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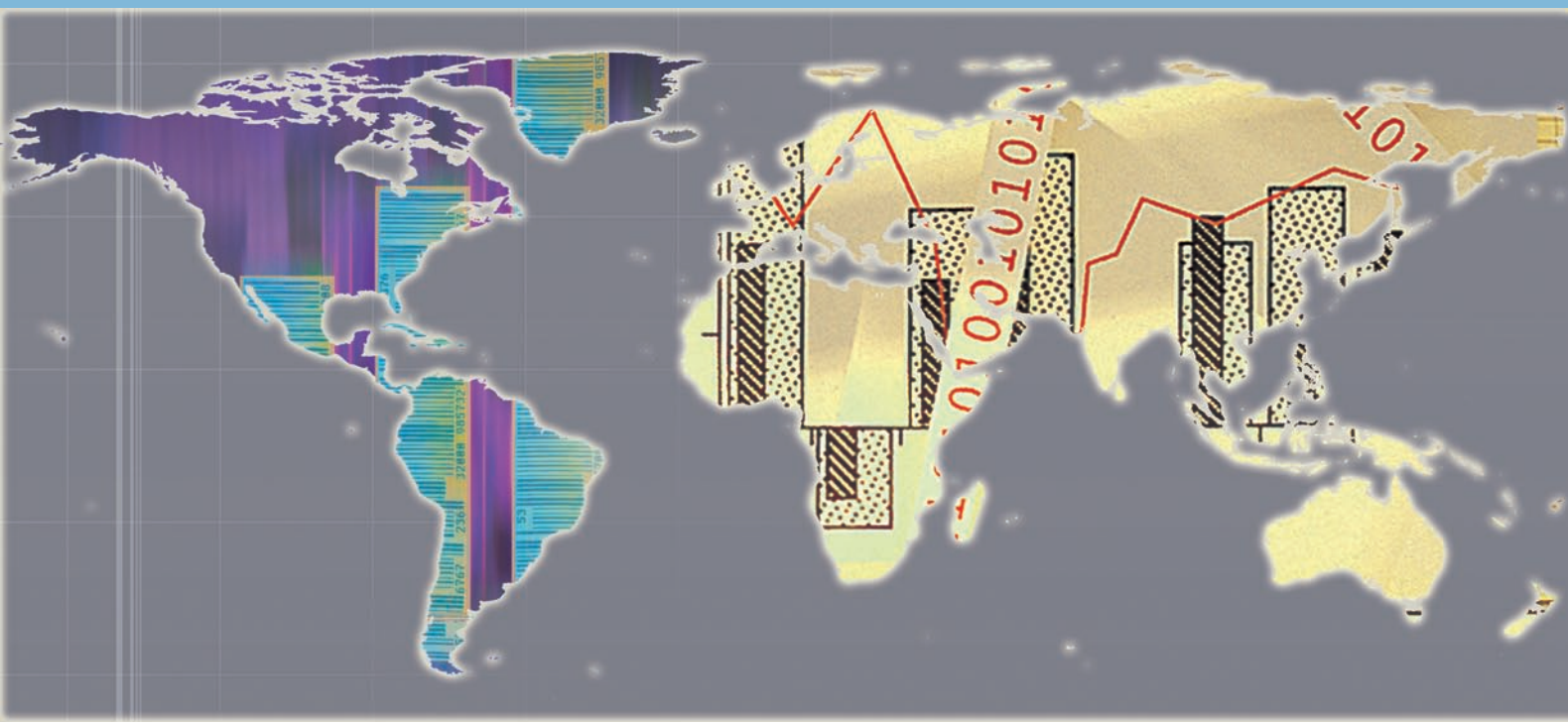

Human Resource Management and Learning based on in-house R&D:

The Pharmaceutical Industry in Mexico

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Human Resource Management and Learning based on in-house R&D: The Pharmaceutical Industry in Mexico

Fernando Santiago
PhD Candidate
UNU-Merit

Ludovico Alcorta
Director
Research and Statistics Branch
Programme Coordination and Field Operations Division
UNIDO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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Abstract

This paper investigates the influence of human resource management practices on the likelihood that a firm performs in-house Research and Development (R&D). The latter is broadly interpreted as learning—a mechanism to promote the absorptive capacity and supporting technology capability-building in latecomer firms. The use of distinct definitions of R&D implies different knowledge requirements that firms need to fulfil in order to innovate. The analysis assumes that firms can choose between two learning strategies: they may exploit existing knowledge, or perform more complex explorations and acquire new knowledge. Different knowledge requirements, in turn, underpin distinct R&D outcomes with varying degrees of novelty, at least for the firm. Unlike the recurrent interest in recent catching-up experiences of countries, such as India, findings in this paper are supported with evidence from the pharmaceutical industry in Mexico. The analysis reveals some linkages between management practices and learning at firm level. Such influence increases with the novelty of the knowledge required by the firm. Learning to improve or enhance generic drugs is somewhat more demanding than imitative R&D.

Keywords: R&D, learning and innovation; human resource management; Mexico; pharmaceuticals

JEL codes: O32, O54, L65

1. Introduction

Literature on the linkages between human resource management practices and innovation performance at firm level is increasing. Scholars have addressed the extent to which sets of new and dynamic work practices influence innovation (OECD, 1998; Barton and Delbridge, 2001), the effects of distinct forms of labour flexibility on innovation performance (Michie and Sheehan, 1999, 2003), and even the complementary relationships that exist between management practices underpinning innovation (Delery, 1998; Laursen and Foss, 2003). Research on the organization and learning of agents involved in the development of new products is likewise increasing (Lund, 2004a and b). Studies based on evidence on developed countries (Lorenz and Wilkinson, 2003; Arundel et al., 2007), investigate how the influence of management practices varies depending on the technological dynamics of different industries (Laursen, 2002; Laursen and Foss, 2003; Terziovski and Morgan, 2006). These strands of literature document the positive relationships between management practices and innovation performance at firm level. What is still missing, however, is a better understanding of mechanisms to explain such relationships (Laursen and Foss, 2003; Lorenz and Wilkinson, 2003), and a consistent theory on what Delery (1998) terms the transmission mechanism from management to innovation performance.

Alongside the ongoing debate on how and why management practices underpin innovation, innovation scholars are introduced into the more extensive debate on how and why such practices generally influence firms' performance. According to Boseli et al. (2005) and Combs et al. (2006) huge challenges stem from the diversity in the number and possible definitions of indicators on management practices, together with the distinct multidisciplinary approaches to research. Arguably, research on management practices and innovation need to be fine-tuned, specifically in the way the issues at stake are approached. Lorenz and Wilkinson (2003) assert that researchers frequently assume linear relationships—from adoption of specific sets of management practices to innovation—leaving little room for more heterogeneous organizational strategies within single industries (Delery, 1998; Hemmert and Oberländer, 1998). Moreover, it is customary to look at innovation outcomes, products/processes, and their degrees of novelty, radical/incremental. Equally understimated is the study of some latent processes associated with the organization of people involved in innovation. It therefore seems pertinent to look at the cumulative learning processes supporting the development of innovation capabilities of individuals and, ultimately, organizations (Cohen and Levinthal, 1989, 1990; March, 1991; Grant, 1996). Accordingly, management practices become mechanisms that influence learning activities within organizations (Wright et al., 2001).

Focusing attention on the learning processes would bestow research greater relevance from a development perspective. White (2002) emphasizes the importance of understanding how management practices contribute to research and other technological capabilities, particularly in developing countries. Specifically, accumulated capacities can be lost because of inadequate or poor management of people. Similarly, research on firms in developing countries necessitates a careful understanding of the nature of the innovation and learning activities they engage in.

This paper attempts to contribute to existing literature on human resource management practices and learning in the context of developing countries. Specifically, empirical evidence here refers to pharmaceutical firms in Mexico. The paper proceeds as follows: Section 1 discusses the literature linking management practices, learning and catching-up processes of in latecomer firms. Based on notions of knowledge exploration and exploitation, the paper investigates the influence of management practices on the likelihood that a firm engages in in-house Research and Development (R&D). The latter is broadly interpreted as learning and is distinguished according to several objectives pursued by the firm,[1] irrespective of whether they relate to improved or new products, or process innovations. Against this background, section 2 characterizes a few management practices that are expected to enhance individuals', and consequently organizational, learning. The discussion proposes the testing of several hypotheses during the empirical analysis. Data is presented in section 3, and defines variables and the corresponding research strategy. Results are provided in section 4, while a discussion of the same is presented in section 5. Section 6 concludes.

2. Management practices, learning and R&D in latecomer firms

2.1. Literature review

Empirical literature documents the contribution that organizational practices, relating to R&D and innovation, have made toward the catching-up processes of latecomer firms. Successful firms have evolved as learners by assimilating and tapping existing technologies, and eventually developing their capacity to generate their own technologies (Hobday et al., 2004). Catching-up involves continuous efforts to mobilize and organize resources that firms have at hand. In the case of Japan, for example, Odagiri (1998) highlighted the importance of building the absorptive capabilities, making efforts in training and entrepreneurship and gaining a sound scientific and technological understanding, including mastering the production and management of skilled personnel. Hemmert (1998) further underscores such

[1] In the interest of the extent and feasibility of the analysis, the focus here is on technological efforts only carried out in-house. A further stage of research addresses efforts supporting learning from external knowledge sources.

factors in his analysis of how Japanese firms have dealt with changing, often adverse, macroeconomic environments, and the challenges associated with business strategies posed by continuous technological innovation. Firms have had to constantly reorganize and restructure their R&D activities in general, and the management of R&D personnel in particular. Continuous improvement in personnel management has underpinned innovative organizational practices to promote incentives, motivation and productivity and attract R&D (Legewie et al., 2000). Accordingly, Hemmert (1998) and, more recently, Michie and Sheehan (1999, 2003) call for a further investigation of the relationship between management practices and firms' capacity to engage in R&D. In a similar vein, Lundvall et al. (2002) argue that in addition to R&D efforts, analyses of firms' innovation capabilities need to consider the influence emanating from the daily experiences of workers, engineers and salesmen, together with interactions among individuals within and outside the boundaries of a firm.

