

Innovation and productivity in services and manufacturing firms: the case of Peru¹

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Abstract

This article analyses the relationship between investment decisions, investment intensity, innovation outcomes and labour productivity for a sample of services and manufacturing firms from Peru in 2004, on the basis of an adjusted CDM model (Crepon, Duguet and Mairesse, 1998). The estimates of the model indicate that firm size was a key factor in the investment decision. Firm size and investment intensity were also key determinants in increasing, respectively, the probability of producing technological and non-technological innovation outputs and labour productivity across services and manufacturing sectors. By contrast, public financial support seemed to have a stronger effect in terms of investment inducement than in terms of investment intensity in services and low-tech manufacturing firms. These results suggest that horizontal science, technology and innovation (STI) policies that encourage firms to increase STI investment intensity may well produce some gains in firms' labour productivity.

Keywords

Service industries, manufacturing enterprises, investments, science and technology, technological innovations, productivity, Peru

JEL classification

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I. Introduction

Despite the importance of the services sector² in many developing economies in terms of real value and employment,³ studies of the sector and its innovation activities in the Peruvian economy are scant. Most work in this area has concerned the analysis of services exports, in particular in the tourism sector.⁴ A handful of descriptive studies have been carried out on innovation, with an emphasis on the analysis of science, technology and innovation (STI) activities, information and communications technology (ICT), tools (e.g. CONCYTEC/INEI, 2005b; Kuramoto, 2008; Tello, 2010 and 2011) and economic policy (e.g. Comisión Consultiva para la Ciencia, Tecnología e Innovación, 2012; Kuramoto and Díaz, 2010 and 2011; Kuramoto, 2007; Tello, 2010; Sagasti, 2011; and UNCTAD/ECLAC, 2011).

In this regard and on the basis of a survey of STI activities at the firm level conducted by the National Council of Science, Technology and Technological Innovation (CONCYTEC) and the National Institute of Statistics and Informatics (INEI), this paper's main contribution is an analysis, for the first time, of the relationship between firms' investment in STI, innovation results and productivity for the services sector of Peru in 2004 through an adjusted standard Crepon, Duguet and Mairesse (CMD) model (1998). For purposes of comparison, this paper also analyses the same relationship for firms in the manufacturing sector.

The analysis below contains five sections. In section II, the literature is summarized briefly. Section III describes the data sample drawn from the National Science and Technology Survey of 2004 (ENCYT-04) (INEI, 2005). Section IV formulates the structural model of innovation and productivity, and section V presents the results of the estimation. Lastly, section VI outlines the article's main conclusions and provides some reflections on policy to foster STI activities.

II. Brief literature review

In the last two decades, literature on the innovation process, its restrictions and its effects on firms' performance in Latin American countries has emerged⁵ as a consequence of surveys undertaken on STI and ICT at the firm level. Contributions⁶ focused on developed and some developing economies are listed in Mairesse and Sassenou (1991), OECD (2009), Mairesse and Mohnen (2010), Crespi and Zúñiga (2010) and Hall (2011). The dominant methodology in most of these is that proposed by Crepon, Duguet and Mairesse (1998), referred to as the CDM model.⁷ The two main features of the CDM model are, first, the specification of a structural model in which variables such as research and development (R&D) expenditures, innovation outputs and firms' (labour) productivity are interrelated and, second, the use of econometric techniques to deal with selection and simultaneity biases and some statistical features of the available data.

² This sector includes electricity and water; financial and insurance services; government services, households and enterprise services; transport, telecommunications, private health and education services; and hotels and restaurants.

³ According to the World Bank (2013), the services sector accounted, on average, for 59% of gross domestic product (GDP) in 2000-2010 and 77% of total formal employment in 2000-2009.

⁴ Services exports account for about 3% of GDP, meaning that services in Peru are mainly a domestic-oriented industry (Tello, 2012a).

⁵ For example, Crespi and Zúñiga (2010) use six data sets from STI surveys in Argentina (covering the period 1998-2001), Chile (2004-2005), Colombia (2004), Uruguay (2006) and Costa Rica (2008) to analyse the effects of innovation on firms' productivity. Balboni, Rovira and Vergara (2011) use ICT surveys to analyse the effects of ICT on manufacturing firms' performance in Chile, Argentina, Uruguay, Colombia and Peru.

⁶ Pioneers of this literature are the studies of Griliches (1979) and Griliches and Pakes (1980).

⁷ The alternative methodology is based on estimations of total factor productivity (TFP) or labour productivity using panel and/or cross sectional data.

