

where,

$\frac{Y_{i,t}}{Y_{i,t-T}}$	represents the annual growth rate of regional GDP per capita.
α	is the constant.
$log(y_{i,t-1})$	depicts the natural logarithm of the level of GDP per capita ($_{t-1}$).
$R\&D_{i,t}$	is the expenditure in research and development as a percentage of the GDP of the state.
$Socfilter_{i,t}$	is the social filter, which is a proxy for the socio-economic conditions in which economic activity in each state takes place.
$Spill_{i,t}$	represents a measurement of knowledge spillovers from neighboring states (using a gravity model of knowledge diffusion).
$ExtSpill_{i,t}$	represents an alternative measurement of knowledge spillovers from neighboring states (limiting it to those states sharing borders).
$ExtSocfilter_{i,t}$	denotes potential spillovers from the socioeconomic conditions of neighboring states.
$ExtPibpc_{i,t}$	represents potential spillovers linked to the wealth of neighboring states.
ε	is the error term.

The reason behind the choice of each variable in the model is as follows:

Annual Growth rate of regional GDP per capita: Our dependent variable, aimed at measuring changes in output across the 31 Mexican states and the Federal District as the ultimate aim of Mexican innovation policies.

Level of GDP per capita $(_{t-1})$: According to Fagerberg (1988), the initial level of GDP per head is also a proxy for the knowledge available in each region, as well as for its distance to the technological frontier. Scholarly research has frequently made use of this indicator in order to assess the presence of regional convergence and/or divergence depending on the side of the coefficient. As is customary in the literature, the level of GDP per capita is transformed using natural logarithms for in order to obtain a linear relationship and to satisfy the normality assumption.

R&D expenditure: R&D expenditure as a percentage of GDP is the main indicator of S&T and innovation policies linked to the linear approach to innovation. R&D is calculated for all Mexican states and it is expected that a high level of investment in R&D will result in higher levels of economic growth.

Social filter: The potential of a region to transform the investment in R&D into greater innovation and economic performance in any given place depends, to a large extent, on its socio-economic and institutional environment and on how different local stakeholders blend into the regional innovation system. The efficiency of the local innovation system facilitates or repels the capacity of territories to innovate. However, reproducing empirically the intricate interrelations developed in a regional innovation system is not easy, particularly in a case such as the Mexican case, where often the information at a regional level is limited. We therefore follow an alternative approach in which, instead of guessing the effectiveness of different innovation systems, we look at the local socioeconomic conditions which may make states in Mexico more innovation prone or innovation averse. This approach selects a set of relevant socioeconomic variables and generates a composite index – the *social filter* index – aimed at identifying the unique combination of factors which make a territory more likely to innovate. The social filter can be understood as the set of “elements which favour or deter the development of successful regional innovation systems” (Rodríguez-Pose 1999: 82). According to this concept, factors such as the availability of adequate skills in the labor force, the use of those skills in the market, the presence of a young and dynamic population, and a favorable sectorial structure would facilitate the returns of the S&T effort and help transform R&D into innovation and economic growth.

Selecting the variables for the social filter index in a country like Mexico implies some compromises. In our social filter the availability and use of skills is proxied by variables depicting the higher educational attainment of the population and of the labor force and participation in life-long training programs at a regional level (Lundvall 1992; Malecki 1997). The demographic structure is approximated by the presence of a young and dynamic population aged between 15 and 24. This is a proxy for the “flow of new resources entering the labor force and thus of the renewal of the existing stock of knowledge and skills” (Rodríguez-Pose and Crescenzi 2008: 56). The remaining factor, sectoral structure, it is measured by the percentage of labor employed in agriculture. This variable is design to identify the low productivity and ‘hidden unemployment’ which characterizes agriculture in Mexico.

In order to construct a social filter for the Mexican states we follow Rodríguez-Pose and Crescenzi (2008) and use principal component analysis (PCA). PCA allows transforming a number of different components into a unique composite variable by maximizing the amount of information included in each variable. The mechanics of the social filter implies introducing in the PCA the education variables (the level of education of the employed population, the level of education of the total population, and life-long training rates), the demographic structure variable (percentage of population aged between 15 and 24), and the sectoral structure variable (employment in agriculture). We use the first principal component. All the variables enter the first principal component – which explains 54% of the variation in the variables – with the expected sign. All the educational and skill variables, as well as the percentage of young population are positively associated with the composite social filter variable, while the percentage of the employed population in agriculture has a negative sign. The level of educational attainment of the population has the strongest association with the composite variable, whereas the weakest is related to the percentage of young population (Appendix 1).

Spillovers: The spillovers indicator measures the capacity for the knowledge generated by investment in R&D scatter over space. The measure of the spillovers is calculated according to the following accessibility index:

$$A_i = \sum_j g(r_j) f(c_{ij}) \qquad (2)$$

where A_i represents the accessibility of region i, $g(r_j)$ denotes expenditure in R&D as a percentage of GDP in region j, $f(c_{ij})$ is the bilateral distance between region i and region j. $f(c_{ij})$ is, in turn, calculated according to the following equation, where:

$$f(c_{ij}) = w_{ij} = \frac{\frac{1}{d_{ij}}}{\sum_j \frac{1}{d_{ij}}}$$

d_{ij} is the distance between regions i and j.

The gravity nature of this approach implies that proximity is a key factor behind the measurement of spillovers. Regions closest to the centers generating new knowledge will be in a better position to assimilate and transform R&D spillovers into innovation and economic development.

Extra spillovers: *Extra spillovers* is an alternative measure of the diffusion of knowledge aimed at capturing the impact on economic growth of being surrounded by regions with or without strong investments in R&D. In contrast to the *spillover* indicator, *extra spillovers* only takes into account investments in R&D in regions sharing a common border.

Extra social filter: Traditionally the scholarly literature has only measured knowledge spillovers based on R&D or alternative innovation indicators. In this paper, following Rodríguez-Pose and Crescenzi (2008), we assume that both the social filter and GDP per head can also generate spillovers which facilitate or deter growth in the region. In *extra social filter* we intend to measure whether being surrounded by regions with a good endowment of conditions which, in theory, favor the transformation of R&D into innovation is conducive to greater economic growth. The *extra social filter* index is calculated using the same accessibility formula employed in order to calculate the *spillover* indicator.