Cohen and Levinthal's (1989, 1990) treatment of the dual role of R&D as a learning mechanism traces a link between management practices and R&D. R&D generates new information and knowledge underpinning searches for new market and technological opportunities through innovation. R&D is equally relevant for assimilating and exploiting existing information and knowledge. In other words, it helps to build the absorptive capacity by tapping existing knowledge. Cohen and Levinthal (1989, 1990) stressed that the contribution of individuals' cognitive processes to accumulate absorptive capacity is contingent on the nature of prior related knowledge and diversity of backgrounds. These elements depend on an individual's capacity to absorb, assimilate, link, analyze and, eventually, create knowledge. The authors further distinguished between expected goals from R&D. Firms may exploit their existing knowledge bases, or engage in knowledge exploration and expansion of knowledge bases. From a management perspective, however, the notions of knowledge exploitation and exploration, as central and distinguishable elements shaping organizational learning and capability-building, are integrated in the so-called knowledge-based theory of the firm (March, 1991). According to this literature, the primary role of firms, which is the basis of organizational capabilities, is to integrate specialized knowledge (Grant, 1996). The latter in turn, is often perceived in tacit form, hence know-how, skills and practical knowledge embedded in individuals are considered core components of an organization (Barney, 1991). Management interventions influence the organization and mobilization of individuals and their corresponding knowledge (Cohen and Levinthal, 1989, 1990; Barney, 1991).

That firms engage in either knowledge exploitation or exploration activities, or both, illustrates the heterogeneity, complexity and distinct use of knowledge. Exploitation refers to the use and refinement of existing knowledge, technologies and products. It entails short-run perspectives, more certainty and proximity to potential benefits. Exploration, for its part, identifies searches for new knowledge, use of unfamiliar technologies, creation of products/services with unforeseen, or, at least, difficult to predict, demand (March, 1991; Greve, 2007). Exploration also implies a long-run mindset and greater uncertainty about future revenues and benefits. Although, exploration and exploitation have potentially reinforcing effects on learning and capability-building, they lead to competing resource allocation, increased risks and tradeoffs in investment decisions. Finding the right balance is problematic, as the choice of either strategy depends on the survival and prosperity of firms: "... Systems that engage in exploration to the exclusion of exploitation are likely to find that they suffer the costs of experimentation without gaining many of its benefits. They exhibit too many undeveloped new ideas and too little distinctive competence. Conversely, systems that engage in exploitation to the exclusion of exploration are likely to find themselves trapped in suboptimal stable equilibria" (March, 1991:71).

From the above, and based on Li et al. (2008), a practical interpretation of exploration and exploitation activities is in terms of the cognitive distance between knowledge requirements and a firm's knowledge base. The latter in turn, is characterized by Kale and Little (2007:594) "as simple and complex, based on the technological challenges involved in developing particular products and underlaying capabilities". Exploitation refers to local searches for familiar, mature, current or proximate knowledge; it builds on existing technological capabilities. By contrast, exploration underpins searches for unfamiliar, distant knowledge. This interpretation induces some flexibility to the analysis, while still capturing traditional views of innovation in terms of incremental and radical outcomes (Greve, 2007). Whereas local searches may lead to incremental innovations, distant searches could lead to radical ones. Nevertheless, there is no a priori reason for such a match to occur.

The proposed interpretation is in line with empirical literature. Instead of focusing on innovation, attention is drawn to the learning process inside the firm. Successful catching-up experiences have coupled local searches, through internal learning efforts, with a few distant searches, and knowledge diffusion and assimilation through, for instance, reverse engineering activities. Firms combine stocks and flows of knowledge. Only when latecomer firms approach the technological frontier, does high quality basic research, more complex scientific techniques and instrumentation progressively gain importance to sustain productivity and competitiveness (Patel and Pavitt, 1994). However, the transition from technology-follower

status to that of technology-leadership status is neither linear nor automatic. Hobday et al. (2004) suggest that the transition requires, as complementary assets, gaining international brand recognition, strong marketing capabilities and control over foreign distribution channels, together with the ability to carry out the necessary organizational and structural changes.

2.2 An example from the pharmaceutical industry

The pharmaceutical industry is illustrative of the issues discussed above. Based on a capability-building model, Kale and Little (2007) argue that "reverse engineering R&D capability–the ability to develop products by copying the process–is categorised as a basic capability. Generics R&D involves incremental change representing intermediate capability while new chemical entity research involves creating new drugs and innovative therapies representing advanced capabilities" (p. 594). Building on the recent experience of Indian pharmaceutical firms, the authors illustrate how each stage of capability accumulation makes different demands on a firm's knowledge base. Over time, local firms use, acquire and accumulate different types of knowledge inputs for innovation, with increasing degrees of novelty. Progression in the technology ladder has accompanied the expansion of learning activities outside familiar cognitive boundaries; knowledge searches have become increasingly exploratory. Knowledge exploitation, however, remains relevant, particularly for firms whose business strategies are still based on the extension of life-cycles of existing pharmaceutical products. This experience, together with those presented by Cardinal and Hatfield (2000) and Kim (1997), for example, show that although the technological dynamism of firms in catching-up modes generally lags behind that of large multinationals, R&D remains the core ingredient for success. The major difference is that, in most cases, R&D in developing countries leads to incremental innovations.

The actual development of generics starts a few years before patent expiry of the innovator product. Firms have to reproduce the knowledge needed to manufacture it while constantly ensuring bioequivalence and biodisponibility, thus supporting its characteristic as a generic interchangeable drug.[2] Speed is necessary, to the extent that first movers are able to gain and retain their relevant market shares (Caves et al., 1991; Hollis, 2002). In most cases, the choice of products is linked to current product portfolios; what firms already know. Nevertheless, expected benefits increase if firms are able to enhance the characteristics of the innovator drug. Quality enhancement includes relatively simple improvements in product packaging, reformulation or recombinition of existing molecules. New products, in turn, include new

[2] Generic interchangeable indicates that the reaction to a generic drug in the human body is exactly the same as that of an innovator drug.

applications of existing drugs, often in different therapeutic areas. The search for new knowledge may relate more to the methods and techniques used to synthesize the components—biotechnology techniques, for instance—than to the characteristics of the drug itself (Kale and Little, 2007).

The mix of current and new knowledge, relative to the firm's knowledge base, remains central for the analysis. In this context, Kim and Cha (2000) and Laursen and Foss (2003) contend that firms with different technological profiles require and mobilize resources differently. More heterogenous organizational models, as compared with those in mainstream literature, are possible. Dávila and Elvira (2007), for instance, stress culture, context and history as inducing a different, yet functional, form of employer-employee interaction. Equally pertinent is the increasing importance of the character of innovation and the frequent dearth of formal R&D units within latecomer firms (Santamaría et al., 2009). All this widens the gap between traditional studies on management practices in manufacturing and those on formal R&D departments. Based on data on the pharmaceutical industry in Mexico—the world's ninth pharmaceutical market and the second in Latin America—this paper endeavours to shed light on some of the issues involved.

3. Management practices & learning through R&D: Mexican pharmaceuticals

Based on a widely accepted theoretical rationale, section 1 dealt with the complexities of defining comprehensive checklists of management practices that determine performance at firm level. Boseli et al. (2005) and Combs et al. (2006), for their part, advise pragmatism in the approach to research, claiming that it should build on a mix of theory, previous empirical evidence, intuition and a careful observance of existing data. In this regard, enhanced organizational practices frequently relate to Japanese management styles. Hemmert (1998), for example, indicated practices targeting R&D personnel, including, hiring and firing, job rotation and continuity and compensation systems. Literature on complementarities identifies sets of interventions explaining distinct productive and innovative performance (Ichniowski et al., 1997; Michie and Sheehan, 1999; Laursen and Foss, 2003; Michie and Sheehan, 2003). These sets include indicators on labour relations—incentives and compensation, recruitment and selection, teamwork, employment security, flexibility in job assignments, training, labour-management communication, grievance rates and so on. Literature on developing countries identifies practices accompanying the adoption of organizational techniques, such as total quality management (TQM) or just-in-time (JIT), including the provision of training, workers' empowerment, payment and staff promotion (Tello and Greene, 1996; Abramo, 1997; Islas, 2003; Vargas, 2004). Additional information was obtained through exploratory

interviews with some 20 multinational and Mexican pharmaceutical firms. In general, firms were affiliated to the main local trade organization—*Cámara Nacional de la Industria Farmacéutica* (CANIFARMA). The goal was to learn about the nature of innovation activities, R&D and associated management practices in the local industry. These inputs were supplemented with information from the dataset described in section 4.

3.1. Training

Training underpins the development of technical and managerial skills among people, who are repositories of the tacit knowledge of an organization (Johnson et al., 1996). Tacit knowledge supports organizational structures as well as the productive and innovation capabilities of a firm. Training takes on two complementary forms: on-the-job and off-the-job. The former is most common. It supports the learning of day-to-day operations and an understanding of basic concepts. The latter is usually available for key personnel and contributes to enhancing the intellectual capital and skills by capturing existing knowledge, that is, latest developments in specific knowledge fields, research techniques and so on (Hara, 2003). Through training, strategies that can be devised to promote motivation and reward human resources. However Gray et al. (2004) stress that the influence of training depends very much on creating an environment where sufficient returns can be expected. In other words, it needs to be accompanied by pertinent incentives and working conditions so that improved skills can be properly used (Laursen and Foss, 2003).