Crespi and Zúñiga (2010) point out that CDM models consists of four stages: a firm's decision to invest in innovation activities;⁸ firms' decisions about the amount of the investment; the production of technological (TI) and non-technological (NTI) knowledge as a result of this investment and the effect of innovation on productivity. These authors also report a list of relevant empirical results concerning the factors included in these four stages. Among others is the fact that firm size, market share and diversification seem to increase the probability of investing in STI activities. Demand pull and technology are push forces that also increase such a probability. Second, firm productivity seems to be correlated positively with innovation output, even after controlling for the skill composition of labour. Third, technological innovation (in products or processes) may lead to increased firm productivity, sales and profits (see Mohnen and Röller (2005) for this conclusion in European firms). Lastly, firms that invest more intensively in R&D are more likely to develop innovations —products, process innovation or patents— after correcting for endogeneity and controlling for firm characteristics such as size, affiliation with a group, or type of innovation strategies (i.e. externalization, collaboration in R&D, and so on).

Evidence with regard to the ability of firms in developing countries to transform R&D into innovation is less clear, however, than in the case of firms in industrialized economies. The results with respect to the impact of innovation on labour productivity are inconclusive for Latin American firms. The failure of R&D to correlate significantly with innovation outcomes and productivity in developing countries could be explained by the fact that firms in developing countries are too far from the technological frontier and incentives to invest in innovation are weak or absent. In many Latin American economies, firms' innovations consist basically of incremental changes with little or no impact on international markets and are based mostly on imitation and technology transfer, such as the acquisition of machinery and equipment, and disembodied technology purchasing. R&D investment is, in many cases, prohibitive (in terms of both financial costs and the human capital needed), and owing to the cumulative effects, it could require longer time horizons to demonstrate results.⁹

In addition to firm characteristics, CDM models also include external forces acting concurrently on firms' innovation decisions. These are traditionally indicators of demand-driven innovation (such as environmental, health and safety regulation), technological push (such as scientific opportunities), innovation policy (including R&D subsidies), and spillovers.

One force pointed out by Álvarez and Crespi (2011) is financial constraints. That credit constraints could severely harm innovation is a longstanding conjecture in the field of the economics of innovation. Innovation is the result of knowledge investments, and there are at least four specific attributes of knowledge that may have important effects on the financing of innovation. The first attribute is the semipublic-good nature of knowledge that prevents innovating firms from excluding others from using the innovations they create. This attribute may explain not only why firms underinvest in innovation but also the constraint on financing innovation. The second attribute is that knowledge investments produce an intangible asset —linked to the human capital (e.g. engineers and technicians) working

⁸ Consistently with the available survey data for Peru, instead of investment in R&D, investment in science, technology and innovation (STI) is used in this paper. This includes expenditures on science and technological (ST) activities (such as research and experimental development, formation of human resources in science and technology and scientific and technological services) and innovation activities (such as research and development, capital investment, hardware and software designed to produce innovation in products, process, organization and commercialization). ST activities are related to the generation, production, dissemination and application of scientific and technical knowledge in all the fields of science and technology. Innovation activities are actions taken by firms with the aim of implementing new concepts, ideas and methods to acquire, assimilate or incorporate new knowledge.

⁹ Raffo, Lhuillery and Miotti (2008) also provide a comparative study of innovation in manufacturing firms from Latin America (Argentina, Brazil and Mexico) and European countries (France, Spain, and Switzerland). They find both structural differences between Europe and Latin America and heterogeneity within each region. In particular, firms tend to engage in innovation activities in order to achieve better economic performance on a similar basis, but their interaction with national systems is weaker in developing countries. Further, subsidiaries of foreign multinationals have a heterogeneous effect on innovation, leading to increased productivity in every country.

in the firm— that might be very difficult to use as collateral. Banks prefer physical assets for securing loans, however, and might be reluctant to lend when the project involves the accumulation of intangible assets, partially embodied in the human capital of firms' employees, that can be lost when they leave the organization. The third attribute is that knowledge investments have tacit components that are idiosyncratic to a firm. That means that a potentially substantial share of investments in STI is sunk and cannot be easily deployed in other activities. The fourth attribute is the uncertainty associated with its outputs. The uncertainty in this case relates to the lack of a well-defined probability distribution of potential effects. In this context, knowledge investments are akin to options, to the extent that some projects with very small probabilities of great success may be worth pursuing even if they do not pass an *ex ante* cost-benefit analysis. All these attributes may have important effects on financing innovation.

