PAPER

Title: Modes of innovation in emerging economies: The case of Mexico

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Abstract: *The combination of STI (Science, Technology, and Innovation) and DUI (Doing, Using, and Interacting) is regarded by the majority of studies in innovation modes, as the best strategy for firms in order to improve their innovation capacity. On the one hand, the STI mode is based in scientific and codified knowledge (i.e. R&D and scientifically trained personnel). On the other hand, the DUI mode is routed in experience and tacit knowledge (i.e. machinery purchase and quality management). This paper sheds some light in the interaction of these modes of innovation in the firms' strategy, particularly in an emerging market economy, and how it contributes to improve firms' innovation performance. The analysis covers 10 200 Mexican firms across the country accounting for 20 or more employees. The results of the logit regression suggest that a jointed STI and DUI innovation approach is better for technological innovation; including radical innovation. Contrariwise, only DUI is best for non-technological innovation. Finally, we show that in an emerging economy context, despite both STI and DUI are significant, the latter exerts more influence than STI for technological innovation.*

Keywords: *Modes of Innovation; STI; DUI; Emerging Economies; Mexico*

JEL codes: O31; O54

1. Introduction

The underlying literature of this paper is based on innovation systems research (Lundvall, 1992). The seminal work of Jensen, Johnson, Lorenz, and Lundvall (2007), demonstrates that firms combining STI and DUI modes of innovation, rather than utilising them individually, improve their innovative performance in terms of product innovation. The aforementioned has been confirmed by studies in Scandinavia (Aslesen, Isaksen, and Karlsen, 2012; Fitjar and Rodríguez-Pose, 2013; Isaksen and Karlsen, 2010), Canada (Amara, Landry, Becheikh, and Ouimet, 2008), Spain (González-Pernía, Parrilli, and Peña-Legazkue, 2015; Parrilli and Alcalde, 2016), China (Guo, Chen, and Jin, 2010), and Portugal (Nunes, Lopes, and Dias, 2013).

Noticeably, these studies have been conducted primarily in market economies (Apanasovich, 2014); therefore, little is known about innovation modes in other economic milieus. After a decade of Jensen and colleagues' work, the modes of innovation in emerging market economies, other than China, have not been a subject of investigation. By turning some attention to innovation in developing countries, researchers will help to develop a better understanding of the innovation process in emerging innovation systems, specifically in territories where firms are missing important scientific and technological capabilities. Those studies would help to avoid the commonly used 'one-size-fits-all' policy practice, which often overlooks science and technology asymmetries in firms and fail thus to improve their innovative capacity. Accordingly, this study is centred in testing the impact of the STI and DUI modes in the innovation performance of firms in an emerging economy setting, particularly: which mode of innovation is more effective to foster firm's innovative performance in an emerging economy context?

This paper is organised as follows. Section 2 examines the theory behind the innovation modes. In section 3, the methodological approach is discussed. Section 4 develops in the results of the econometric analysis. In the final section, concluding remarks are added; limitations of the study and policy implications are discussed.

2. Theoretical rationale

2.1 The modes of innovation

Scholars find themselves divided between a linear view and a systemic perspective of the innovation process, as the best way to generate innovative outputs (Fitjar and Rodríguez-Pose, 2013). In this sense, Jensen et al. (2007) developed a taxonomy that acknowledges the importance of science and technology but, at the same time, the relevance of experience and interactions in the innovation process. The authors measured the innovative patterns of Danish firms considering, on the one hand, those using explicit and codified scientific knowledge (STI) and, on the other, those relying in experienced-based tacit knowledge (DUI).