Pharmaceutical firms in Mexico show great propensity to provide training to employees (Annex table 3). This is more frequent in the case of knowledge exploitation. In general, firms combine internal and external sources of training, in an effort to capture the synergistic effects between the two types of training. The local industry acts in the same manner as observed at global level. Pharmaceuticals firms are strongly inclined to train personnel across operations (Bureau of Labor Statistics, 2007). Training ranges from a few hours of on-the-job training to years of formal education, including job experience. Training not only includes the development of general skills, but also those needed to carry out specific projects, develop particular processes, conduct specific analyses, handle specialized equipment and so on. Firms frequently train in safety, environmental and quality control and technological advances. Training in marketing and sales is expected to increase the market success of a product. It can thus be concluded that the provision of training could have a positive influence on the likelihood that firms perform R&D.

3.2. Remunerations

Adequate compensation and reward for good performance are expected to positively and significantly impact learning and innovation (Badawy, 1988). Appreciation of individual and professional aspirations promotes motivation and commitment to an organization (Mumford, 2000; Quinn and Rubb, 2006). Effective reward systems encourage employees to take risks, pursue the development of new products and continuously generate ideas that can be realized (Mumford, 2000), whereas creativity can be encouraged if freedom, financial rewards, promotion and other forms of recognition exist (Amabile, 1997).

Remunerations contribute to skill development cycles (Samstad and Pipkin, 2005); they may strategically attract talent from outside, thereby minimizing the cost of internal training (Labarca, 1999). Setting up an adequate remuneration system is complex. More importantly, creative individuals may prefer a challenging and innovation-driven environment instead of high salaries. For instance, Terziovski and Morgan (2006) argue that in science-based industries, such as biotechnology, performance-linked rewards might not be as attractive and stimulating as compared to access to sophisticated scientific equipment and instruments enabling researchers to work while increasing their intellectual capacity. In Mexico, remunerations in the pharmaceutical industry are higher than in other manufacturing industries, and are even higher in firms that conduct in-house R&D. As a mechanism to motivate and retain workers, remunerations are frequently limited to adjustment without altering the firm's structure of compensations as a whole. These considered, remunerations can be expected to positively influence learning through R&D.

3.3 Empowerment

Self-esteem—feeling of power—is an important determinant of employee performance (Gupta and Singhal, 1993). Empowering employees is the basis for high-performance work systems (Bartlett et al., 2002). It provides people the opportunity and means to tackle new problems, they gain varied experiences, and are prepared to take on more challenging tasks. They are also able to participate by defining their personal objectives, or the time they spend at work. They can voluntarily request to be involved in assignments promoting skills development, or in the establishment and management of effective mentoring relationships and so on (Hemmert 1998; Laursen and Foss, 2003; Michie and Sheehan, 2003). In such a way firms are able to foster innovative activities (OECD, 1998; Mumford, 2000). However, Bartlett et al. (2002) warn that mismatches between increased responsibility and means and skills to perform the job could render empowerment meaningless; even counterproductive.

Successful empowerment is often associated with teamwork, training and other practices (Carrillo and Ramírez, 1997; García, 2002).

Workers in the Mexican pharmaceutical industry have limited opportunities to participate in decision-making with regard to working conditions and, whenever that happens, it is of limited relevance to the firm. In this regard, it must be acknowledged that strict regulations faced by the industry could reduce opportunities to modify the working conditions. In fact, these are already among the best throughout manufacturing activities. Manufacturing processes and operations, in general, must comply with strict current good manufacturing practices[3] (GMPs) and other industry standards, and work closely with regulatory authorities. Regarding R&D, literature documents that drug development activities, such as those underpinning the formulation of generic drugs, may be more structured and defined in terms of timing, nature of tasks, formality in the organization, conduction of activities, and so on. Exploratory interviews with the local industry revealed that R&D staff may frequently succumb to the needs of manufacturing and quality control departments. Nevertheless, empowering employees is expected to positively affect the probability of R&D performance.

3.4. Rotation assignments

Gupta and Singhal (1993) state that innovative firms encourage employees to work in various departments and divisions, to enable them to can gain experience and a better understanding of operations, products and resources available at the firm. Rotation potentially increases knowledge-sharing and awareness of problems affecting different parts of the organization and, if at all present, its multi-faceted innovation processes (Laursen, 2002). Rotation supports learning if participants are carefully selected and practices are adequately timed and framed within specific skill development strategies (Mumford, 2000). However, relatively little evidence was found on the concrete use of rotational assignments in the Mexican pharmaceutical industry. In general, the practice was found to be relatively unimportant as a learning mechanism. Rather, and particularly, in firms with some formal R&D activities, it was frequently associated with new recruits who are expected to move around the laboratory, meet senior staff, and generally learn more about the activities of the department. In light of this diverging evidence, concrete conclusions can be drawn from the empirical analysis.

[3] In most countries, sanitary authorities ensure effectiveness and safety of pharmaceutical products by implementing comprehensive safeguards and procedures of obligatory observance for drug manufacturers. These are summarized under good manufacturing practices (GMPs) which, in simple terms, indicates the best rules/practices to manufacture drugs (FDA, 2004a; Seiter, 2005). GMPs include layout and functionality of buildings, qualification and training of personnel, cleanliness and sanitation, monitoring, supervision and many other aspects. GMP's are reviewed and adjusted according to scientific and technological advances, hence the term "current" GMPs.

3.5 Hiring staff

Badawy (1988) claims that effective human resource planning is the key to innovation. This includes determining staffing needs, hiring qualified people according to job characteristics, knowledge and skill competencies, as well as ensuring an appropriate mix of personnel during the innovation processes (Terziovski and Morgan, 2006). Hiring helps to tap external knowledge in the interest of internal requirements (Du and Ai, 2008; Santamaría et al., 2009). New staff should possess predefined personality traits, knowledge and experience, and work well with existing teams and organizational dynamics. Particularly in managerial positions, potential for creativity and learning should be accompanied by the capacity to promote such behaviour among other staff members (Gupta and Singhal, 1993). Staffing practices in developing countries are often constrained; whether firms seek blue-collar or better skilled white-collar personnel. For the first category of workers, the process appears relatively simple, given the traditionally low qualifications of local labour. However, it becomes more complicated when hiring staff for higher positions; availability of well trained and experienced people is scarce. Finding the right candidates for off-line positions requires strategic hiring. It also becomes more complicated and involves higher costs (Flynn, 1994; Forest, 1994). In this regard, Peña (2000) documents that in high turnover maquiladora contexts, hiring practices may focus more on compensating a worker's lost, rather than acquiring new, talents. Here again empirical results could help to shed light on the impact that staff hiring has on internal learning strategies.

3.6 Staff promotion

Promotion policies and associated practices substantially affect professional perspectives. The first step for designing sound professional development programmes includes diagnostics of career issues in the organization (Badawy, 1988). Igbaria et al. (1999) mention that career development should focus on retaining and motivating workers by matching organizational and individual needs. Perspectives for professional advancement, ways to measure productivity in R&D, consideration of distinct professional aspirations and different backgrounds of scientists and engineers guarantee loyalty and willingness to engage in innovative activities. These groups of professionals may feel and react differently towards fairness and objectivity of career development systems (Tremblay et al., 2002). Additional elements derive from the balance between internal and external labour markets, whether firms hire for entry level jobs, but fill higher levels from within; or if positions are filled by hiring outsiders at all levels (Lazear and Oyer, 2004).

With regard to staff promotion, multinational affiliates in Mexico tend to follow Japanese-style management approaches—favouring internal labour markets over external sources. Firms implement programmes on career development, including succession plans to enhance internal mobility. Employees, at least at mid-rank level, apply for a vacant position with the hope of being selected for the position, especially if it involves a promotion or affects the turnover. By contrast, firms of Mexican origin showed very limited use of the practice. Smaller firm size or lack of specific plans to do so could explain this. Formalization of promotion mechanisms could have a positive impact on R&D.

4. Data sources, variable definition and research strategy

Data used in this paper were extracted from the *Encuesta Nacional de Empleo, Salarios, Tecnología y Capacitación* (ENESTyC). This survey was carried out by the *Instituto Nacional de Estadística, Geografía e Informática* (INEGI) on behalf of the *Secretaría del Trabajo y Previsión Social* (STPS), Mexico. ENESTYC represents the entire Mexican manufacturing sector. The manufacturing establishment constitutes the unit of analysis. The survey builds on a stratified sample based on the size of the establishment, as measured by total employment: Large: 251 and over; medium: 101-250; small: 10-100 and micro: 0-5. Classification of activities is based on the North American Industrial Classification System (NASCI). Establishments with 100 or more employees are included together with a random sample of those with less than 100 employees. The total number of manufacturing units is 9,920. Confidence level is 95 per cent, with an estimated non-response of 10 per cent.

The latest available publication of ENESTYC corresponds to 2001. Nevertheless, based on an agreement to comply with pertinent confidentiality requirements by INEGI, personnel from this Institute processed the preliminary data based on information for 2004. ENESTYC provided information on technological and organizational profiles, employment and remuneration levels, management practices and the provision of training. The module for the pharmaceutical industry (NASCI code 3254) includes 141 data points, representing 388 establishments. The effective working sample, excluding missing values, is 112 data points, which is equivalent to some 308 establishments. Due to the inability to match data points with specific firms, the terms establishment and firm are used interchangeably in the rest of this paper. However, it must be pointed out that firms could own more than one establishment.