Another relevant issue identified in the innovation and productivity literature is the specificity of the productive activities analysed. As pointed out by Tacsir and others (2011), services are not viewed as activities very disposed to innovation, and policymakers from developing economies do not usually treat services as a strategic area in their quest to achieve sustainable growth. This is not the case for developed economies, which increasingly recognize services as a powerful growth-driving sector and a leading job provider (Gallouj and Weinstein, 1997; Gallouj, 2002; Evangelista and Savona, 2003; Cainelli, Evangelista, and Savona, 2006; Crespi and others, 2006; Gallouj and Savona, 2009; Gallouj and Djellal, 2008 and 2010; and European Commission, 2011).

Theoretical, conceptual and empirical analysis of innovation in services in developed countries is reported in Gallouj and Savona (2009), Gallouj and Djellal (2008 and 2010), and Mothe and Nguyen Thi (2010), among others. In their theoretical and conceptual approach, Gallouj and Savona (2009) and Mothe and Nguyen Thi (2010) distinguish between a technologist or assimilation approach (either innovation in services is the adoption and use of technology or services are similar to manufacturing); a service-oriented differentiation or demarcation approach (highlighting the specificities in the service product and production processes whereby service innovation requires specific theories); and the integrative or synthesizing approach (wherein innovation can occur in both services and manufacturing and, given the trend of convergence between manufactured goods and services, supports the development of a common conceptual framework). In this regard, the CDM model applied to services seems to be best aligned with the synthesizing approach.

Turning to the empirical literature on innovation in services (Gallouj and Djellal, 2010; Carayannis, Varblane and Roolah, 2012), the studies indicate that, first, R&D plays only a marginal role in some services and that services firms seldom use patents to protect their innovative output from imitation. Second, a large group of sectors that rely heavily on ICT expenditures are the most innovative after the science-based sectors. These sectors cooperate actively with client industries and firms positioned downstream along the value chain (retail and financial services). Third, a set of poor innovators that aim to introduce cost-cutting and rationalized hardware technologies, which involve ICTs to a small extent, are included in the most traditional service sectors (public services). Fourth, the characteristics of service products and production and delivery processes (as well as firm size), in terms of degree of standardization, were the main variables affecting the propensity to innovate and the type of innovation introduced. Fifth, service firms tend to cooperate and establish "open modes" of innovation and rely on high-level skills and a particular type of human capital, that is, they tend to arise from the humanities and soft disciplines. Finally, despite great sectoral and firm heterogeneity in the service sector, innovation plays a significant role in affecting productivity gains at firm level.

Results of comparative studies on innovation between services and manufactures reported in Tether (2005), Rubalcaba, Gago and Gallego (2010) and Masso and Vahter (2011) point out that firms in services activities do in fact innovate, although it is not clear if their innovation intensity is greater or less than that of manufacturing firms. In contrast to manufacturing, innovation in services seems to be oriented towards organizational change, use collaboration with customers and suppliers,

acquire external intellectual property and emphasize the skills and professionalism of their workforces. Innovation is frequent in knowledge-intensive business services (KIBS) and product innovation is strongly correlated with higher productivity. As in manufacturing, the main determinant of innovation in services is formal knowledge resulting from R&D or from acquisition of equipment, patents or licences. However, as an input in the innovation process, R&D tends to play a much smaller role, on average, in the service sector overall than it does in manufacturing. This may be explained by the fact that in services, R&D is often carried out on a more informal basis.

These studies seem to agree that, notwithstanding large disparities between goods and services, differences between these two sectors overall are, to a certain extent, smaller than the differences among some pairwise service sectors arising from the heterogeneity of service activities.

Interactive aspects of innovation between clients and suppliers are gaining ground within all economic sectors (including services and manufacturing). Evidence in European countries shows that clients may play a highly significant role in the quality impact of services, unlike in goods industries. This growing integration between goods and services opens the door to an interpretation of services-innovation-related studies and policies that considers peculiarities, goes beyond the differences, and focuses on commonalities across all productive activities. Thus, horizontal policy measures may also be used to promote a service-friendly policy, based on treating services innovation as a systemic dimension of any innovative system.

Unlike for advanced economies, literature and empirical evidence on innovation in services for Latin American countries are limited. The literature that does exist indicates the increasing importance of innovation in services (e.g. Garrido, 2009) and that Latin American service firms do innovate, sometimes even more than their manufacturing peers. Further, they often face burdensome financial constraints when seeking to innovate, and these constraints can sometimes be more binding in the service sector than in the manufacturing sector (Llisteri and García-Alba, 2008). This work attempts to fill a gap in this literature by focusing on the interrelationship between innovation and productivity for both manufacturing and services firms in Peru using two CDM models. These models are presented in the following section.