Particularly, the STI mode is based on the need for technical and scientific knowledge that encompasses both know-what and know-why types of knowledge (Lundvall and Johnson, 1994). Scientific knowledge must be necessarily expressed in explicit and codified terms. Applying scientific-based knowledge yields innovation in the form of new products and processes, these also tend to be more radical innovations (Asheim and Coenen, 2006). In addition, high levels of scientifically trained labour force are prone to increase assimilation of knowledge in organisations (Cohen and Levinthal, 1989). Therefore, people with postgraduate and research degrees (e.g. Master's and PhD degrees) are featured within the STI mode of innovation (Apanasovich, 2016; Isaksen and Karlsen, 2010; Jensen et al., 2007). Production of scientific-based knowledge is addressed in specialised research organisations such as research centres, R&D departments, and universities. Firms that depend on this type of knowledge are likely to interact with those scientific organisations (Apanasovich, 2016; Fitjar and Rodríguez-Pose, 2013; Parrilli and Elola, 2012). Finally, STI's conceptual driver is the linear model of innovation. That means, technological knowledge emerging from scientific organisations and being subsequently transferred to firms in order to be commercialised (Isaksen and Karlsen, 2010).

In comparison, the DUI mode of innovation uses tacit and experience-based knowledge to generate innovative outputs (Asheim and Coenen, 2006; Aslesen et al., 2012). Learning-by-doing explains that repeated operations in the workplace allow experimentation of new ways of organising work; therefore, reaching efficiency and increasing performance (Amara et al., 2008; Arrow, 1962). Learning-by-using reflects the knowledge obtained from the iterative design of the products, as a result of user-experience feedback (Rosenberg, 1982). Because of its nature, tacit knowledge is highly localised (Jensen et al., 2007). Most of it must be learned through direct observation and communication, followed by further assimilation and practice. Similarly, interaction with clients, suppliers, and competitors also contributes to increasing experience-based knowledge (Apanasovich, 2016; González-Pernía et al., 2015; Parrilli and Alcalde, 2016). In opposition to STI, DUI is related to incremental innovation. That is, the innovation outputs are observed as the modification of products and processes (Asheim and Coenen, 2006). In addition, recent studies have linked the DUI mode with the enhancement of organisational innovations that are 'initially developed through processes of trial-and-error and learning-by-doing within the innovating firms' (Apanasovich, Alcalde, and Parrilli, 2016, p. 3). The benefits of organisational innovation could be embedded in the ability of firms to learn, use, and exchange new knowledge and technologies (OECD, 2005).

2.2 The emerging economy context

In the last decade, the importance of the economic output of emerging economies has grown. This growth has been fuelled by the deregulation of their markets, allowing thus privatization of companies and entrance of foreign direct investment (FDI).

The economic growth in developing countries tends to be factor-driven or, in some cases, efficiency-driven rather than innovation-driven (Floricel and Miller, 2003; Voeten, 2017). In this sense, emerging economies struggle to create value from domestic innovations. It is estimated that innovation in factor-driven economies accounts only to 5% of the economic activity, whereas in innovation-driven economies it contributes with 30% (Ács and Szerb, 2009). Similarly, science-based innovation activities are underinvested. Firms might avoid the expensive and risky process of creating new knowledge (Szirmai, Naudé, and Goedhuys, 2011). Instead, they are inclined to absorb and disseminate technology developed somewhere else, resulting in a more incremental type of innovations (OECD, 2005) or, in other cases, producing innovations lacking relevant novelty, referred as 'imitative' innovations (Chaminade and De Fuentes, 2015; Szirmai et al., 2011). Feria and Hidalgo (2011) argue that this strategy might not be good for firms in the long run. Dependency on foreign technology, without the proper support of domestic scientific capabilities, might turn organisations unable to develop their own technologies. Inversely, firms with enough scientific and technological capabilities, are expected to gradually increase the novelty of their innovations as they move closer to the technological frontier (Chen, 2007).

Relatively recently, Mexico's economy undertook an important economic restructuration, moving from commodity-oriented to service and manufacturing-oriented (Rullán and Casanova, 2015). After the creation of the North American Free Trade Agreement (NAFTA) in the 1990s, the country has been targeted by multinational companies (MNCs) to locate their production. This sparked an uneven industrialisation in the country, benefiting mainly the northern regions because of their proximity to larger markets, such as the United States and Canada. Furthermore, NAFTA's efforts in terms of knowledge and technology exchange are rather deficient, as a result of economic and cultural asymmetries amongst countries (Feria and Hidalgo, 2008). Additionally, given the limited years of experience, Mexican firms are yet perfecting skills and accumulating know-how of their trades. Thus, making it difficult for them to focus in advanced science-based knowledge. In this vein, the Mexican private sector barely invests in R&D and lacks collaborations with knowledge agents (e.g. universities), leaving almost all efforts in the hands of government through publicly funded initiatives (Rullán and Casanova, 2015).