Extra GDPpc: Following the same logic, we calculate the spillovers linked to being surrounded by rich or poor states. Once again, the accessibility index used for the *spillover* variable is used to calculate the impact of different levels of GDP per capita in neighboring states.

Table 1 presents a summary of the variables used in the analysis together with the expected coefficients of the analysis. The sources for the different variables are included in Appendix 2.

Table 1. Key variables and expected signs of the coefficients.

Variable	Expected Sign	Interpretation
Log GDP per capita$_{(t-1)}$	Negative	According to neoclassical growth theory, due to constant or diminishing returns to investment, poorer states will tend to grow faster than richer ones.
Expenditure in R&D	Positive	The linear model of innovation predicts that greater investment in R&D will lead to greater innovation and, in turn, to greater economic growth.
Social filter	Positive	Adequate socio-economic conditions in a given state will facilitate not only the generation of innovation, but also a quick absorption of innovation generated elsewhere. This will translate into greater economic growth.
Spillovers	Positive	States geographically close to other states with high levels of investment in R&D will tend to grow faster than those states located farther away from the main sources of knowledge.
Extra Spillovers	Positive	States surrounded by other states with high levels of investment in R&D will tend to grow faster than states surrounded by states with low levels of investment in R&D.
Extra Social Filter	Positive	States geographically close to other states with good socio-economic conditions for the generation and assimilation of knowledge and its transformation into innovation will, in all likelihood, grow faster.
Extra GDPpc	Positive or negative	Being surrounded by richer or poorer states will affect economic growth in a given state positively or negatively, depending on whether we adopt a neoclassical or an endogenous growth framework.

6. Analysis of results.

In order to assess which factors linked to S&T and innovation policy affect growth across states in Mexico, we consider a static and a dynamic time dimension. First, we resort to a static panel data analysis following model (1) using heteroscedasticity-consistent random effects (REM). We resort to random effects, as the Hausman test does not reject the null hypothesis of independence between the explanatory variables. Taking into account that economic growth may affect any of the independent variables – and, especially, the capacity of any given Mexican state to invest in R&D – we lag all explanatory variables by one year, implying that economic growth rates will be the result of past endowments and of investments aimed at enhancing the innovation capacity of Mexican states.

In a second stage we use a general method of moments (GMM) two-stage dynamic panel estimation. This approach is conducted not only to assess the robustness of the results of our random effect analysis, but also to take into account in a much more explicit way any potential risk of endogeneity and to include the influence of past growth trends on current levels and growth. For the definition of the instruments in order to carry out the GMM estimation we impose a lag structure on all the explanatory variables, calculating the dynamic model with two time lags. This is because we expect that there would be a delay between the implementation of policy measures aimed at improving innovation and their impact on economic growth.[1] In the dynamic model we first use – as is customary in these types of models – endogenous lagged variables as instruments. Later, these instruments are complemented by additional instruments, which include for every Mexican state the percentage of women in the total population and in employment, the percentage of

[1] Alternative time lags have been used and the results of Tables 4 and 5 remain consistent. These results can be provided upon request.

indigenous population, the unemployment rate, infant mortality, the kilometers of roads relative to GDP, and the murder rate.

Both static and dynamic analyses are conducted for the 31 Mexican states plus the Federal District during the period 2000 to 2010.

6.1. Static panel data analysis

The results of the static analysis are presented in Tables 2 and 3. The results in Table 2 underline that – despite a relatively poor fit reflected in the low R^2 – in the case in Mexico all of the factors associated with S&T and innovation policy play a non-negligible role in the generation of economic growth. As can be seen in Table 2, the states that have invested more in R&D have also experienced greater levels of economic growth. The coefficient for the R&D variable is always positive and significant in all specifications of the static model. The level of significance varies according to the different specifications, but, in most cases and with the main exception of Regression 10, where it is significant at the 10% level, the coefficient is significant at the 1% level. The effect of R&D on economic growth is complemented by that of the social filter. Mexican states with a more favorable social filter do perform better in economic terms. In particular, a good endowment of skills becomes a key factor behind high growth across Mexican states. States with a higher level of overall education, with a higher level of education of those in employment, and with a higher percentage of life-long and on-the-job training have witnessed higher rates of growth (Table 2, Regressions 4, 5 and 6). The percentage of the population in the primary sector has, as expected, a negative association with economic growth, although the association is weaker than that of education and skill availability (Table 2, Regression 6). The structure of the population, by contrast, seems to have no bearing on economic growth.

Table 2. Innovation and regional growth. 2000-2010. Random effects model.