III. Data description

The main data source at the firm level used in this article is the National Survey of Science, Technology and Technological Innovation of 2004 (ENCYT-04) conducted by CONCYTEC and INEI between October and November 2004 (CONCYTEC/INEI, 2005a).¹⁰ ENCYT-04 provides information on science, technology and technological innovation activities for 4,898 firms from 44 sectors of the International Standard Industrial Classification (ISIC Rev. 3). Table 1 summarizes a set of key indicators for a sample of 3,888 firms in the services (2,732) and manufacturing (1,156) sectors.

The estimation of the CDM model is based upon the figures shown in table 1. Services sector firms are divided into KIBS and traditional services and manufacturing firms into high-tech and low-tech firms.¹¹

¹⁰ These institutions recently conducted another survey similar to ENCYT-04, gathering data for 2012 but for manufacturing firms only.

¹¹ KIBS include ISIC code 6, such as transport (by land, water and air), auxiliary transport activities, post and telecommunications, financial intermediation, and insurance and pension funding, as well as code 7, such as computer and related activities, R&D, and other business activities. Traditional services include ISIC branches from codes 3 to 9, such as recycling, electricity, water, wholesale and retail trade, hotels and restaurants, real estate, renting of machinery, health and social work, sewage and refuse disposal, membership organizations, and recreational activities. High-tech manufacturing firms include ISIC codes 2 and 3, such as chemicals, machinery and equipment, electrical machinery, communication equipment, medical and precision instruments, and vehicles and other transport. Low-tech manufacturing firms include ISIC codes 1, 2 and 3, such as food products, beverages, tobacco products, textiles, clothing, leather and footwear, wood, paper, recorded media, refined petroleum, rubber, non-metallic mineral products, base metals, other transport equipment, fabricated metal products and furniture.

Table 1
Peru: STI indicators by firm type, in relation to all firms, 2004
(Percentages)

Industry	Services					Manufacturing				
	Total	KIBS	Traditional	National	Foreign	Total	Low-tech	Hi-tech	National ^a	Foreign ^a
I. Output indicators										
Number of firms	2 732	738	1 994	2 592	140	1 156	954	202	1 071	85
<i>Technological innovation</i>										
Prod.	12.8	17.2	11.1	11.5	35.7	24.6	23.1	31.7	25.6	49.0
Proc.	13.1	16.1	11.9	12.1	31.4	26.0	24.3	33.7	26.3	49.0
Inn. ^b	18.0	23.0	16.1	16.6	44.3	32.9	30.8	42.6	34.5	59.6
In-Hou. ^c	10.0	14.2	8.4	8.9	30.0	19.6	17.9	27.7	20.3	40.4
New ^d	4.7	6.4	4.0	4.4	8.6	9.4	8.9	11.9	10.0	15.4
<i>Non-technological innovation</i>										
Org.	19.6	20.6	19.3	19.1	30.0	22.5	20.1	33.7	22.5	43.3
Mark.	14.4	13.4	14.7	14.1	19.3	15.2	13.5	23.3	15.0	33.7
NTI ^e	23.2	23.4	23.1	22.6	33.6	25.8	23.6	36.1	25.8	52.9
Any In. ^f	28.1	31.3	26.9	26.9	50.7	38.2	35.7	49.5	39.9	68.3
TI/NTI ^g	13.1	15.2	12.3	12.3	27.1	20.5	18.7	29.2	20.3	44.2
II. Input indicators										
STI Ex. ^h	4.9	9.4	2.9	5.2	2.1	4.4	4.3	5.0	4.7	2.5
R&D ⁱ	2.6	3.3	2.2	2.5	3.0	10.2	8.6	16.5	8.9	20.4
STI-K ^j	19.9	16.9	21.2	20.8	11.2	28.8	31.0	22.8	30.1	23.3
O. STI ^k	77.5	79.8	76.5	76.7	85.8	61.0	60.4	61.0	61.1	56.7
R&D F. ^l	5.3	7.1	4.5	5.1	6.6	18.3	15.4	29.7	16.5	32.8
R&D Fc ^m	9.6	11.3	8.9	9.1	18.6	14.8	12.9	23.8	13.7	28.2
III. Policy indicators										
Int M. ⁿ	1.6	2.0	1.5	1.4	5.0	4.8	4.6	5.5	4.3	10.6
Coop. ^o	3.7	4.2	3.6	3.6	7.1	6.6	6.3	5.0	5.8	9.4
Co-U/G ^p	2.1	2.6	1.9	1.9	4.3	3.8	3.9	3.5	3.7	4.7
PS ^q	2.2	3.1	1.8	1.9	7.1	7.9	7.9	15.4	6.5	24.7
Patent. ^r	1.2	0.8	1.4	1.0	4.3	3.9	3.9	6.9	3.8	4.7