4.1 Dependent variables

ENESTYC provides information on R&D and the objectives of such activities (table 1). In the context of pharmaceutical firms, it identifies cost-reducing innovations through:

1. improvements in existing drug manufacturing processes
2. improvements in or design of new machinery and equipment for the firm's own use. This is interpreted as R&D for new process innovation.

Alternatively, R&D seeks demand-enhancing innovations including:

3. quality improvements on existing pharmaceutical products
4. design of new products.

Based on the discussion in section 2, (1) and (3) above are interpreted as knowledge exploitation activities, and improvements in pharmaceutical products and processes lead to searches within familiar knowledge bases. By contrast, the introduction of some new drugs or new manufacturing processes, indicators (2) and (4), relate to knowledege searches outside familiar cognitive, including physical and geographical, boundaries.[4] This distinction coincides with Kale and Little's (2007) differenciation of pharmaceutical firms, based on their accumulated technological capabilities. By combining (1) and (3) a variable on R&D for knowledge exploitation, *rd_exploit* is obtained. Likewise, by combining (2) and (4) the variable on R&D for knowledge exploration, *rd_explore* is obtained. In general, firms in Mexico pursue imitative and incremental innovations.

Table 1. Indicators on in-house R&D performance by pharmaceutical firms in Mexico

Variable	Definition	Mean	Std Dev	Value
rd_inhouse	Firm carries out R&D in-house	.741	.440	1 if yes; 0 otherwise
rd_design_meq	Goal of R&D is to improve or design new machinery and equipment for own use	.187	.392	
rd_improve_process	Goal of R&D is to improve existing manufacturing processes	.634	.484	
rd_drug_design	Goal of R&D is to design new pharmaceutical products	.616	.488	
rd_drug_improvement	Goal of R&D is to improve existing pharmaceutical products	.661	.476	
rd_exploit	Firm performs R&D for knowledge exploitation	.714	.454	
rd_explore	Firm performs R&D for knowledge exploration	.625	.486	

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.

4.2 Explanatory variables

Table 2 presents the explanatory and control variables in this paper. Boseli et al. (2005:74) acknowledge three ways to measure human resource management variables: "by its presence (that is, a dichotomous scale for whether it is actually in effect 'yes' or 'no'), by its coverage

[4] Similar interpretations in the context of biotechnology and pharmaceuticals are found in Rothaermel and Deeds (2004); Gilsing (2006); and Kettler and Modi (2001).

(that is, a continuous scale for the proportion of the workforce covered by it) or by its intensity (that is, a continuous scale for the degree to which an individual employee is exposed to the practice or policy). The overwhelming majority [of studies] rely only on measures of presence." In general, this is the case with ENESTYC. Only a few variables reflect the intensity in management practices. For example, the indicator on workers' participation in decision-making shows the perceived importance of the practice by the employer. Wright and Boswell (2002) and Boseli et al. (2005) advise caution on differences in measuring management variables in terms of either policies or practices. Whereas the former reflects an organization's stated intentions regarding management activities, the latter reflects the actual, functioning, observable activities, as experienced by employees. Written policies will influence performance only if individuals perceive them as important for organizational well-being. ENESTYC contains several variables representing regulations on management practices. Detailed information on how such rules translate into actual practice is missing. Consequently, great care was taken when introducing them in the analysis.

Table 2. Management and control variables included in the analysis

	Min.	Max.	Description
train04	0	1	1 if the firm provided training to its employees in 2004; 0 otherwise
training_internal	0	1	1 if training is provided by colleagues in-house; 0 otherwise
external_training	0	1	1 if the firm provides training through external providers (specialized public job training centres, public/vate universities, other firms, consultants or the industry's trade organization); 0 otherwise
internal_external_tr	0	1	1 if the firm provides training both in-house and externally; 0 otherwise. Interaction term between training_internal and external_training
ln_avg_rem	2.674	5.749	Natural logarithm of the average remuneration per worker: total remuneration (salaries and benefits) paid in 2004 divided by total number of employees in that same year
imp_empowerment	0	2	1 if workers participate in decision-making and the firm declares such practice as important; 2 not important; 0 workers do not participate
rule_promotion	0	1	1 if the firm regulates staff promotion through either collective contracts or other internal negotiations; 0 otherwise
rule_hiring	0	1	1 if the firm regulates hiring staff through either collective contracts or other internal negotiations; 0 otherwise
rule_temprot	0	1	1 if the firm regulates the use of temporary rotation practices through either collective contracts or other internal negotiations; 0 otherwise
Control variables			
modern_practice	0	1	1 if the firm reports the use of total quality management and/or just-in-time organizational practices irrespective of actual importance; 0 otherwise
large_sme	1	2	Size of the firm 1=Large, 2=Medium, small and micro
expt_largesme	0	2	Firms classified by exporting behaviour and size. Interaction term between export_dummy and large_sme; 1=large, 2=small and medium sized (SME), 0 no participation in export markets
fdi_largesme	0	2	Firms classified by size and foreign ownership. Interaction term between foreign_share and large_sme: 1=large, 2=SME, 0 no participation of foreign capital in total social capital of the firm

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.
Notes: Information for the 112 data points in working sample; * Thousand Mexican pesos; variables in bold are those created by the authors with information from the source.

Control variables. Lundvall and Valeyre (2007) in the case of Europe, OECD (1998) for the OECD countries and Kaplinsky (1995) for developing countries document the interrelation between modern management practices and organizational strategies adopted by firms. Such strategies correspond with the type of management practices available for firms and shape the environment in which learning takes place (Arundel et al., 2007). In the case of pharmaceutical firms, and in the context of current GMPs, TQM practices assist in meeting the strict quality control required by regulatory authorities. In this paper, the variable *modern_practice* controls for the use of JIT and/or TQM practices. Capital origin and export behaviour reflect the technological performance of pharmaceutical firms in developing countries such as Mexico (Kim et al., 1989; Zúñiga et al., 2007). By normalizing the variables on export exposure and capital origin with respect to firms' size it was possible to correct

problems of high and positive correlations among some variables on the right hand side of the equation. It also captured the scale effects (Cockburn and Henderson, 2001).

4.3. Research strategy

The dependent variables in this section denote the likelihood that a pharmaceutical firm carries out in-house R&D. A suitable approach for studying this type of decision variables is a probability model, such as binary probit regression (Liao, 1994; Greene, 2003). The dependent variable can be expressed as:

$$y = \begin{cases} 1, \text{ if } y^* > 0 \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

The linkage function between the vector of dependent variables Y and the explanatory variables x's can be expressed as:

$$E(Y) = \mu = \sum_{k=1}^{K} \beta_k x_k + \varepsilon \quad (2)$$

Given the binary nature of Y, one can express the linkage function between Y and x_i in a more general fashion as η . A probit model is a generalized linear model with a probit link:

$$\eta = \Phi^{-1} \mu \quad (3)$$

where Φ is the standard normal cumulative density function (CDF) in the form of a standardized variable, Z score, expressed in probability terms (Liao, 1994). Probit analysis assumes binomial distribution of the dependent variable and normal distribution in the errors term, ε.[5]

The analysis proceeded as follows: some basic model specifications based on statistical significance and theoretical consistency were identified. To minimize potential multicolinearity problems, combinations of variables with correlations equal to or larger than ± 0.5 were avoided (Annex table 1). Accordingly, the provision of training, the log of average monthly remuneration, and the importance of worker's participation in decision-making processes were retained. As for the variables on formal regulations that govern

[5] An alternative is logit regression analysis where the errors term, ε would assume a logistic distribution. In general, probit and logit render similar results (Greene, 2003).

temporary rotation and procedures to hire new staff and staff promotion, these were merged to correct for their positive correlations in excess of 0.5[6]. The new variable, *rules_hrm*, runs from 0-3 depending on the number of practices regulated by the firm.[7] Additional models tested the adequacy of variables on modern organizational practices. The variable on JIT highly correlated with other indicators, such as worker's participation in decision-making, use of temporary rotation assignments and so on. The use of *modern_practice*, indicating the simultaneous adoption of TQM or JIT by the firm, helped to overcome these problems. Alternative models, which include only the TQM variable, rendered similar results to those presented here.

Analysis started by exploring the extent to which control and management practices explain the likelihood that a firm performs in-house R&D. Then, the definition of the dependent variable was iteratively changed, while keeping the basic structure at the right hand side of the equation unchanged. (Note a minor difference in the definition of training used in models with *rd_design_meq* as the dependent variable.) Most firms reported having provided training to employees during 2004. Consequently, models with *train04* had problems converging; the variable predicted the probability that a firm performs such type of R&D. The choice was for the alternative, *internal_external_tr*, which denotes interactions between internal and external training. Individual effects of internal and external training, respectively, were tested on the remaining definitions of R&D. Several checks were performed to ensure accuracy and robustness of results. Models were included, where each dependent variable was regressed on the control variables only. Thus it was possible to observe the extent to which control variables explain the learning behaviour of pharmaceutical firms. Equations were then run by including only those explanatory and control variables that reveal some statistical significance, at 5 per cent or less, in the basic model. For reasons of space and feasibility of the analysis, results from those models are included but, in all cases, estimations corroborated robust results.

5. Empirical results

5.1 Learning behaviour of pharmaceutical firms in Mexico

Annex table 2 summarizes the learning behaviour of pharmaceutical firms in Mexico. Some 74.1 per cent of firms performed R&D in 2004, with some 63.4 per cent and 70.5 per cent

[6] Factor analysis showed that the three practices on the regulation of management practices show a tendency to cluster independently from the other management variables in the equation.