Similarly, Mexico's pool of talent in terms of research skills is limited. Although the number of engineers and science graduates is high (Rullán and Casanova, 2015), weak research skills in higher education institutions impede proper training of human capital devoted to research. This diminishes an important determinant for innovation, such as highly skilled human capital, and reduces opportunities for scientific knowledge to be disseminated within organisations. Codified knowledge requires people with specific knowledge to decode it. Lacking highly educated human capital in firms might slow the rate of technological change. For all these reasons, we expect that Mexican companies will lack strong STI components in their innovation activities. Contrariwise, is more likely that the DUI mode of innovation will play an important role for firms to achieve innovation.

2.3. Hypotheses

In this article, we follow the latest (3rd) edition of the Oslo Manual to analyse the impact of innovation modes on innovation output. This considers innovation as 'technological' for new products or manufacturing processes, and 'non-technological' for marketing and organisational innovations. This technical classification is important for our discussion, as non-technological innovation forms are more likely to require lower levels of scientific and technological focus and expenditure. These 'softer' innovation forms are likely to rely on different types of human capital, such as skilled production or human resource managers, marketing experts, and well-connected distributors, amongst others.

Most of the studies have concluded that combining STI and DUI modes is the most effective strategy to improve innovation performance regarding technological outputs (Apanasovich et al., 2016; Chen and Guo, 2010; González-Pernía et al., 2015; Guo et al., 2010; Isaksen and Nilsson, 2013; Jensen et al., 2007; Parrilli and Alcalde, 2016). It is argued that scientific and codified knowledge are the main sources of technological innovation. Although this claim is widely supported, it is not possible to rule experience-based learning and tacit knowledge out of the equation. For example, tacit knowledge is present when laboratory experimentation is conducted; researchers possess and further develop know-how that allows them to execute certain tasks. In addition, research personnel must have prior related knowledge to fully understand the information in handbooks and other technical documents. Firms tend to combine science and technology learning with on-the-job learning and users' feedback to boost innovation (Jensen et al., 2007). Thus, technological innovation, especially in emergent economies, is expected to use a context-specific combination of STI and DUI modes of innovation (Lundvall, 2007). Therefore,

H1: In the Mexican context, the combination of STI and DUI modes of innovations is expected to produce better results in technological innovation (product and process) than STI or DUI modes alone.

Secondly, some authors agree that technology absorption and competence-building are the main drivers for innovation in developing economies (Chaminade, Lundvall, Vang, and Joseph, 2009; Sánchez, 2008; Viotti, 2002). Therefore, a stronger presence of DUI components might foster technological development in firms. Constantino and Lara (2000) emphasise that firms can improve the efficiency of their operations through the knowledge embodied in new machinery and equipment. Consequently, it is likely to observe more investment destined to purchase new technology than any other activity related to innovation in emerging economies. For instance, in Mexico and Brazil, acquisition of machinery and equipment account for more than 50% of their expenditures in innovation activities; inversely, expenditure in R&D tend to be considerably lower (Sánchez, 2008). The opposite situation is observed in industrialised economies where R&D constitute most of the innovation expenditure (Bloch and López-Bassols, 2009). In this vein,

H2: In the Mexican context, the DUI mode of innovation is expected to exert greater influence on technological innovation than the STI mode.