	1	2	3	4	5	6	7	8	9	10	11
Constant	0.1132***	0.1257***	0.1265***	0.1212***	0.1374***	0.1480***	0.1436***	0.1233***	0.1130***	0.1345***	0.131***
	(3.34)	(3.83)	(3.96)	(3.91)	(4.63)	(4.24)	(4.64)	(3.89)	(3.64)	(4.69)	(4.50)
$log(y_{i,t-1})$	-0.0118***	-0.0124***	-0.0142***	-0.0150***	-0.0163***	-0.0160***	-0.0141***	-0.0113***	-0.0142***	-0.0164***	-0.0162***
	(-3.40)	(-3.50)	(-4.42)	(-4.81)	(-5.09)	(-4.35)	(-4.67)	(-2.99)	(-4.60)	(-5.72)	(-5.59)
R&D	0.1540***	0.0879**	0.1453***	0.1501***	0.1207**	0.1498***	0.1534***	0.1576***	0.1350***	0.0984*	0.0983**
	(3.63)	(2.07)	(3.12)	(3.24)	(2.53)	(2.98)	(3.58)	(3.68)	(3.02)	(1.91)	(2.00)
Spillovers	0.0160*		0.0176**	0.0193**	0.0163**	0.0162**	0.0165**	0.0169**	0.0168**	0.0175**	0.0174**
	(1.96)		(2.31)	(2.34)	(2.24)	(2.00)	(2.08)	(2.07)	(2.24)	(2.33)	(2.30)
Social filter		0.0236**	0.0255**						0.0291***	0.0386***	0.0379***
		(2.23)	(2.50)						(3.18)	(4.02)	(3.90)
Education of the population				0.1364**							
				(1.98)							
Education of the labor force					0.2535**						
					(2.01)						
Life-long learning						0.1724***					
						(4.11)					
Employment in agriculture							-0.0422*				
							(-1.90)				
Young population								-0.0801			
								(-0.74)			
Extra Social filter									0.0084***		0.00180
									(3.52)		(0.70)
Extra GDPpc										0.0000***	0.000***
										(4.00)	(3.35)
R^2 Within	0.0359	0.0338	0.0409	0.0369	0.0416	0.0719	0.0376	0.0309	0.0520	0.0594	0.0608
R^2 Between	0.1027	0.1560	0.1716	0.2076	0.1668	0.1310	0.1675	0.1560	0.2692	0.3458	0.3357
R^2 Overall	0.0423	0.0450	0.0524	0.0522	0.0535	0.0772	0.0494	0.0430	0.0731	0.0873	0.0878
Chi 2	18.32	16.19	33.35	33.62	34.83	31.27	33.69	25.82	56.60	62.75	62.07
No. observations	352	352	352	352	352	352	352	352	352	352	352

* Significant at al 90%, ** Significant at 95%, *** Significant at 99%. T-statistics in parenthesis.

The economic performance of Mexican states is also associated to the presence of different types of spillovers. Traditional knowledge spillovers linked to investments in R&D positively affect economic growth, as indicated by the coefficients in all specifications. The connection between spillovers and regional growth is robust to the introduction of different variables and is not affected by considering other types of spillovers, such as those linked to the social filter and GDP per head. In addition, regions which are surrounded by regions with a more favorable social filter and by wealthier states also tend to benefit from spillovers effects which are later translated into greater economic growth (Table 2, Regressions 9 and 10).

The negative sign of the coefficient for the log of GDP per head points towards conditional convergence during the period of analysis, indicating that the neoclassical tendency for automatic convergence is, in the case in Mexico, counterbalanced by the positive returns of greater investment in R&D and of favorable local socioeconomic conditions, which tend to take place in the wealthiest and more developed states of the Centre and North of the country.

Looking at the standard deviation impacts of the variables of Table 2 allows us to assess the relative importance of the variables. The strongest connection with growth comes from the social filter and, in particular, from the three educational stock variables included in the analysis. When considering the full model (Table 2, Regression 11), the association between the social filter index and economic growth at a regional level in Mexico is not only more significant than that of R&D and knowledge spillovers, but also close to 40% stronger than that of R&D investment and more than 60% stronger than that of knowledge spillovers. R&D investment has also a more powerful link to economic growth in most regressions – with the exception of Regressions 10 and 11, where there is virtually no difference – than the knowledge spillovers.

In Table 3 we reproduce the same analysis substituting our continuous variable for R&D spillovers by one in which only the spillovers from neighboring states – i.e. those that share a common geographical border – are considered. The reason for limiting the scope of spillovers geographically is linked to the fact that knowledge travels badly and suffers from strong distance-decay effects, as evidenced by research both in Europe (Moreno et al. 2005; Rodríguez-Pose and Crescenzi 2008) and in the US (Anselin et al. 1997; Varga 2000; Sonn and Storper 2008). Although the overall R^2 in Table 3 remains low, pointing to a potential omitted variable bias, the introduction of R&D spillovers from neighboring states does indeed render the coefficient for R&D spillovers stronger – in most specifications it is not only positive, but also significant at the 1% level – but does not affect the sign and the strength of the most of the coefficients reported in Table 2. The two exceptions are the impact on knowledge spillovers of the introduction of social filter and GDP spillovers and the dimension of the coefficient for R&D expenditures. The introduction of these two variables in Table 3 (Regressions 9 and 10) lowers considerably the coefficient for R&D spillovers, indicating that being surrounded by wealthier states and by states with a more favorable social filter is connected to greater economic growth than sharing borders with states with a high degree of R&D investment. Limiting the analysis to spillovers from bordering regions also weakens the coefficients for R&D investment in relationship to Table 2, making them even not significant in Regressions 10 and 11 (Table 3). This possibly indicates that being surrounded by other states with a relatively higher investment in R&D makes spillovers stronger at the expense of indigenous R&D.

Table 3. Innovation and regional growth. 2000-2010. Random effects model (Spillovers from neighboring states.

	1	2	3	4	5	6	7	8	9	10	11
Constant	0.0984***	0.1257***	0.1118***	0.1044***	0.1255***	0.1333***	0.1376***	0.1014***	0.1103***	0.1256***	0.1280***
	(2.79)	(3.83)	(3.39)	(3.23)	(4.15)	(3.67)	(4.40)	(3.08)	(3.38)	(4.06)	(4.21)
log($y_{i,t-1}$)	-0.0100***	-0.0124***	-0.0128***	-0.0134***	-0.0154***	-0.0141***	-0.0132***	-0.0098**	-0.0128***	-0.0144***	-0.0147***
	(-2.76)	(-3.50)	(-3.78)	(-4.10)	(-4.72)	(-3.73)	(-4.22)	(-2.47)	(-3.78)	(-4.54)	(-4.72)
R&D	0.1041***	0.0879**	0.0881**	0.0884**	0.0639	0.0990**	0.1025***	0.1045***	0.0833**	0.0466	0.0445
	(2.92)	(2.07)	(2.19)	(2.28)	(1.52)	(2.37)	(3.03)	(2.94)	(2.08)	(1.07)	(1.01)
Spillovers	0.0037***		0.0047***	0.0047***	0.0044***	0.0033***	0.0047***	0.0037**	0.0024	0.0022*	0.00296*
	(3.11)		(3.57)	(3.40)	(3.27)	(2.94)	(3.52)	(3.14)	(1.48)	(1.89)	(1.80)
Social filter		0.0236**	0.0321***						0.0302***	0.0384***	0.0399***
		(2.23)	(3.24)						(3.07)	(3.79)	(3.87)
Education of the population				0.1614**							
				(2.35)							
Education of the labor force					0.3043**						
					(2.40)						
Life-long learning						0.1651***					
						(4.01)					
Employment in agriculture							-0.0583***				
							(-2.73)				
Young population								-0.0236			
								(-0.21)			
Extra Social filter									0.0053*		-0.0023
									(1.90)		(-0.61)
Extra GDPpc										0.0000***	0.000***
Constant										(3.67)	(3.35)
R^2 Within	0.0359	0.0338	0.0409	0.0369	0.0416	0.0719	0.0376	0.0309	0.0520	0.0594	0.0561
R^2 Between	0.1027	0.1560	0.1716	0.2076	0.1668	0.1310	0.1675	0.1560	0.2692	0.3458	0.3404
R^2 Overall	0.0423	0.0450	0.0524	0.0522	0.0535	0.0772	0.0494	0.0430	0.0731	0.0873	0.0838
Chi 2	18.32	16.19	33.35	33.62	34.83	31.27	33.69	25.82	56.60	62.75	50.28
No. observations	352	352	352	352	352	352	352	352	352	352	352