[7] The rules_hrm were computed based on both exploratory factor analysis and the arithmetic mean of the three original variables: rules_hrm=(rule_promotion+rule_hiring+rule_temprotation)/3. In either case, results were similar to those reported here. For simplicity of the analysis, the index variable was retained.

focusing on process and product innovations, respectively. Of those performing R&D for process innovation, 25.3 per cent did so to improve or design machinery for their own use, while some 63.4 per cent to improve productive processes. As for demand-enhancing innovations, some 61.1 per cent of firms pursued new products, and some 66.1 per cent focused on improvements in existing drugs. In this context, indicators, such as sales and employment show that, on average, R&D performers slightly outperform those reporting no R&D activities. For instance, average employment, total sales and sales per employee are, respectively, 1.4, 1.6 and 1.1 times larger in firms with active learning strategies. By contrast, indicators on capital origin and export orientation tend to favour non-R&D performers. Some 70 per cent of firms were engaged in either knowledge exploitation or exploration. The corresponding figures on employment, sales and so on, are very close within each group, with a slight advantage for active learners. A significant number of firms participate in external markets. However, since the average share of exports in total sales of the industry is rather modest, one could argue that pharmaceutical firms are strongly oriented to serving the local market. In line with the current general management practices (GMPs) requirement, ENESTYC reports an extensive adoption of modern manufacturing practices in the pharmaceutical industry.

5.2 Learning through in-house R&D

Table 3 presents estimates obtained from the econometric analysis. Model (1) corresponds with in-house R&D, irrespective of the goals pursued by the firm. Models (2) and (3) include cost-reducing R&D, while models (4) and (5) relate to demand-enhancing R&D. As can be seen, the table is split into two sections; models with control variables only, and those with the full set of explanatory and control variables. Liao (1994) and Long and Freese (2006) suggest that instead of maximizing the value of any specific scalar measure of goodness of fit, the analysis should be consistent with theory and previous research. The Wald tests for the value of X^2, which is different from zero, confirm that the models are statistically significant at standard confidence levels. The classification table of observed and predicted values—cutting point at 0.5—show that, in general, the predictive power of each model is acceptable (Liao, 1994). For instance, in model (1) 100 positive cases were predicted, with 78 of them correctly classified because the actual observation corresponded with an R&D performer, (y=1). The remaining 22 cases were incorrectly assigned because the actual observation was a negative response, (y=0). Conversely, from the 12 responses predicted as negative, 7 were correctly, while 5 were incorrectly, classified. The values of the Cragg-Uhler R^2 suggest that the models better reflect the probability of performing exploration-related R&D.

Table 3. Results from probit analysis: management practices and learning in the Mexican pharmaceutical industry

Variables	(1) *rd_inhouse*		(2) *rd_improve_process*		(3) *rd_design_meq*		(4) *rd_drug_improvement*		(5) *rd_drug_design*	
train04		1.40***		1.08**				0.98**		1.40***
		(0.45)		(0.46)				(0.43)		(0.50)
internal_external_tr						0.57**				
						(0.23)				
ln_avg_rem		0.49*		0.32		0.62**		0.55**		0.56***
		(0.26)		(0.22)		(0.29)		(0.24)		(0.25)
imp_empowerment		0.28		0.29*		0.74***		0.18		-.39***
		(0.18)		(0.16)		(0.23)		(0.17)		(0.18)
rules_hrm		-0.23		0.07		0.37		0.16		-0.67**
		(0.36)		(0.32)		(0.40)		(0.33)		(0.34)
modern_practice	0.33	-0.16	0.51*	0.10	0.19	-0.57	0.18	-0.20	0.48*	-0.01
	(0.28)	(0.33)	(0.26)	(0.31)	(0.31)	(0.41)	(0.26)	(0.31)	(0.27)	(0.33)
expt_largesme	0.45**	0.34	0.14	0.06	0.04	-0.19	0.19	0.039	0.62***	0.56***
	(0.20)	(0.22)	(0.17)	(0.18)	(0.17)	(0.25)	(0.18)	(0.19)	(0.21)	(0.22)
fdi_largesme	-0.46**	-0.71***	-0.27	-0.44**			-0.27	-0.47**	-0.68***	-1.02***
	(0.23)	(0.24)	(0.21)	(0.22)			(0.21)	(0.23)	(0.25)	(0.27)
Constant	0.32	-2.76**	0.011	-2.27**	-0.95***	-5.29***	0.26	-2.91***	-0.16	-3.41***
	(0.24)	(1.17)	(0.23)	(1.04)	(0.26)	(1.26)	(0.23)	(1.08)	(0.23)	(1.19)
Log Likelihood Full	-60.6	-52.8	-71.0	-65.3	-53.3	-41.3	-70.6	-63.8	-67.0	-57.6
X^2	[3]7.99**	[7]26.1***	[3]5.18	[7]17.4**	[3]1.65	[7]22.1***	[3]2.20	[7]15.8***	[3]13.9***	[7]29.5
Cragg-Uhler R^2		0.267		0.188	0.328		0.182		0.355	

Classification tables: Predictive power of models[/a]

Count R^{2}[/b]	75.9			68.8			81.3		[3]1.65	[7]22.1***	68.8		70.5		
Classified	**D**	**-D**	**Total**	**D**	**-D**	**Total**	**D**	**-D**	**Total**	**D**	**-D**	**Total**	**D**	**-D**	**Total**
+ values	78	22	100	64	28	92	3	3	6	67	28	95	58	22	80
- values	5	7	12	7	13	20	18	88	106	7	10	17	11	21	32
Total firms	83	29	112	71	41	112	21	91	112	74	38	112	69	43	112

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.
Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1; DF, Degrees of freedom within squared brackets; /a. These refer to model especifications including the full set of explanatory and control variables. Entries are classified as positive if predicted Pr(D) >= .5 True D defined as internal different from zero, D and -D indicate a positive or a negative predictive value, respectively; /b. Percentages.

Considering the non-linearities involved in binary regression models, interpreting individual coefficient estimates is problematic. Moreover, it is difficult to grasp what a positive or negative effect of a given independent variable on the probit [$\Phi^{-1}\mu$] is. Associated literature recommends looking beyond the direction and significance of individual coefficient

estimates. Liao (1994) identifies four complementary approaches to interpret the results: (1) predicted values of the link function η or transformed η assuming specific values for the remaining variables in the model; (2) the marginal effects of an explanatory variable on η or transformed η; (3) the predicted probabilities assuming some specific values on the independent variables; and (4) the marginal effect of an explanatory variable on the probability of occurrence of an event. Approaches such as (1) are rare for logit or probit (Liao, 1994), hence they are not treated in the subsequent discussion.

The individual estimates reveal that training has the strongest and most significant effect on learning. It also increases the likelihood that firms carry out R&D. Remunerations are important for new process- and new product-related R&D. Workers' empowerment has positive and statistically significant effects on knowledge exploration. The regulation of some management practices, *rules_hrm*, is relevant only for *rd_design*, albeit with negative effects. Contrary to expectations, the control variables have little influence on R&D performance. The exception is knowledge exploration which supports new drug design. While exports and capital ownership play relevant roles, their effects, however, run in opposite directions. Whereas export participation induces learning, foreign ownership inhibits it. Scale effects are also captured as the two latter variables are normalized by the firm's size. Adoption of *modern_practice* does not reveal any specific effect on learning. Overall, the estimates suggest a passive learning behaviour of the pharmaceutical industry in Mexico. The constant term is consistently negative and statistically significant. If all right-hand side coefficients were set at zero, the probability that a pharmaceutical firm carries out R&D is rather low.

A complementary way to look at results in table 3 is by computing the marginal effects derived from modifications in the value of a given explanatory variable. These are changes in the likelihood of observing a given outcome contingent on changes in the value of an explanatory variable. In this regard, non-linearities imply that shifts in probabilities depend on two combined effects. One is the actual change in the variable of interest, and the other is the values adopted by the remaining elements in the equation. The latter are assumed to remain constant, usually, at the mean value. Comparisons are made relative to specific characteristics of the issue under investigation. For binary variables, the only relevant change in probabilities is the shift from 0 to 1, and vice versa (Long and Freese, 2006). This can be interpreted as going from the absence, to the adoption, of a particular management practice. By contrast, changes in continuous variables can be evaluated in different magnitudes, such as standard deviations or, directly, in percentages (Christofides et al., 1997; Christofides et al., 2000).

Table 4 corroborates that the influence of management practices on learning is more pronounced in the case of *rd_design*. Marginal increases in remunerations have a positive impact on learning. The exception is *rd_impr_proc*. By contrast, one can confirm the negative impact of *rules_hrm* on *rd_drug_design*. Interpretation of discrete probability changes should be handled with care; they are meaningful only for variables spanning a sufficiently large range of values (Long and Freese, 2006). A pertinent case is that of remunerations. Column 1 in table 4 reveals that a change in the logarithm of remunerations, equivalent to an increase from minimum to maximum, raises the likelihood that a firm conducts *rd_drug_design* by some 0.54. The effects of changes in remunerations are stronger for demand-enhancing R&D than for cost-reducing activities. The impact caused by changes of half a standard deviation in the log of remunerations, column 4, are larger for *rd_design* than for any other type of process R&D.

So far, the analysis has considered some detailed definitions of the R&D variable. Thus it was observed that management practices distinctly affect learning through R&D. Here, two major patterns were identified. First, in line with the notion of exploitation and exploration, the most significant effects are associated with knowledge exploration, whether for new process or product innovations. Besides, the more explorative the search, the stronger the exigency on the human resources. Second, table 4 underlines some differentiated influence of management practices on R&D for both process or product innovations. For reasons of space and pertinence of the analysis, in what follows, concentration is placed on the first observed pattern.