Source: Prepared by the author, on the basis of National Council of Science, Technology and Technological Innovation (CONCYTEC)/National Institute of Statistics and Informatics (INEI), *Encuesta Nacional de Ciencia, Tecnología e Innovación Tecnológica (ENCYT-04)*, Lima, 2005.

- ^a The sample of the output indicators for national and foreign firms was 1,196 and 104 firms, respectively.
- ^b Product or process innovation.
- ^c These firms produced innovation of any kind (product, process, marketing and organization) with their own funds and without collaboration from other entities.
- ^d New to market product innovation.
- ^e Organization or marketing innovation.
- ^f Technological or non-technological innovation.
- ^g Technological and non-technological innovation.
- ^h Total expenditures on STI (as a percentage of total turnover).
- ⁱ Expenditure on R&D as a percentage of total expenditure on STI.
- ^j Expenditure on STI capital as percentage of total expenditure on STI.
- ^k Expenditure on other STI activities as a percentage of total expenditure on STI. These STI activities include training, consultancy services, engineering and industrial design, software and technology services.
- ^l Firms that invested in R&D.
- ^m Firms that invested in R&D at any point in the last three years.
- ⁿ Share of firms that were active on international markets.
- ^o Share of firms that cooperated on innovation activities.
- ^p Share of firms that cooperated with universities, higher education institutes or government research institutes.
- ^q Share of firms that received public financial support for innovation.
- ^r Share of firms that applied for one or more patents.

These firms' real value added¹² (at 1994 prices) represented 31.9% of total value added for both sectors in 2004: 33.3% for the services sector and 27.4% for manufacturing.¹³ The main features of the figures in table 1 are the following: first, the share of the number of firms that innovate (either technological and non-technological innovation or both) was greater for manufacturing firms (38.2%) than for services (28.1%). However, services firms did have a greater share of NTI innovation than TI innovation. The opposite was true of manufacturing firms.

The share of foreign-owned firms (i.e. those with more than 10% of capital foreign-owned) that innovate was greater than that of nationally owned firms in both sectors. Second, firms' investment intensity ratio (measured as the share of expenditure on STI activities out of total sales) was slightly higher for services (4.9%) than for manufacturing (4.4%). KIBS and high-tech manufacturing had the highest ratios (9.4% and 5%, respectively). Further, national firms' STI investment ratios were higher than foreign firms in both the manufacturing and services sectors. On the other hand, the share of firms that performed innovation on a continuous basis in manufacturing (14.8%) was higher than in services (9.6%). More than 50% of the total STI expenditures in both sectors went to STI activities related to training, consultancy services, engineering and industrial design, software and technology services.

Third, and from the policy standpoint, firms in general did not collaborate with other entities for innovation purposes. In any case, the share of manufacturing firms that did collaborate (6.1%) was higher than the respective share for services firms (3.7%). The same low shares apply for firms' international exposure, with manufacturing firms showing a higher share (4.8%) than services firms (1.6%). Similar figures are obtained for the share of firms that held patents. A higher share of foreign than domestic firms collaborated with respect to patent applications and international exposure in both sectors. Finally, the share of firms receiving public financial support for innovation was higher for manufacturing (7.9%) than for services (2.2%). Unexpectedly, the share of foreign firms receiving public financial support was greater than the respective share of domestic firms in both sectors.

Summing up, the 2004 figures for firms' STI activities are consistent with Peru's low STI investment indicators, even for 2012. Although a third of the interviewed firms in the sample do not perform STI activities, the average amount spent on these activities per worker in both sectors was US\$ 2,353 (in constant 1994 dollars), which is less than US\$ 6.5 dollars per day per worker. The extent to which this small amount affects firms' performances (such as labour productivity) is investigated in the following sections.