*Significant at 90%, ** Significant at 95%, *** Significant at 99%. T-statistics in parenthesis.

In light of these results, it can be said that regional economic performance in Mexico over the period of analysis has responded well to the different stimuli associated to changes in innovation policies. The policy aimed at increasing investment in R&D, which is at the heart of the linear model of innovation, has yielded significant results. But, similarly, improving the conditions under which knowledge can be generated, transferred, and absorbed have also proved highly conducive to economic growth. States which have better social filters for the assimilation of knowledge – and, in particular, those which have managed to generate and/or attract better human resources – have better functioning innovation systems. And knowledge, wealth, and socio-economic spillovers are at play in determining the growth capacity of Mexican states.

6.2. Dynamic panel and instrumental variable (IV) analysis.

The estimations derived from the application of the dynamic GMM panel data analysis yield results that – with the exception of those regressions where the social filter is included – are close to those of the random effect model. This underlines the strength of the connection between the different factors driving S&T and innovation policy and economic growth in Mexico.[2]

[2] It has to be borne in mind that the introduction of methods aimed at addressing endogeneity – albeit somewhat imperfectly, as endogeneity is a theoretical problem, rather than an econometric one – also has implications for the strength of the coefficients. While system-GMM can be considered as an elegant and attractive technique to handle potential endogeneity problems, internal instrumenting is also known for suffering from a series of limitations. The main limitation is the risk of accepting results that are invalid because of weak instruments, which nonetheless appear valid because of instrument proliferation. This is, in turn, responsible for weakening the test of over-identifying restrictions (Roodman 2009). The same problems linked to instrument proliferation apply to our IV analysis. Hence, and although the Sargent tests suggest that the instruments use in Tables 4 and five are the right ones, the results of the dynamic panel and instrumental variable (IV) analysis have to be considered with some caution.

Table 4 reports the results of the two-stage GMM analysis using endogenous instrumental variables lagged by two periods. As in the static analysis, Table 4 includes knowledge spillovers as determined by geographical distance across the whole of Mexico. The introduction of the lagged dependent variable in the dynamic analysis clearly improves the fit of the model relative to the static analysis and leads to strongly significant coefficients, while not affecting the influence of our three main variables of interest behind economic growth in Mexico. First, having a lagged level of GDP per capita growth reinforces the conditional convergence trend. It is not only states with a higher GDP per head that tend to grow at a slower pace, once other factors are controlled for, but also the states which have grown faster in the previous year tend to perform worse.

Regarding our explanatory variables of interest, both R&D investment and social filter conditions remain positively and significantly associated with economic growth, as are the different types of spillovers (Table 4, Regressions 2 and 3). It is worth noting, however, that, in contrast to the static analysis, the introduction of the spillover variable for the social filter renders the coefficients for the social filter itself not significant and weakens the coefficients for R&D expenditure, regardless of the type of knowledge spillovers considered (Table 4, Regression 4 and 6). The same occurs when knowledge spillovers are limited to just the surrounding states (results available upon request). This implies that Mexican states which have a greater investment in R&D, that are surrounded by other states spending in R&D, and which are close to states with favorable socioeconomic conditions experienced a greater rate of economic growth than states which have a better endowment of socioeconomic conditions in their own right. Being surrounded by relatively wealthy states, while conducive to economic growth, does however not limit the capacity for knowledge spillovers to favorably impinge on economic performance (Table 4, Regression 5 and 6).

Table 4. Two-stage GMM estimation of the link between innovation and regional growth (*Spillovers*).

	1	2	3	4	5	6
Constant	0.109***	0.0756***	0.0746***	0.0369***	0.0861***	0.0545***
	(11.36)	(6.02)	(4.95)	(2.80)	(6.04)	(4.32)
$Y_{i,t}/Y_{I,t-T}$ ($\rho=1$)	-0.168***	-0.188***	-0.193***	-0.228***	-0.197***	-0.276***
	(-6.72)	(-3.06)	(-3.49)	(-3.99)	(-3.04)	(-4.25)
$Y_{i,t}/Y_{I,t-T}$ ($\rho=2$)	-0.252***	-0.262***	-0.300***	-0.288***	-0.259***	-0.273***
	(-11.49)	(-7.83)	(-8.41)	(-7.05)	(-4.92)	(-6.39)
$log(y_{i,t-})$	-0.0121***	-0.0112***	-0.0130***	-0.0137***	-0.0147***	-0.0159***
	(-10.54)	(-8.08)	(-10.22)	(-9.01)	(-9.35)	(-8.97)
R&D	0.246***	0.174***	0.204***	0.139*	0.164*	0.162*
	(7.73)	(3.00)	(3.78)	(1.83)	(1.89)	(1.81)
Spillovers	0.0268***		0.0199***	0.0106**	0.0198***	0.0137***
	(10.12)		(4.55)	(2.03)	(3.75)	(2.89)
Social filter		0.121***	0.130***	0.0234	0.103***	0.00342
		(4.91)	(3.70)	(0.69)	(2.66)	(0.13)
Extra Social filter				0.0659***		0.0639***
				(6.46)		(10.96)
Extra GDPpc					0.0000***	5.34e-08***
					(6.93)	(3.79)
#Instruments	160	160	190	190	190	191
Sargan Test	30.67	30.63	28.51	28.87	28.48	28.16
P-Value	1	1	1	1	1	1
AR(1) Test	-2.827	-2.84	-3.003	-3.142	-2.89	-3.079
P-Value AR(1)	0.0047	0.0044	0.0027	0.0017	0.0038	0.0021
AR(2) Test	-.1005	0.4055	0.3673	0.911	0.357	0.5126
P-Value AR(2)	0.9199	0.6851	0.7133	0.3623	0.971	0.6082
N	256	256	256	256	256	256