Table 4. Changes in probabilities and marginal effects for models in table 3

rd_inhouse	**(1) min->max**	**(2) 0->1**	**(3) -+1/2**	**(4) -+sd/2**	**(5) MargEfct[1]**	**(6) MargEfct[2,a]=0.779**
train04	0.51	0.51	0.4	0.13	0.42	0.51**
ln_avg_rem	0.42	0.08	0.15	0.1	0.15	0.15*
imp_empowerment	0.15	0.09	0.08	0.07	0.08	0.08
rules_hrm	-0.07	-0.07	-0.07	-0.03	-0.07	-0.07
modern_practice	-0.05	-0.05	-0.05	-0.02	-0.05	-0.05
expt_largesme	0.19	0.11	0.1	0.08	0.1	0.1
fdi_largesme	-0.5	-0.22	-0.21	-0.14	-0.21	-0.21
rd_impr_proc						**0.650**
train04	0.41	0.41	0.39	0.12	0.4	0.41***
ln_avg_rem	0.33	0.08	0.12	0.08	0.12	0.12
imp_empowerment	0.21	0.11	0.11	0.09	0.11	0.11*
rules_hrm	0.03	0.03	0.03	0.01	0.03	0.03
modern_practice	0.04	0.04	0.04	0.02	0.04	0.04
expt_largesme	0.04	0.02	0.02	0.02	0.02	0.02
fdi_largesme	-0.34	-0.16	-0.16	-0.11	-0.16	-0.16**
rd_design_meq						**0.101**
Internal_external_tr	0.18	0.02	0.1	0.1	0.1	0.10***
ln_avg_rem	0.27	0	0.11	0.07	0.11	0.11**
imp_empowerment	0.35	0.11	0.13	0.11	0.13	0.13***
rules_hrm	0.06	0.06	0.06	0.03	0.06	0.06
modern_practice	-0.11	-0.11	-0.1	-0.05	-0.1	-0.11
expt_largesme	-0.06	-0.04	-0.03	-0.03	-0.03	-0.03
fdi_largesme	-0.17	-0.14	-0.15	-0.1	-0.15	-0.15**
rd_drug_imp						**0.674**
train04	0.38	0.38	0.34	0.11	0.36	0.38**
ln_avg_rem	0.53	0.04	0.2	0.13	0.2	0.20**
imp_empowerment	0.12	0.06	0.06	0.06	0.06	0.06
rules_hrm	0.06	0.06	0.06	0.02	0.06	0.06
modern_practice	-0.07	-0.07	-0.07	-0.03	-0.07	-0.07
expt_largesme	0.03	0.01	0.01	0.01	0.01	0.01
fdi_largesme	-0.36	-0.17	-0.17	-0.11	-0.17	-0.17
rd_design						**0.667**
train04	0.51	0.51	0.48	0.16	0.51	0.51***
ln_avg_rem	0.54	0.03	0.2	0.14	0.2	0.20**
imp_empowerment	0.26	0.15	0.14	0.12	0.14	0.14**
rules_hrm	-0.24	-0.24	-0.24	-0.1	-0.24	-0.24**
modern_practice	0	0	0	0	0	0
expt_largesme	0.37	0.21	0.2	0.17	0.2	0.20***
fdi_largesme	-0.68	-0.37	-0.36	-0.24	-0.37	-0.37***

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.

Notes: Min->Max: change in predicted probability as x changes from minimum to maximum;
0->1: change in predicted probability as x changes from 0 to 1;
-+1/2: change in predicted probability as x changes from 1/2 unit below base value to 1/2 unit above;
-+sd/2: change in predicted probability as x changes from 1/2 standard deviation below base to 1/2 standard deviation above;
MargEfct: partial derivative of the predicted probability/rate with respect to a given independent variable.
1. Computed based on the method of discrete changes;
2. Computed based on the method of marginal changes; robust standard errors in parentheses;
***,**,* denote significance at the 1, 5 and 10 per cent levels, respectively;
[a] changes for binary variables from 0 to 1.

5.3 R&D for knowledge exploitation or exploration

Human resources, a core ingredient of a firm's resource base, are expected to contribute in a different way to learning and innovation, depending on the knowledge involved in such activities.[8] Nelson and Winter (1982) and Fransman and King (1984) argue that, over time, firms gain experience and, eventually, develop routines that increase their efficiency and productivity in manufacturing and, in general, the management of current product portfolios. Improvements in products and processes, or both, are generally based on searches within a firm's accumulated knowledge. Conversely, the more alien the intended innovation relative to what the firm knows, the greater the need to look beyond familiar cognitive boundaries. Management systems influence and play a mediatory role in these processes via the creation, transfer and integration of knowledge flows that enrich a firms' human capital, as a stock (Wright et al., 2001), in ways that are valuable, rare and inimitable (Grant, 1996). So far, the findings here suggest that management practices are associated more with knowledge exploration than with other activities. These findings were investigated further by running two additional models using two dummy variables. First, R&D for knowledge exploitation (*rd_exploit*), and second, R&D for knowledge exploration (*rd_explore*). Results are presented in table 5. Similar to table 3, it includes two specifications. First, models with control variables only, later, those with the full set of variables.

Table 5 confirms the expected differences in the contribution of management practices to exploration and exploitation strategies. Knowledge exploration, in the sense of research, experimentation and technological capability-building, is associated with stronger exigencies on management practices. The provision of training, remunerations and worker's empowerment have positive and statistically significant effects. Exports and the origin of capital ownership, controlled by size of the firm, report significant, yet opposed, effects on knowledge exploration. Table 5 includes the computation of marginal effects. In general, they confirm that the effects of management variables are much stronger for R&D for knowledge exploration.

[8] To some extent such differences result from the distinct nature of innovation across industrial sectors (Pavitt, 1984; Laursen, 2002).

Table 5. Influence of management practices on knowledge exploitation and exploration by pharmaceutical firms in Mexico

	rd_exploit			*rd_explore*		
Variables			**Mg effect**			**Mg effect**
train04		1.25***	.465***		1.48***	0.53***
		(0.44)	(0.16)		(0.50)	(0.14)
ln_avg_rem		0.44*	0.14*		0.55**	0.20**
		(0.24)	(0.08)		(0.25)	(0.09)
imp_empowerment		0.24	0.08		0.45**	0.16**
		(0.17)	(0.06)		(0.19)	(0.07)
rules_hrm		0.07	0.02		-0.66*	-0.24*
		(0.35)	(0.11)		(0.34)	(0.12)
modern_practice	0.22	-0.25	-0.08	0.41	-0.15	-0.05
	(0.27)	(0.33)	(0.10)	(0.27)	(0.33)	0.12
expt_largesme	0.30	0.17	0.06	0.59***	0.54**	0.19**
	(0.19)	(0.21)	(0.07)	(0.20)	(0.23)	(0.08)
fdi_largesme	-0.43*	-0.64***	-0.21***	-0.68***	-1.04***	-0.37***
	(0.22)	(0.24)	(0.08)	(0.25)	(0.27)	(0.10)
Constant	0.39	-2.46**		-0.073	-3.34***	
	(0.24)	(1.11)		(0.23)	(1.20)	
Observations			112			
Log likelihood full	-64.6	-57.6		-67.2	-57.1	
X^2	[3]4.66	[7]20.3***		[3]12.7***	[7]29.6***	
Cragg-Uhler R^2	--	0.221		--	0.358	
Count R^2		0.72			0.70	

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; Degrees of freedom within squared brackets.

5.4 Investigating the effects from different types of training

So far, training has revealed a positive and robust influence on the likelihood that a firm performs R&D. This is consistent with the literature on human capital development and some previous studies on innovation and human resource management (Michie and Sheehan, 1999, 2003). In order to extract meaningful conclusions, more disaggregated measures on the actual nature of training were introduced. Section 3.2 identified two complementary forms: internal (on-the-job) and external (off-the-job). The former was expected to support knowledge diffusion and sharing within the organization, as it would relate more closely to exploitation strategies. By contrast, external training would generally support the expansion and enrichment of knowledge bases through interaction with other knowledge producers (Casas, 2005).

Table 6. Testing the influence of internal and external training on performance of in-house R&D

Variables	*rd_inhouse*	*rd_exploit*	*rd_explore*	*rd_improve_process*	*rd_drug_design*	*rd_drug_improvement*
training_internal	0.68**	0.73**	0.64*	0.64**	0.56*	0.41
	(0.33)	(0.32)	(0.34)	(0.33)	(0.34)	(0.31)
external_training	0.53*	0.37	0.83***	0.43	0.78**	0.29
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.30)
ln_avg_rem	0.37	0.34	0.41	0.23	0.42*	0.47**
	(0.25)	(0.24)	(0.25)	(0.23)	(0.24)	(0.24)
imp_empowerment	0.31*	0.27	0.50***	0.32**	0.43**	0.18
	(0.18)	(0.17)	(0.19)	(0.16)	(0.19)	(0.17)
rules_hrm	-0.21	0.05	-0.70**	0.05	-0.68**	0.19
	(0.36)	(0.34)	(0.35)	(0.32)	(0.35)	(0.33)
modern_practice	-0.07	-0.18	-0.12	0.15	0.03	-0.12
	(0.33)	(0.32)	(0.32)	(0.31)	(0.32)	(0.30)
expt_largesme	0.38*	0.19	0.61***	0.06	0.62***	0.05
	(0.21)	(0.21)	(0.21)	(0.19)	(0.21)	(0.19)
fdi_largesme	-0.70***	-0.63**	-1.06***	-0.42*	-1.02***	-0.44*
	(0.24)	(0.25)	(0.26)	(0.23)	(0.26)	(0.23)
Constant	-1.95*	-1.77*	-2.53**	-1.71*	-2.61**	-2.31**
	(1.12)	(1.07)	(1.09)	(0.99)	(1.07)	(1.04)
Observations	112					
Log Likelihood Full	-53.5	-58.0	-56.0	-64.7	-57.0	-64.8
X^2 [8]	26.9***	20.8***	38.0***	19.7**	37.9***	13.7*
Cragg-Uhler R^2	0.25	0.21	0.38	0.20	0.37	0.16
Count R^2	0.79	0.75	0.74	0.70	0.73	0.73

Source: Authors, bsed on information obtained from ENESTYC 2005, INEGI.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; Degrees of freedom within squared brackets.