Thirdly, as argued before, organisational and marketing innovations make use of low levels of scientific and technological knowledge (Parrilli and Alcalde, 2016). These non-technological innovation outputs are likely to rely on different types of human capital, such as skilled production or human resource managers, marketing experts, and well-connected distributors, amongst others. Echoing the initial definition of Jensen et al. (2007, p. 13), Apanasovich et al. (2016) claimed, with evidence from Belarusian firms, that non-technological innovations are a likely result of a strong emphasis in DUI strategies. They concluded that Belarusian SMEs might acquire advanced managerial techniques and practices through interaction with internal and external partners; thus, leading to produce organisational innovations. From that point of view, we believe that local firms' interactions with MNCs, especially in developing countries, could be beneficial for the adoption of non-technological related practices (e.g. managerial practices, training, and access to markets). Although the interactions with MNCs, through FDI, are widely accepted as an important vehicle for technology dissemination in the developing world (Borensztein, De Gregorio, and Lee, 1998; Fu, Pietrobelli, and Soete, 2011), these are also relevant for transferring managerial and organisational knowledge, such as advanced skills and market information (Fu, 2012; Noorbakhsh, Paloni, and Youssef, 2001). In that vein, in the mid-90s, after restrictions in different economic sectors were lifted, Mexico's protected economy gradually shifted towards a highly open market for foreign investment. As a result, FDI in Mexico has reached important thresholds. In 2016, this investment was around $27 447 million, representing 2.63% of the country's GDP (OECD, 2018). Hence,

H3: In the Mexican context, the combination of STI and DUI modes of innovations is expected to produce better results in non-technological innovation (organisational and marketing) than STI or DUI modes alone.

H4: In the Mexican context, the DUI mode of innovation is expected to produce greater results on non-technological innovation (organisational and marketing) than the STI mode.

Finally, we aim to test whether the combination of STI and DUI modes exert influence in the degree of novelty of innovations. Radical innovation has a significant impact on the markets, changing them or creating new (OECD, 2005). We understand it as 'new or significantly improved products (goods or services)… which represent a novelty not only for the company but also for the market in which the firm operates' (Parrilli and Alcalde, 2016, p. 750). This type of innovation may benefit from scientific and technological activities carried out by organisations; it may result from the STI mode of innovation (Isaksen and Karlsen, 2012; Isaksen and Nilsson, 2013). Nevertheless, it is argued that some components closely related to the DUI mode of innovation (e.g. creativeness and a flexible organisation), largely contribute to radical forms of innovation (Lorenz, 2012; OECD, 2005). In addition, some studies (Apanasovich et al., 2016; Parrilli and Alcalde, 2016) provide empirical evidence that a combined STI-DUI strategy is highly correlated and more significant than STI or DUI modes used alone. Thus,

H5: In the Mexican context, the combination of STI and DUI modes of innovations is expected to produce better results in radical innovation (new or significantly improved products introduced to the market, national, and international) innovation than STI or DUI modes alone.

3. Methodology

3.1 Sample and methodological approach

We used Mexican data from the 2012 Research and Technological Development Survey (ESIDET) compiled by the National Institute of Statistics and Geography (INEGI), in cooperation with the National Council of Science and Technology (CONACYT). The ESIDET focuses on firms' financial and human resources destined for research, technological development, and innovation activities, as well as in factors that both foster and hinder innovation. The conceptual approach has been designed following well-recognised guidelines from OECD's Manuals: Frascati, Canberra, and Oslo (INEGI, 2014). The ESIDET, in its 2012 edition, contains information from 2010 to

2011 of 10 200 firms across 32 states in Mexico. The sample comprises firms with 20 or more employees, whether they reported innovation or not.

3.2 Dependent variables

We categorised innovation outcomes according to the Oslo Manual (OECD, 2005), regarding their technological dimension. Technological innovation refers to the introduction of product innovation, as new or significantly improved goods and services, and/or process innovation, as new or significantly improved production, delivery method, techniques, equipment, and software. Thus, TECHINNO is a dichotomous categorical variable that represents whether a firm introduced technological innovation to the market (coded 0 if no and 1 if yes). The second dependent variable, non-technological innovation embodies, firstly, marketing innovation, understood as new marketing methods involving product design or packaging and product placement, promotion, or pricing policies. Secondly, organisational innovation, as new organisational methods in the firm's business practices, organisation, or commercial relations. The dichotomous categorical variable NONTECH refers to whether the firm introduced non-technological innovation to the market. Finally, we employed radical innovation, as a dependent variable to measure the effect of the innovation modes in the innovation output. In this sense, the variable RADINNO describes whether the firm introduced new or significantly improved products to the market at national and international level.