Instrumental variables: Endogenous variables lagged by two periods.
*Significant at 90%, ** Significant at 95%, *** Significant at 99%.
T-statistics in parenthesis.

An additional way of dealing with potential endogeneity is to include additional own instruments in the GMM estimation. The inclusion of new instrumental variables (IV) implies looking for variables that would satisfy the two conditions to be used as valid instruments: 1) exogeneity, meaning that it must be uncorrelated with the error term in the model, and 2) relevance, inferring a correlation with the endogenous explanatory variable.

Finding such instruments is always tricky, especially as it is very difficult for any non-physical geography variable to fulfil the condition of exogeneity. However, we have identified a number of instruments – the percentage of women in the total population and in employment, the percentage of indigenous population, unemployment rate, infant mortality, endowment of infrastructure measured in kilometers of roads relative to GDP, and the murder rate – which depict characteristics of Mexican states closely correlated with the main explanatory variables (social filter, R&D investment, GDP per head, and knowledge spillovers), but not with the error term. This is confirmed by the Sargan test (Table 5), meaning that we cannot reject the null hypothesis of independence between these instruments and the random disturbances of the equation, and that the use of these instruments is appropriate. The introduction of additional instruments enhances the problem of instrument proliferation, meaning that the results of this type of analysis have to be taken as a complement to those of the static panel data analysis of Tables 2 and 3.

The introduction of these additional instruments (Table5) improves once again the fit of the model and leaves most of the coefficients of the dynamic analysis presented in Table 4 virtually unchanged, with the exceptions of those regressions (Regressions 5 and 6) where the spillover of regional wealth (GDP per head) is introduced. This implies that Mexican states benefit more from spillovers in R&D, social filter conditions and wealth from neighboring states, than from their own investment in R&D or social filter conditions. Hence, after controlling for path dependency in state growth rates, regional economic growth in Mexico is mainly connected to R&D and social capital spillovers, rather than to own research and social filter conditions. However, as mentioned earlier, given the problems of instrument proliferation, these results have to be considered with some caution.

Table 5. Two-stage GMM estimation of the link between innovation and regional growth with additional instrumental variables (IV) (*Spillovers*).

	1	2	3	4	5	6
Constant	0.107***	0.0807***	0.0786***	0.0516***	0.0921***	0.0563***
	(11.32)	(5.86)	(5.53)	(3.12)	(5.87)	(3.61)
$Y_{i,t}/Y_{I,t-T}$ ($\rho=1$)	-0.173***	-0.186***	-0.220***	-0.246***	-0.203***	-0.234***
	(-5.78)	(-4.18)	(-3.94)	(-4.37)	(-3.04)	(-3.56)
$Y_{i,t}/Y_{I,t-T}$ ($\rho=2$)	-0.256***	-0.251***	-0.295***	-0.298***	-0.237***	-0.265***
	(-10.69)	(-8.05)	(-9.30)	(-7.49)	(-5.87)	(-5.15)
$log(y_{i,t-})$	-0.0117***	-0.0121***	-0.0142***	-0.0154***	-0.0147***	-0.0152***
	(-9.47)	(-9.46)	(-9.92)	(-8.10)	(-8.74)	(-7.49)
R&D	0.236***	0.196***	0.257***	0.171**	0.120	0.130
	(6.75)	(3.57)	(5.71)	(2.14)	(1.63)	(1.56)
Spillovers	0.0262***		0.0226***	0.0118**	0.0163***	0.0132**
	(9.72)		(6.08)	(2.09)	(3.67)	(2.08)
Social filter		0.126***	0.140***	0.0252	0.0984**	0.00123
		(3.79)	(4.06)	(0.75)	(2.46)	(0.04)
Extra Social filter				0.0662***		0.0596***
				(6.67)		(6.67)
Extra GDPpc					9.86e-08***	6.28e-08***
					(7.30)	(4.04)
#Instruments	167	166	197	215	198	199
Sargan Test	30.24	30.67	271.18	28.56	29.64	26.84
P-Value	1	1	1	1	1	1
AR(1) Test	-2.86	-2.775	-3.064	-2.97	-2.81	-2.987
P-Value AR(1)	0.0042	0.0055	0.0022	0.003	0.0048	0.0028
AR(2) Test	-0.0785	0.334	0.2115	0.89	-0.1062	0.7545
P-Value AR(2)	0.9374	0.7377	0.832	0.373	0.915	0.4505
N	256	256	256	256	256	256

Own instrumental variables lagged by two periods.
*Significant at 90%, ** Significant at 95%, *** Significant at 99%.
T-statistics in parenthesis.

7. Conclusions

In this paper we have examined the factors which determine regional economic growth in Mexico in light of changes in the S&T and innovation policies undertaken by the Mexican government since 2000. Using a static and dynamic panel data analysis, we have tried to untangle the relevance for economic growth of the three basic components of the revamped Mexican S&T and innovation strategy. These components include investment in R&D (as a key indicator representing the dominating linear approach to innovation paradigm), a measure of the socio-economic conditions conducive to the formation of efficient innovation systems (social filter), and different indicators of spillovers. One of the novelties of the analysis is the inclusion of three different dimensions of spillovers. On top of the knowledge spillovers associated to investment in R&D, which have been commonly used in the scholarly literature on innovation, we have considered spillovers linked to the wealth of the different Mexican states and to the presence (or lack of it) of advantageous socio-economic conditions for innovation and growth.