Two additional variables, namely, *training_internal* and *external_training*, captured the dual nature of training. The analysis excluded models with *rd_design_meq* because *training_internal* tended to predict perfectly the probability of a firm performing this specific type of R&D.[9] Table 6 contains estimates for models with the alternative definitions on training. The Wald tests show that, with the exception of *rd_drug_improvement*, the remaining models are statistically significant at conventional confidence levels. Estimates confirm that internal training is more closely related to knowledge exploitation, while that provided by external agents impacts more directly on exploration, particularly *rd_design*. Management interventions are confirmed to have a very strong influence on exploration-like R&D. However, it is somewhat surprising to see the significance of remunerations deteriorating while, at the same time, worker's empowerment appears to be gaining

[9] In the case of perfect prediction, STATA drops the problematic variables out from the equation. An option was to use an interaction term, internal_external_tr, to capture the simultaneous provision of internal and external training. In the interest of space and consistency of the analysis, they have been omitted from the presentation; however, results for the rest of models were similar to those reported here.

prominence. The models corroborate the negative impact of *rules_hrm* on learning. Finally, export participation appears to stimulate learning, particularly for (new) product innovation.

6. Discussion

This paper investigated the influence of management practices on the likelihood that a firm performs in-house R&D. Firms could choose between two alternatives, not necessarily mutually exclusive, learning strategies. In the context of the pharmaceutical industry, firms may tap their accumulated knowledge base and engage in some imitative R&D. This underpins the manufacture of generic drugs according to well established parameters set by the drug innovator. Alternatively, firms may perform more formal R&D activities and seek to incorporate some significant improvements in the quality of products. Looking at distinct R&D outcomes with diverging degrees of novelty, some positive linkages between management practices and learning at firm level were observed. More specifically, the influence from such practices was stronger as the novelty of the knowledge required increased. The variable *new drug design* revealed more interesting results. This supports previous studies on new product development. Management practices stimulate creativity, risk-taking and exploration; they assist in channelling and increasing the knowledge and skills of the personnel involved (Lund 2004a). In this context, although some evidence is provided on the impact of management practices on R&D for process innovation, further research is needed to extract more concrete conclusions. This is relevant considering that process innovations enjoy a significant share of innovations in developing countries.

With regard to specific personnel management interventions, comments are as follows. Referring to the hypotheses presented in section 3.2.1, some results on specific management variables can be highlighted. The provision of training systematically exerts positive effects on the likelihood that a firm pursues R&D. This supports Domínguez and Brown's (1998) and Samstad and Pipkin's (2005) perception that training and general qualifications of the labour force dictate the type of management practices needed and feasible in countries such as Mexico. Raising skill levels facilitates the adoption of advanced management systems in Mexican firms. A similar conclusion can be drawn for workers' empowerment, the practice was positive, particularly with regard to exploration-related R&D. This is also consistent with previous literature. Increasing the decision-making capacity and encouraging the experimentation of new ideas are key for new product development; they foster creativity and innovation (Mumford, 2000). However, this finding questions the perception that working environments, which are more rigid and have stronger hierarchical structures, relative to more advanced countries, are unsuitable for enhancing performance. Kim and Cha (2000) and Bae

and Rowley (2004) state that research on organizational practices and R&D in developing countries needs be addressed in a more critical manner. It needs to carefully consider the contexts where such practices occur. According to Dávila and Elvira (2007) distinct environments lead to distinct relationships of mutual obligation—supervisor-employees. There is no reason for such differences, relative to more advanced countries, to have a negative impact on firms' performance.

Also limitations on the influence of workers' empowerment on R&D should be recognized. The practice was not significant for knowledge exploitation, although further research is needed to obtain more concrete conclusions. Yet one may speculate these results from the nature of drug manufacturing processes. Concerns over product quality and safety led to close scrutiny and approval by sanitary authorities thereby limiting the capacity to change the processes. It may also require additional review and approval by the regulatory authorities. FDA (2004a and b) recognizes that this can be cumbersome for the firm; it reduces the scope for process innovation in the pharmaceutical industry. Moreovoer, the development of generic drugs is restricted by the need to comply with specific parameters set by the drug innovator. If firms are required only to reproduce the knowledge behind such products, it makes little sense to allow employees to pursue new forms of technology.

The literature review here suggests that remunerations would have a positive influence on learning. Estimates also reveal that raising remunerations increases the probability of a firm to engage in R&D. However, the effect was not robust. It loses significance in models distinguishing between internal and external training. Albeit difficult to corroborate based on data used here, a possible explanation results from the frequent mark-up on pecuniary remunerations, more specifically wages, in countries such as Mexico. Other factors, such as enhanced training and/or promotion opportunities, may be equally or even more relevant as reward mechanisms. Remunerations would underpin learning, but only under certain conditions and for specific types of R&D, namely, knowledge exploration.

Equally intriguing was the finding that regulations on practices, such as staff recruitment, staff promotion or temporary rotation, failed to provide conclusive results. This could reflect the gap between discourse and practice in management approaches in Latin America. Managerial issues are quoted as a key ingredient for success; yet, implementation would be fragmented and lack consistency with stated principles. Considering the limited information at hand, it is difficult to corroborate this hypothesis. The exploratory evidence here suggests other possible lines for research. For instance, no matter how well defined the policies to hire new staff may be, the Mexican market for R&D professionals remains rigid. It is hard to find

people with sufficient knowledge and experience in pharmaceutical research. This includes advanced and applied research techniques aligned with drug manufacturing and design. Even those with PhD degrees would find it unattractive to work for local generic firms, as publishing perspectives would be limited. Firms, in turn, may be unable to fulfil the researchers' economic and professional expectations. Similar to the Indian experience (Kale and Little, 2007), some corrective strategies include the search for talent abroad. However, such practice is limited to a few Mexican firms.

Considering staff promotion, at first sight the results here seem intriguing. Particularly among multinational affiliates, personnel and career development plans, and designing precise succession strategies are of great concern. This notwithstanding, since R&D activities in such firms are limited, opportunities to pursue R&D careers are scarce. In the case of Mexican firms, properly designed plans for staff promotion focus exclusively on small groups of talented people. This may induce some negative incentives for people outside such groups. In the case of rotation assignments, the expected positive influence on knowledge-sharing and diffusion could not be confirmed. Staff rotation may serve very different purposes, but this needs further research. Abramo (1997) points out that staff rotation may help to minimize burn-out and other negative effects associated with highly routined and repetitive jobs. In some Mexican generic manufacturing firms, rotation assignments implied temporary transfers of personnel, from the development unit, for instance, to supporting manufacturing or quality control activities, thereby linking R&D to the daily operation of manufacturing requirements.

The findings here also contradict the usual perception that foreign firms are more technologically dynamic than domestic firms. The choice of performance indicators is very important. In terms of R&D, a careful reflection points to the position that countries, such as Mexico, occupy within business and innovation strategies of multinationals. Local affiliates maintain a low profile when assisting in the exploitation of knowledge generated at the parent location or elsewhere in the developed world (von Zedtwitz and Gassmann, 2002). Acquisition of new knowledge, demanding R&D activities, seldom occurs in developing countries. By contrast, exposure to external competition and larger market opportunities was found to increase the likelihood that a firm pursues R&D. The strongest effect was associated with new drug designs. In line with Kale and Little's (2007) findings, the managing director of an affiliate of Indian origin argued that "Success requires strong commitment of financial and human resources, particularly in research. The goal is to develop a portfolio of products to be launched in export markets over a significant time horizon". In the case of the Mexican industry, strong reliance on the local pharmaceutical market may inhibit incentives to innovate; management strategies would aim to increase productivity and efficiency. In other

words, the adoption of modern organizational practices may contribute to the establishment of what Cimoli (2002) identifies as a 'global modern manufacturing centre'.

7. Conclusions

Efforts made to establish a consistent theory on the relationship between human resource management practices and innovation performance at firm level is at an early stage, since the linkages between those variables are yet to be comprehended. This paper, nevertheless, provides some evidence that management practices influence innovation by stipulating, first, learning and capacity-building through in-house R&D. This is one of the first systematic analyses of the influence of human resource management over learning through R&D in developing countries. Focus on the Mexican pharmaceutical industry illustrates the importance of carefully considering the contexts in which management practices work. Overall, macroeconomic conditions and the social environment around R&D dictate not only what is possible and feasible, but also what can be expected from management interventions. No matter how advanced a well trained and experienced labour force may be, it will generate positive results in terms of innovation only if it is consciously provided with opportunities to do so. The effects of management practices on performance may depend on how countries get involved in and contribute to innovation in specific industries. Learning mechanisms differ among firms and countries.

Pharmaceuticals are highly R&D intensive. The capacity to perform R&D determines the viability and capacity of a firm to grow in the market. In a catching-up context, R&D is intertwined with the capacity to exploit and explore technological and market opportunities. At a basic level of technlogical capabilities, R&D supports the accumulation of knowledge and experience needed to progressively introduce more sophisticated drugs into the market. Recent experiences in India support this argument. In addition, sectoral differences in the nature of R&D lead to distinct knowledge requirements and, consequently, demands on human resources.