3.3 Independent variables

For this study, several indicators were used to represent the different modes of innovation. Indicators for STI are purely related to the creation and use of scientific knowledge. We used 'R&D expenditure' to capture whether the firm reported expenditure in in-house R&D and external R&D projects. The investment in R&D activities is a major indicator for firms relying on new knowledge creation to position themselves in the frontier of knowledge (Parrilli and Alcalde, 2016). Similarly, the indicator 'R&D departments' informs whether the company hosted a formal in-house R&D department (Apanasovich et al., 2016; Parrilli and Alcalde, 2016). When a firm holds full-time R&D personnel, it reflects a strong capacity to assimilate knowledge (Cohen and Levinthal, 1989; Veugelers, 1997). Therefore, 'researchers', which reflects highly trained personnel, indicates whether the firm reported researchers and technologists working in in-house R&D activities.

The DUI mode of innovation combines a heavy practice-oriented and interactive approach to learning with an experienced-based knowledge. We used ‘market expenditure’ as a proxy for learning-by-doing (Amara et al., 2008). This indicator explains whether the firm reported expenditure in marketing related to technological innovation (i.e. market research, feasibility studies, adaptation of the product in different markets, and advertising). Learning-by-using is fostered by the acquisition and adaptation of new technologies and machinery (Apanasovich et al., 2016; Ritter and Gemüden, 2004). Therefore, ‘technological preparation’ measures whether a firm reported expenditures on technological preparation for production, including design, engineering of machinery and products, technical support services, and IT activities. Finally, to measure learning-by-interacting, we considered both internal and external sources of interaction (Aslesen et al., 2012; Isaksen and Karlsen, 2010). To measure internal learning-by-interacting we used the indicator ‘training systems’. This shows whether training activities take place within the firm, in the form of investments for technical assistance and in training related to innovation activities. Labour force skills and knowledge becomes essential to develop innovations (Amara et al., 2008; Laursen and Foss, 2003; Lorenz and Lundvall, 2011; Romijn and Albaladejo, 2002). For external learning-by-interacting, we selected ‘interaction and cooperation’ to determine whether the firm reported interaction with same-group companies, competitors, customers, suppliers, and other local and foreign firms. The actors along the supply chain may provide important knowledge about technologies (OECD, 1997), markets (Alcalde Heras, 2014; Apanasovich, Alcalde, and Parrilli, 2017), and technical assistance and knowledge (Amara et al., 2008).

Additionally, this study introduces new indicators for measuring the DUI mode. Firstly, a proxy for know-how has been added to capture whether the firm is generating this type of knowledge (Guo et al., 2010). Consequently, ‘know-how’ refers to whether firm reported sales for know-how disclosure at national and international markets. Secondly, we used quality management as a practice closely related to the DUI mode of innovation. Implementation of best practices and quality assurance foster innovations in a broad sense, from incremental to radical innovation (Kim, Kumar, and Kumar, 2012).

For instance, a regular codification of knowledge might help to elaborate best practices manuals and databases; thus, improving the technification of the processes. Hence, 'quality control' refers to whether the firm makes use of high-performance quality control practices. Finally, Chaminade et al, (2009) pointed out that developing countries would benefit rather from skilled technicians. Technicians might not directly relate to the creation of scientific knowledge; instead, they might be able to perform activities using certain components of it, internalising codified knowledge (Ikojiro Nonaka, 1994). Technicians are responsible for building and further develop know-how from embodied knowledge in machinery, and from implicit knowledge facilitated through hired technical assistance. Moreover, this group can socialise (Nonaka, 1994; Nonaka, Takeuchi, and Umemoto, 1996) their experience amongst companies' labour force, through on-the-job training and internal technical assistance. Therefore, 'technicians' refers to whether the firm reported technicians and personnel related to technical support working in in-house R&D activities.

The independent variables have been transformed from categorical to ordinal scale aiming to capture a better understanding of the intensity with which firms deploy their STI and DUI strategies. We grouped the indicators into three levels of intensity for either mode of innovation: 0 (low), 1 (intermediate) and 2 (high). We added the values of the indicators for STI on the one hand, and for DUI, on the other. We calculated the mean of non-zero cases for both STI and DUI. The mean values obtained were used as a threshold for the creation of the scale. Therefore, if the sum of the indicators for STI or DUI resulted equal to zero, the variable accounting STI or DUI would be fixed with low intensity (0). The intermediate value (1) would be assigned if the sum was higher than zero but lower or equal to the mean. Finally, the high valuation (2) was given if the sum was higher than the mean.