Since its reform in the late 1990s and early 2000s Mexican S&T and innovation policy has been trying to juggle these three dimensions. On the one hand, it has remained firmly anchored in the linear model of innovation and on the expectation that greater resources devoted to R&D will lead to greater innovation and innovation will, in turn, deliver greater connectivity and growth. The majority of funds aimed at science and technology and innovation are still earmarked for investments in R&D. However, at the same time, greater attention has been paid to the conditions which allow for the formation of efficient national and regional systems of innovation, by trying to enhance the interaction between centers for the production of knowledge and firms, while improving the innovative and absorptive capacity of both firms and territories. This has allowed the diffusion of knowledge and the generation of spillovers to come to the fore as the third key element of the policy.

The analysis has covered all 31 Mexican states and the Federal District hosting the capital of the nation over the period 2000-2010. The results of the analysis highlight that, in the case of Mexico, regional economic growth is strongly influenced by the three elements that represent the basic components of the national S&T innovation policy. Recent efforts to increase the amount of resources devoted to R&D – albeit from very low starting levels –

seem to have paid off. States promoting a greater percentage of their GDP to investment in R&D have performed better over the last decade than those in which the R&D effort is either non-existent or testimonial. Similarly, the presence of favorable socioeconomic conditions has been a fundamental element behind recent growth trends. In particular states with a better endowment of human capital have not only been able to grow at a faster rate, but also have been capable of reaping the benefits of additional investments in R&D. Finally, and in contrast to other parts of the world, such as the US and China (e.g. Crescenzi et al. 2007, 2012; Crescenzi and Rodríguez-Pose 2013), territorial spillovers work well in Mexico. Knowledge, socio-economic and wealth of spillovers are all important factors behind the economic dynamism of certain Mexican states. States surrounded by states with a better endowment in R&D investment, a more favorable social filter, and by wealthier regions tend to perform better than those whose neighbors have poor endowments in all three categories. And the results point towards a greater influence of the social filter spillover on economic growth than that of the traditional measurement of knowledge spillovers.

These results underline that Mexican S&T and innovation policy seems to have veered in the right direction in recent years. Yet, if that is the case, why has the Mexican innovation and growth performance not lived up to expectations in recent years? Given the results of the analysis, the paltry economic performance in Mexico over the last decade seems to be more related with the dimension of public policy and with inherited factors than with its general orientation. While the policy has played the right keys in terms of the factors that stimulate growth, at 0.44% of GDP it remains far too small to contribute to a radical change to the Mexican economic trajectory. The geographical distribution of the effort is a further factor undermining its impact. A large number Mexican states have virtually no resources devoted to R&D. These states are likely to be too far away from the technological frontier and hence the concentration of R&D along the central axis of the country and in Monterrey – where the largest firms and the most capable and competitive universities and research centers located – may not be such a bad idea. However, even in many of these states investment in R&D does not exceed 0.3% of GDP, making their translation from R&D into innovation and economic growth extremely difficult to achieve.

Widespread deficiencies in social filter conditions, and especially in the overall endowments in human resources, are also proving to be an important barrier for the transformation of any effort aimed at generating greater innovation into economic dynamism. This affects both the generation of knowledge, as well as its assimilation. Mexico still has, even in its most developed parts, strong deficits in terms of scientists and researchers able to match the knowledge generation in most developed countries. Despite the presence of some world-class research teams in the country and a considerable on-going effort to train scientists both in Mexico and abroad, the deficit in this realm is still far too broad and would require considerable attention in the future. As important – if not more important – is the need to raise the overall skills of the population as a means to enhance the capacity of firms regardless of where they are located in Mexico to absorb innovation created elsewhere and to benefit from the spillovers being generated by the system. With levels of illiteracy which still hover around 7% and a substantial deficit both in stock and in quality (according to the OECD PISA report) in high school graduates, Mexican firms face important handicaps in transforming basic knowledge into applied knowledge and innovation.

Overall, the analysis conducted in this paper has unearthed a series of factors which represent fundamental drivers of regional growth in Mexico and which go in the direction of recent policy changes. However, if Mexico is to unleash its full potential for innovation and economic growth, it will first have to address some of the major bottlenecks which still prevent it from making the most of policies which, regardless of how well designed they are, face considerable odds in delivering their objectives.

Acknowledgements

The authors are grateful to Dan Rickman, the editor of this paper, and to the anonymous reviewers for their useful comments and suggestions to an earlier version of the article. The authors acknowledge the generous financial support of the European Research Council under the European Union Seventh Framework Programme (FP7/2007-2013)/ERC grant agreement no 269868.

References

Aage, T. 2003. *Absorptive Capacity of Industrial Districts*. Department of Industrial Economics and Strategy, Copenhagen Business School.

Albaladejo, M. 2001. *Determinants and Policies to Foster the Competitiveness of SME clusters: Evidence from Latin America*. Working Paper (71), Queen Elizabeth House, London.

Anselin, L., A. Varga, and Z. Acs. 1997. Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics* 42(3): 422-448.

Audretsch, D., and M. Feldman. 1996. R&D spillovers and the geography of innovation and production. *American Economic Review* 86(3): 630-640.

______________________________ 2004. Knowledge Spillovers and the Geography of Innovation. In *Handbook of Urban and Regional Economics*, ed. J.V. Henderson, J-F. Thisse, 4: 2713-2739. Amsterdam: North-Holland.

Bush, V. 1945. *Science: the endless frontier*. North Stanford: Ayer.

Capdevielle, M., M. Casalet, and M. Cimoli. 2010. S*istema de innovación: el caso mexicano*, Proyecto: Instituciones y mercados, CEPAL/Sociedad Alemana de Cooperación Técnica (GTZ).