From a methodological perspective, the paper highlights the benefits of pursuing research on management practices and innovation. A more careful investigation of the latent processes involved, in this case learning, is necessary. This is already a familiar approach for management scholars interested in understanding how management practices affect creativity and creative thinking. This type of approach could pave the way towards understanding how human factors and their organization within firms could contribute to the building and operation of systems of innovation in both developed and developing countries.

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Annex

Table 1. Correlation analysis of variables on management practices and firm characteristics considered for the analyses

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	*Modern_practice*	1.00													
(2)	*Large_SMEs*	0.07	1.00												
		(0.47)													
(3)	*Expt_large SMEs*	0.14	0.09	1.00											
		(0.14)	(0.33)												
(4)	*FDI_large SMEs*	0.18	-0.14	0.44	1.00										
		(0.06)	(0.14)	(0.00)											
(5)	*Train 04*	0.25	-0.11	0.12	0.13	1.00									
		(0.01)	(0.23)	(0.20)	(0.18)										
(6)	*Training_internal*	0.14	-0.26	0.18	0.19	0.66	1.00								
		(0.14)	(0.01)	(0.05)	(0.04)	(0.00)									
(7)	*External_training*	0.12	-0.27	0.05	-0.02	0.60	0.30	1.00							
		(0.21)	(0.00)	(0.60)	(0.87)	(0.00)	(0.00)								
(8)	*Internal_external_tr*	0.15	-0.32	0.11	0.06	0.74	0.63	0.93	1.00						
		(0.11)	(0.00)	(0.24)	(0.52)	(0.00)	(0.00)	(0.00)							
(9)	*ln_avg_rem*	0.14	-0.50	0.45	0.40	0.14	0.22	0.21	0.26	1.00					
		(0.14)	(0.00)	(0.00)	(0.00)	(0.14)	(0.02)	(0.03)	(0.01)						
(10)	*Imp_empowerment*	0.49	0.05	0.07	0.15	0.12	0.01	0.09	0.07	0.04	1.00				
		(0.00)	(0.64)	(0.49)	(0.11)	(0.21)	(0.96)	(0.35)	(0.43)	(0.67)					
(11)	*Rule_promotion*	0.02	-0.09	0.09	0.04	0.21	0.28	0.10	0.19	0.12	-0.01	1.00			
		(0.85)	(0.33)	(0.32)	(0.66)	(0.03)	(0.00)	(0.28)	(0.04)	(0.21)	(0.95)				
(12)	*Rule_hiring*	0.13	-0.12	-0.01	-0.02	0.15	0.15	0.09	0.13	0.08	0.07	0.53	1.00		
		(0.16)	(0.22)	(0.88)	(0.83)	(0.10)	(0.12)	(0.33)	(0.17)	(0.41)	(0.46)	(0.00)			
(13)	*Rule_temp.rotation*	0.10	-0.02	-0.12	0.04	0.25	0.21	0.10	0.16	-0.05	0.26	0.52	0.48	1.00	
		(0.31)	(0.86)	(0.22)	(0.68)	(0.01)	(0.03)	(0.28)	(0.08)	(0.62)	(0.01)	(0.00)	(0.00)		
(14)	*Rules_HRM*	0.10	-0.09	-0.01	0.02	0.25	0.26	0.12	0.20	0.06	0.13	0.83	0.82	0.81	1.00
		(0.29)	(0.33)	(0.88)	(0.80)	(0.01)	(0.01)	(0.20)	(0.04)	(0.52)	(0.17)	(0.00)	(0.00)	(0.00)	

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.

Table 2. Summary statistics for the pharmaceutical industry in Mexico, 2004

	Mean			Standard deviation		Minimum		Maximum	
R&D in-house	**Internal[3] (I)**	**No R&D[4] (II)**	**(I)/(II)**	**Internal**	**No R&D**	**Internal**	**No R&D**	**Internal**	**No R&D**
Employment	475.7	331.2	1.4	555.2	259.1	1.1	63	3391.5	1158.4
Total sales[1]	694094.8	433261.5	1.6	1270892	694938.1	2394	12127.5	6958020	2297038
Domestic sales	609320.3	394477.4	1.5	1055332	634741.2	2394	0	6334508	2069799
Export share	.07	.08	0.9	.13	.20	0	0	.69	1
Share of FDI	.30	.34	0.9	.46	.48	0	0	1	1
Age[2]	33.2	27.5	1.2	19.4	16.6	1	0	74	70
Improved process	**Imp_proc[5]**	**No R&D[6]**		**Imp_proc**	**No R&D**	**Imp_proc**	**No R&D**	**Imp_proc**	**No R&D**
Employment	492.5	344.3	1.4	589.2	261.3	1.1	63.0	3391.5	1158.4
Total sales[1]	741488.3	427531.3	1.7	1354405.0	641430.5	2394.0	12127.5	6958020.0	2297038.0
Domestic sales	656732.5	375254.1	1.8	1120739.0	583423.9	2394.0	0.0	6334508.0	2069799.0
Export share	0.1	0.1	0.6	0.1	0.2	0.0	0.0	0.6	1.0
Share of FDI	0.3	0.3	0.9	0.5	0.5	0.0	0.0	1.0	1.0
Age[2]	33.2	29.2	1.1	20.6	15.1	1.0	0.0	74.0	70.0
New process	**Mach & quip[7]**	**No R&D[8]**		**Mach & equip**	**No R&D**	**Mach & equip**	**No R&D**	**Mach & equip**	**No R&D**
Employment	655.0	388.3	1.7	804.2	386.7	2.2	1.1	3391.5	2852.9
Total sales[1]	1140099.0	508048.1	2.2	1808071.0	914265.9	31859.5	2394.0	6958020.0	6772189.0
Domestic sales	919528.0	469267.5	2.0	1307236.0	856102.8	31859.5	0.0	4359928.0	6334508.0
Export share	0.1	0.1	1.4	0.2	0.1	0.0	0.0	0.6	1.0
Share of FDI	0.3	0.3	0.9	0.5	0.5	0.0	0.0	1.0	1.0
Age[2]	39.2	30.0	1.3	17.7	18.7	16.0	0.0	74.0	72.0
Improved drug	**Imp_drug[9]**	**No R&D[10]**		**Imp_drug**	**No R&D**	**Imp_drug**	**No R&D**	**IImp_drug**	**No R&D**
Employment	496.6	324.7	1.5	577.4	261.5	1.1	63.0	3391.5	1158.4
Total sales[1]	738053.8	409433.5	1.8	1328800.0	653886.7	2394.0	7717.9	6958020.0	2297038.0
Domestic sales	654131.2	358097.9	1.8	1101783.0	587750.3	2394.0	0.0	6334508.0	2069799.0
Export share	0.1	0.1	0.6	0.1	0.2	0.0	0.0	1.0	1.0
Share of FDI	0.3	0.3	0.9	0.5	0.5	0.0	0.0	1.0	1.0
Age[2]	34.2	26.8	1.3	19.8	15.9	1.0	0.0	74.0	70.0

New drug	**drug_design**[11]	**No R&D**[12]		**drug_design**	**No R&D**	**drug_design**	**No R&D**	**drug_design**	**No R&D**
Employment	526.1	297.4	1.8	592.1	238.0	2.2	1.1	3391.5	1158.4
Total sales[1]	765674.0	403324.4	1.9	1367771.0	631241.8	2394.0	7717.9	6958020.0	2297038.0
Domestic sales	676530.3	356577.6	1.9	1134408.0	564394.8	2394.0	0.0	6334508.0	2069799.0
Export share	0.1	0.1	0.7	0.1	0.2	0.0	0.0	0.7	1.0
Share of FDI	0.3	0.3	0.8	0.5	0.5	0.0	0.0	1.0	1.0
Age[2]	34.6	27.1	1.3	19.9	16.2	1.0	0.0	74.0	70.0
Exploitation	**rd_exploit (I)**[13]	**No R&D II)**[14]	**(I)/(II)**	**rd_exploit**	**No R&D**	**rd_exploit**	**No R&D**	**rd_exploit**	**No R&D**
Employment	475.9	344.3	1.4	560.7	276.6	1.12	63	3391.5	1158.4
Total sales[1]	708400	421951.7	1.7	1291759	665506.5	2394	12127.5	6958020	2297038
Domestic sales	626251.9	372290	1.7	1071360	607670.3	2394	0	6334508	2069799
Export share	.1	.1	1	.1	.2	0	0	.6	1
Share of FDI	.3	.4	0.7	.4	.5	0	0	1	1
Age[2]	33.3	27.7	1.2	19.7	16.1	1	0	74	70
Exploration	**rd_explore**[15]	**No R&D**[16]		**rd_explore**	**No R&D**	**rd_explore**	**No R&D**	**rd_explore**	**No R&D**
Employment	488.1	319.0	1.5	565.6	249.1	1.12	63	3391.5	1158.4
Total sales[1]	705485.3	437609.6	1.6	1292822	693483.2	2394	7717.9	6958020	2297038
Domestic sales	620633.8	393435.2	1.6	1073893	623592.3	2394	0	6334508	2069799
Export share	.1	.1	1	.1	.2	0	0	.7	1
Share of FDI	.3	.3	1	.5	.5	0	0	1	1
Age[2]	33.6	27.2	1.2	19.4	16.7	1	0	74	70

Source: Authors, based on information obtained from ENESTYC 2005, INEGI.

Note: Firms in sample: 112; 1. Thousands of Mexican pesos; 2. difference between the year in which a firm started operations in current business and the year of the survey, 2004; Number of firms: 3. (83); 4. (29); 5. (71); 6. (41); 7. (21); 8. (91); 9. (74); 10. (38); 11. (69); 12. (43); 13. (80); 14. (32); 15. (79); 16. (33); For variable definitions, see table 1.

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26026-0, Fax: (+43-1) 26926-69
E-mail: unido@unido.org, Internet: www.unido.org