3.4 Control variables

Firstly, firm's size (SIZE) is measured in terms of the natural logarithm of the income per employee. Secondly, 'international market' (INTMARKT) refers to whether the firm reported sales coming from outside their own country (Filippetti, Frenz, and Ietto-Gillie, 2011).

4. Econometric results

Because of the binary nature of the dependent variables, we ran a logistic regression to test the different hypotheses (Hosmer and Lemeshow, 2000). The statistics reported in table 1, provide an overall picture of the sample.

Table 1. Descriptive statistics. Source: own elaboration on the basis of SNIEG (2012).

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
TECHINNO	10 200	0.077	0.267	0	1
NONTECH	10 200	0.032	0.178	0	1
RADINNO	10 200	0.059	0.236	0	1
STI	10 200	0.133	0.463	0	2
DUI	10 200	1.175	0.591	0	2
SIZE	10 200	4.679	1.602	-0.693	11.844
INTMARK	10 200	0.284	0.451	0	1

Table 2 shows the distributions of firms using different intensities of both STI and DUI modes of innovation. Most firms display low levels of STI, around 91.65%. This indicates a poorly supported R&D component in Mexican firms. Conversely, almost 90% of firms present medium or high levels of DUI; thus, showing a great emphasis of Mexican firms in practice-oriented and experiential knowledge development.

Table 2. Distribution of firms adopting different intensities of the modes of innovation. Source: own elaboration on the basis of SNIEG (2012).

STI/DUI	Low	Medium	High	Total of firms
Low	1042 (10.22%)	6212 (60.90%)	2094 (20.53%)	9348 (91.65%)
Medium	3 (0.03%)	69 (0.68%)	273 (2.68%)	345 (3.38%)
High	0 (0.00%)	40 (0.39%)	467 (4.58%)	507 (4.97%)
Total firms	1045 (10.25%)	6321 (61.79%)	2834 (27.78%)	10 200 (100.00%)

4.1 Technological innovation

Table 3 contains the parameter estimates for the regression analysis. It can be observed that both intermediate and high levels of STI and DUI, exhibit strong and positive correlation with technological innovation. The latter to a greater extent than the former. As a result, the coefficients and significance levels suggest that the combination of STI and DUI modes perform better in terms of technological innovation than their utilisation in separate ways.

Table 3. Parameter estimates. Source: own elaboration on the basis of SNIEG (2012).

Dependent variable	TECHINNO		C.I (95%)	
Independent variables	Estimate	S.E.	Lower bound	Upper bound
STI=0	0a	-	-	-
STI=1	1.938***	0.128	1.685	2.190
STI=2	1.995***	0.110	1.779	2.123
DUI=0	0a	-	-	-
DUI=1	1.398***	0.417	0.579	2.216
DUI=2	3.195***	0.415	2.380	4.010
SIZE	—0.073***	0.027	—0.128	—0.018
INTMARKT	0.259***	0.091	0.079	0.439
No. obs.			10 200	
Log Likelihood			—2038.655	
Chi-square			1496.53***	

0a-reference level.

Level of significance: ****p≤0.01, **p≤0.05, *p≤0.1*

To confirm the first hypothesis, we computed the predictive margins (see Williams, 2012), accounting for interactions of different intensities (low, intermediate, high) of STI and DUI. Margins help to further interpret results beyond coefficients and significance levels, resulted from estimation models (Williams, 2012). Margins are calculated based on a fitted model; therefore, the base for our estimations was the logit model. Table 4 shows these predicted probabilities.

Table 4. Predicted probabilities for technological innovation. Source: own elaboration on the basis of SNIEG (2012).