Capdevielle, M., and G. Dutrénit. 2012. Políticas para el desarrollo productivo y la innovación: desafío y oportunidad para la economía mexicana. In *Nueva estrategia de industrialización. Análisis estratégico para el desarrollo*, ed. J.L Calva, 7: 153–185. Mexico City: Consejo Nacional Universitario.

Capdevielle, M., and J. Flores. 2004*. La política tecnológica en México: enfoque teórico e implementación, Tecnología y finanzas en un marco de política económica sistémica*. México DF: UAM-X, CSH.

Carrión-i-Silvestre, J., and V. Germán-Soto. 2007. Stochastic convergence amongst Mexican states. *Regional Studies* 41(4):531-541.

Chiquiar, D. 2005.Why Mexico's income convergence broke down. *Journal of Development Economics* 77(1): 257-275.

Cimoli, M. 1998. *National System of Innovation: A Note on Technological Asymmetries and Catching-Up Perspectives*. Working Papers, International Institute for Applied Systems Analysis, IIASA, WP, Interim Report, IR-98-030/June.

__________ 2001. *Developing Innovation Systems: Mexico in a Global Context.* New York-London: Continuum-Pinter Publishers.

Cimoli, M., J.C Ferraz, and A. Primi. 2005. Science and technology policies in open economies: The case of Latin America and the Caribbean. *Serie Desarrollo Productivo* (165). Santiago de Chile: CEPAL.

Cooke, P., and K. Morgan. 1999. *The Associational Economy. Firms, Regions and Innovation.* New York: Oxford University Press.

CONACYT. 2011. *Informe General del Estado de la Ciencia, la Tecnología y la Innovación*. Mexico City: Consejo Nacional de Ciencia y Tecnología.

Crescenzi, R., A. Rodríguez-Pose, and M. Storper. 2007. The territorial dynamics of innovation: a Europe-United States comparative analysis. *Journal of Economic Geography* 7(6): 673-709.

_____________2012.The territorial dynamics of innovation in China and India. *Journal of Economic Geography* 12(5): 1055-1086.

Crescenzi, R., and A. Rodríguez-Pose. 2013. Regional knowledge creation in China, India and the US. Lessons for European regions. In *Territorial patterns of innovation: an inquiry on the knowledge economy in European regions*, ed., R. Capello and C. Lenzi, 263-298. London: Routledge.

De Fuentes, C., and G. Dutrénit. 2011. SMEs' absorptive capacities and large firms' knowledge spillovers: Micro evidence from Mexico. Centre for Innovation, Research and Competence in the Learning Economy. CIRCLE Electronic Working Papers, Lund University.

Dettori, B., E. Marrocu, and R. Paci. 2012. Total Factor Productivity, Intangible Assets and Spatial Dependence in the European Regions. *Regional Studies* 46(10): 1401-1416.

Dosi, G., K. Pavitt, and L. Soete. 1990. *The Economics of Technical Change and International Trade*. Brigthon, Wheatsheaf, and New York: New York University Press.

Dutrénit, G. 2009. *Sistemas regionales de innovación: un espacio para el desarrollo de las PYMES. El caso de la industria de maquinados industriales*. Mexico City: UAM/Textual S.A..

Esquivel, G. 1999. Convergencia regional en México, 1940-1995. *El Trimestre Económico* 66(287): 725-761.

Etzkowitz, H., and L. Leydesdorff. 2000. The dynamics of innovation: from National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations. *Research Policy* 29(2):109-123.

Fagerberg, J. 1988. Why Growth Rates Differ. In *Technical Change and Economic Theory*, ed., G. Dosi, C. Freeman, R. Nelson, G. Silverberg, L. Soete, 432–457. London: Pinter.

Foro Consultivo Científico y Tecnológico (FCCyT) 2006. *Diagnóstico de la política científica, tecnológica y de fomento a la innovación en México (2000-2006*). Mexico City: FCCYT.

Freeman C. 1979. The Determinants of Innovation: Market Demand, Technology and the Response to Social Problems. *Futures* 11(3): 206-215.

Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics* 10(1): 92-116.

___________1992. The Search for R&D Spillovers, *Scandinavian Journal of Economics* 94: 29-47.

Jaffe, A. 1986. Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value. *American Economic Review* 76(5): 984-1001.

Jaffe, A. 1989. Real effects of academic research. *American Economic Review* 79: 95-970.

Jaffe, A., M. Trajtenberg, and R. Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics* 108(3): 577-98.

Juan-Ramón, V.H., and L. Rivera-Batiz. 1996. *Regional growth in Mexico: 1970-1993,* IMF Working Paper. 96/92, Washington D.C.

Lederman, D., and W.F Maloney. 2003. R&D and Development. *Policy Research Working Paper Series* (3024), World Bank, Washington D.C.

____________________________2006. Innovation in Mexico: NAFTA is Not Enough. In *Global Intergration and Tech Transfer*, ed., B. Hoekman and B.S. Javorcik, 305-338. Basingstoke: Palgrave MacMillan.

Lemarchand, G. 2010. *Sistema Nacional de Ciencia y Tecnologia*. *Estudios y Documentos de Política científica de América Latina y el Caribe. Vol. 1*. Montevideo: UNESC.

Lemos, M. B., B. Campos, E. Biazi, and F. Santos. 2006. Technological capacity and catching up: the case of the Brazilian emerging metropolitan areas. *Revista de Economia Política* 26(101): 95-118.

Li, X. 2009. China's regional innovation capacity in transition: An empirical approach. *Research Policy*. 38(2): 338-357.

Lundvall, B. 1992. *National systems of innovation: Towards a theory of innovation and interactive learning*. London: Pinter.

Malecki, E. 1997. *Technology and economic development: The dynamics of local, regional and national competitiveness* (2nd edn). London: Addison Wesley Longman.

Moreno, R., R. Paci, and S. Usai. 2005. Spatial spillovers and innovation activity in European regions. *Environment and Planning A* 37(10): 1793-1812.

Navarro, M., J.J. Gibaja; Bilbao-Osorio B., and R. Aguado. 2009. Patterns of innovation in EU-25 regions: a typology and policy recommendations. *Environment and Planning C*: Government and Policy 27(5): 815–840.