STI	DUI	TECHINNO
0	0	0.005
	1	0.022
	2	0.122
1	0	0.038
	1	0.138
	2	0.490
2	0	0.040
	1	0.145
	2	0.504

If the combination of STI and DUI displays high levels of intensity (both have a value of 2), the probability of obtaining technological innovation raises to 50.45%. This probability is higher than any other case; consequently, supporting H1. Therefore, our study is aligned with the findings of Jensen et al. (2007) in Denmark and other developed market economies (Aslesen et al., 2012; Isaksen and Karlsen, 2010; Isaksen and Nilsson, 2013; Nunes et al., 2013; Parrilli and Alcalde, 2016), and transition economies (Apanasovich et al., 2016). Additionally, whenever DUI is present in intermediate and high levels (with STI at low, intermediate, or high), an increase in the probabilities to obtain technological innovation is observed. For example, if the firm shows an intermediate level (1) of STI and a high level (2) of DUI, the probability rises to 49.01%. DUI mode of innovation seems to exert greater influence over the technological innovation outputs, compared to its STI counterpart. In conclusion, the results obtained are aligned with our second hypothesis.

The outcomes obtained differ from other studies (Parrilli and Alcalde, 2016), where STI resulted more important for technological innovation. The explanation of this might concern contextual specificities affecting firms' approaches towards innovation. In Mexico, investments in science-based innovation activities (e.g. internal/external R&D projects) and researchers employed in the private sector, tend to be low. Instead, firms would engage in learning-by-using processes by purchasing new machinery from industrialised countries. They expect to improve their productivity and build know-how, using new technologies that contribute to increasing their technological knowledge base. Also, they recur to technology transfer services when aiming to leap into more advanced technologies. Additionally, firms may invest in process management, looking for the implementation of best practices and ensuring the quality of their products. These practices provide a base for learning and promote innovation. Likewise, is more likely that companies exercise learning-by-interacting through informal relationships, as opposed to formal ones in the STI mode. Important internal interactions might result from on-the-job-training and technicians socialising knowledge. Collaboration with partners along the supply chain, including users, may allow them to collect new business knowledge. These strategies could result more feasible in terms of financial resources, but contributing, in part, to a weak STI component in their innovation strategy.

4.2 Non-technological innovation

The results for non-technological innovation are presented in table 5. Our fourth hypothesis, where DUI is expected to produce larger influence over non-technological innovation (compared to the STI mode), is well supported. The coefficients for STI do not show any level of statistical significance. This may be related to the incipient use of advanced technology-related techniques, in the attempts to produce market and organisational innovations. Mexican firms may follow more traditional methods. In this sense, learning processes promoted by the DUI mode are more dominant. Routinary activities supported by technical assistance and on-the-job training, spark learning-by-doing. This type of learning helps firms to develop new methods for organising work and introduces changes in their organisational structure, improving thus their productivity; and finally, leads them to become more creative organisations. Additionally, when firms perform market and feasibility studies, they reach users' insights, which are useful in providing tailored products and services, adapted sales strategies, and convenient delivery methods. On the other hand, under the same reasoning, the H3 is rejected because the STI mode does not contribute to reaching greater levels of non-technological innovation when combined with DUI.

Table 5. Parameter estimates. Source: own elaboration on the basis of SNIEG (2012).

Dependent variable	NONTECH		C.I (95%)	
Independent variables	Estimate	S.E.	Lower bound	Upper bound

STI=0	0a	-	-	-
STI=1	0.030	0.256	—0.269	0.654
STI=2	—0.316	0.245	—0.732	0.190
DUI=0	0a	-	-	-
DUI=1	1.318***	0.363	0.634	2.057
DUI=2	2.211***	0.368	1.541	2.985
SIZE	—0.022	0.037	—0.092	0.050
INTMARKT	—0.412***	0.136	—0.664	—0.142
No. obs.			10 200	
Log Likelihood			—1432.603	
Chi-square			89.16***	

0a-reference level

Level of significance: ****p≤0.01, **p≤0.05, *p≤0.1*

4.3 Radical innovation

Table 6 shows the estimates for radical innovation. Radical innovation is observed to be significantly influenced by both STI and DUI modes of innovation. Table 7 shows that combinations of STI and DUI, with intermediate (1) or high (2) levels of intensity, are more likely to produce radical innovation. Accordingly, we can confirm H5. In Mexico, most of the radical innovations are new to the market at a national level, rather than at international level. Most firms do not rely on their limited R&D capabilities to develop cutting-edge technologies, matching or surpassing those from abroad. Scientific and technological capabilities are complemented with licensing of technologies and patents developed somewhere else; hence, allowing companies to be first movers in a local market. This may explain to a certain extent, why STI underperforms compared to DUI for radical innovation.