Nelson, R., ed. 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

OECD. 2008. *OECD Science, Technology and Industry* Outlook. Paris: OECD.

OECD. 2009a. *Reviews of Innovation Policy: México*. Paris: OECD.

OECD. 2009b. *Reviews of Regional Innovation: 15 Mexican States*. Paris: OECD.

OECD/CEPAL. 2011. *Perspectivas Económicas de América Latina 2012. Transformación del Estado para el desarrollo*. Paris: OECD publishing.

Rodríguez–Pose, A. 1999. Innovation prone and innovation averse societies. Economic performance in Europe. *Growth and Change* 30(1): 75-105.

Rodríguez–Pose, A., and R. Crescenzi. 2008. Research and development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe. *Regional Studies* 42(1): 51-67.

Roodman, D. 2009. A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics* 71(1), 135–158.

Rózga, R. 2002. Hacia una geografía de la innovación en México. *Nueva Antropología* 18(60): 29-46.

Rózga, R. 2009. La dimensión local y regional de los procesos de innovación tecnológica. In *Sistemas regionales de innovación: un espacio para el desarrollo de las pymes*, G. Dutrénit, 20-32. Mexico City: UAM/ Textual S.A..

Sánchez-Reaza, J., and A. Rodríguez-Pose. 2002. The impact of trade liberalization on regional disparities in Mexico. *Growth and Change* 33(1):72-90.

Sanz Menéndez, L., L. Cruz Castro, C. Martínez, D. Malkin, J. Guinet, E. Banda, G. León, and J. Mulet. 2007. *Evaluación de la política de I+D e innovación de México (2001-2006)*. Mexico City: ADIAT.

Schumpeter, J. 1934. *The Theory of Economic Development*. Cambridge, Mass: Harvard University Press.

Usai, S. 2011. The geography of inventive activities in OECD regions. *Regional Studies* 45(6):711-731.

Varga, A. 2000. Local academic knowledge spillovers and the concentration of economic activity. *Journal of Regional Science* 40(2): 289–309.

Verspagen, B. 1991. A new empirical approach to catching up and falling behind. *Structural Change and Economic Dynamics* 2(2): 359-380.

Villavicencio, D. 2008. Los cambios recientes de la política de ciencia y tecnología en México: incentivos a la innovación. In *Generación y protección del conocimiento: propiedad intelectual, innovación y desarrollo económico*, ed., J.M. Martínez, 333-362. Mexico City: CEPAL.

Villavicencio, D. 2011. Retos para el diseño de políticas en México. In *Ciencia, tecnología e innovación para el desarrollo económico*, ed. A. Bracamonte, and O. Contreras, 28-43. Hermosillo: El Colegio de Sonora-COECYT.

Villavicencio, D. and P. López de Alba, eds. 2010. *Sistemas de Innovación en México: Regiones, Redes y Sectores*. Xochimilco: Plaza y Valdez.

Appendix 1.

Eigenanalysis of the correlation matrix: Social filter.

Eigenvalue	2.702	1.053	0.91	0.26	0.0735
Proportion	0.5404	0.2106	0.1822	0.0521	0.0147
Cumulative	0.5404	0.7511	0.9332	0.9853	1

Coefficients of the principal components analysis: Social filter.

Variable	CP1	CP2	CP3	CP4
Education of the population	**0.5830**	0.0192	-0.0376	0.4108
Education of the labour force	**0.5701**	-0.2090	0.0417	0.3856
Life-long learning	**0.2100**	0.4934	0.8216	-0.1906
Employment in agriculture	**-0.5307**	0.1432	0.2348	0.8015
Young population	**0.0965**	0.8319	-0.5163	0.1677

Appendix 2.

Source or the variables used in the empirical analysis

Variable	Source
$logy_{i,t}$-$logy_{i,t-1}$ $log(y_{i,t0})$ *ExtraGDPpc*	*Banco de Información Económica INEGI* http://www.inegi.org.mx/sistemas/bie/ http://www.inegi.org.mx/sistemas/olap/proyectos/bd/consulta.asp?p=14043&c=10683&s=est&cl=4#
R&D Spillovers *Extra Spillovers*	**Ramo 28 of the Mexican budget (higher education): unconditional transfers to states and municipalities:** federal and state budgets for higher education by state. *Dirección General de Planeación y Programación de la Secretaría de Educación Pública (Geneneral Directorate for Planning and Programming of the Public Education Secretariat)* http://dgpp.sep.gob.mx/presupuesto.html **Ramo 33 (higher education): federal conditional transfers:** Multiple Transfer Fund (FAM) targeting higher education by state. *Dirección General de Planeación y Programación de la Secretaría de Educación Pública (General Directorate for Planning and Programming of the Public Education Secretariat).* http://dgpp.sep.gob.mx/estadistica.html **Training of scientists and technology experts:** National System of Researchers and Institutional Consolidation (retainment and repatriation of Mexican researchers abroad) **Research funds:** Sectoral, mixed and institutional research funds for technological progress. **Fiscal stimulus for R&D and innovation and Avance (**Alto Valor Agregado en Negocios con Conocimiento, High Value-added in Knowledge-based Businesses) **programme**. *Sistema integrado de información sobre investigación científica, desarrollo tecnológico e innovación (integrated information system about scientific research, technological development and innovation).* http://www.siicyt.gob.mx/siicyt/cms/paginas/ActividadCONACYTporEstado.jsp?pSel
Accessibility index	*Secretaría de Comunicaciones y Transportes, Subsecretaria de Infraestructura, Dirección General de Desarrollo Carretero (Secretariat for Communications and Transport, Infrastructure Division, General Directorate for Road Development).* http://aplicaciones4.sct.gob.mx/sibuac_internet/ControllerUI?action=cmdEscogeRuta
Social Filter *ExtraSocial Filter*	*Encuesta Nacional de Empleo INEGI (National Labour Survey)* http://www.inegi.org.mx/est/contenidos/Proyectos/encuestas/hogares/historicas/ene/Default.aspx