Table 6. Parameter estimates. Source: own elaboration on the basis of SNIEG (2012).

Dependent variable	RADINNO		C.I (95%)	
Independent variables	Estimate	S.E.	Lower bound	Upper bound
STI=0	0a	-	-	-
STI=1	1.931***	0.137	1.663	2.200
STI=2	2.012***	0.117	1.781	2.243
DUI=0	0a	-	-	-

DUI=1	1.423***	0.510	0.422	2.424
DUI=2	3.227***	0.507	2.231	4.222
SIZE	—0.088***	0.030	—0.148	—0.0276
INTMARKT	0.327***	0.102	0.127	0.527
No. obs.		10 200		
Log Likelihood		—1680.471		
Chi-square		1230.59***		

0a-reference level

Level of significance: ****p≤0.01, **p≤0.05, *p≤0.1*

Table 7. Predicted probabilities for radical innovation. Source: own elaboration on the basis of SNIEG (2012).

STI	DUI	RADINNO
0	0	0.003
	1	0.015
	2	0.087
1	0	0.025
	1	0.098
	2	0.396
2	0	0.027
	1	0.105
	2	0.415

5. Concluding remarks

This work contributes to the literature by broadening the milieus in which modes of innovation research is conducted. We consider that emerging market economy context is too important to be overlooked in this research field. By analysing these firms' innovative behaviour, we shed some light in the innovation black box, especially, in a country where the innovation systems are incipient, and flows of knowledge, money, and people are precarious. By performing an empirical analysis of the modes of innovation in this new setting, we add robustness by confirming the results obtained by Jensen et al. (2007). Additionally, we enrich the measurement of the DUI mode by adding a new set of indicators. We included variables accounting for know-how creation within firms, quality control practices, and presence of technicians in the labour force.

We found that Mexican firms combining STI and DUI modes are better in producing technological innovation. This also applies to radical innovations. However, DUI is more important than STI in both kinds of outputs. Unlike in advanced market economies, the knowledge base of most of the firms in developing countries, predominantly sourced in on-the-job-learning, adaptation of technologies, and interactions with non-scientific partners, induce a stronger influence of learning-by-doing, learning-by-using, and learning-by-interacting processes. Consequently, firms produce technological innovations; however, most of them do not reach a great degree of radicalness, although some of them do. On the other hand, the same joint strategy fails to increase the creation of non-technological innovation. STI is not relevant in this case, which is not surprising. As indicated by the literature, most organisational and marketing innovations do not make use of advanced scientific and technological inputs.

This study is not absent of limitations. The main restraint is the availability of longitudinal data. In that sense, this paper must be understood as a first approach to the analysis of modes of innovation in emerging market economies. The literature on innovation in developing economies and emerging innovation systems put special attention on the factors that hinder innovation in companies. Therefore, advising not to focus on innovation outputs, but rather understand the innovation process 'and emphasize how capabilities, efforts and results are dealt with' (OECD, 2005, p. 139). The aim of this type of studies is to frame the innovation patterns present in the firm base; consequently, providing reliable information for both managers and policymakers to foster innovation activities in the system.

In terms of policy implications, innovation policy in emerging market economies has been predominantly science-driven and technology-driven, pushing forward practices that in many cases are not aligned with the scientific and technological endowments of the very same firms they target. Many scholars agree that firms are able to benefit and even innovate from of informal structures and relationships (Voeten, 2017), sharing and accumulating tacit knowledge, which is embodied in people. Hence, policymakers should acknowledge the importance of the DUI type of learning for innovation and introduce mechanisms for DUI dynamics to be more present in policies. Policies borrowed from advanced economies might not work the same way in emerging economies, even turning counterproductive. Hence, policymakers should engage in a thorough design of tailor-made policies, considering unique cultural, economic, and organisational specificities.

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