IV. CDM models and estimation strategy

The CDM model to be estimated has the following equations:

$$ID^*_i = X_{1i} \cdot b_1 + a_1 \cdot FC_i + e_{1i}; \text{ where if } ID^*_i > \mu_i \text{ then } D_{IDI} = 1; \text{ otherwise } D_{IDI} = 0; \quad (1)$$

$$IE^*_i = X_{2i} \cdot \beta_2 + \alpha_2 \cdot FC_i + e_{2i}; \text{ where } IE^*_i = IE_i \text{ si } ID^*_i \geq \mu_i; \text{ i.e., } D_{IDI} = 1; \text{ otherwise } IE^*_i = 0; \quad (2)$$

$$TI^*_i = \delta \cdot IE^*_i + X_{3i} \cdot \beta_3 + \varepsilon_{3i}; \text{ where } D_{TII} = 1 \text{ si } TI^*_i > 0, D_{TII} = 0 \text{ otherwise } D_{TII} \text{ is zero}; \quad (3)$$

$$NTI^*_i = \delta \cdot IE^*_i + X_{4i} \cdot \beta_4 + \varepsilon_{4i}; \text{ where } D_{TII} = 1 \text{ si } TI^*_i > 0, D_{NTI} = 0 \text{ otherwise } D_{TII} \text{ is zero}; \quad (4)$$

$$\ln Prod_i = \varphi_1 \cdot TI^*_i + \varphi_2 \cdot NTI_i + \varphi_3 \cdot IE^*_i + X_{5i} \cdot \beta_5 + \varepsilon_{5i} \quad (5)$$

¹² Firms' value added comes from sales data. These are obtained using the average ratio of value added over value of production of the respective ISIC sector from the input output tables of 1994 and 2007 provided on a preliminary basis by INEI.

¹³ For the four ISIC groups, the shares of the real value of the firms out of the respective real value of the universe were: for KIBS, 21.19%; for traditional services, 43.79%; for high-tech firms, 22.44%; and for low-tech firms, 27.37%. In the case of formal employment, the figures are KIBS, 12.53%; traditional services, 18.87%; low-tech manufacturers, 24.25%; and high-tech manufacturers, 23.56%.

Table 2 shows a list of the dependent and X_{ji} variables and data sources used to estimate the set of equations in this model. Most of the X_{ji} variables are taken from Crespi and Zúñiga (2010). Equation (1) corresponds to the decision of firm i to invest in STI activities and this is represented by ID^*_i . Specifically, a firm decides to invest if ID^*_i is greater than zero or on the threshold, μ_i . Note this latent variable is positive if the firms have in fact invested in STI, i.e. if the dummy variable $D_{ID^*=1}$. X_{1i} is the set of factors that affects the appropriability aspect of firms' decisions to invest in STI. These are the following: firm size (represented by the number of workers), a dummy for export firms (D_x), another for foreign firms with capital share greater than 10% (FO) and a last one for patent protection ($PatenP$, if firms had patents during the period 2002-2004).

Table 2
List of variables and data sources of the CDM model

Name	Description	Source
ID	Dummy variable with value of one for firms that decided to invest in STI activities, otherwise zero.	CONCYTEC/INEI (2005), section VI.1, item 42.h
Dx	Dummy variable with value of one for firms exporting for at least two years between 1993 and 2004, otherwise zero.	SUNAT (2012)
FO	Dummy variable with value one for firms with more than 10% of the total capital foreign owned; otherwise zero.	Peru Top Publication (2000-2007)
InSize	Natural logarithm of the number of workers in a firm.	CONCYTEC/INEI (2005), section I, item 22
PatenP	Dummy variable with value of one for firms with patents, otherwise zero.	CONCYTEC/INEI (2005), section VI.1, item 48
PFS	Dummy variable with value equal to one for firms having public financial support, otherwise zero.	CONCYTEC/INEI (2005), section II, items 2, 3 and 4, Section XI, item 42.a; section II, item 1.b
FC	Dummy variable with value of one for firms that declared that credit constraints were an important obstacle to innovation, otherwise zero.	CONCYTEC/INEI (2005), section VI.1, item 46.h
Dcoord	Dummy variable with value of one for firms that coordinated with other entities, otherwise zero.	CONCYTEC/INEI (2005), section VI, item 49
INFO ₁	Dummy variable with value of one for firms using Internet to search for information on products and processes, otherwise zero.	CONCYTEC/INEI (2005), section V, item 5.1
INFO ₂	Dummy variable with value of one for firms using Internet for research activities, otherwise zero.	CONCYTEC/INEI (2005), section V, item 5.1
INFO ₃	Dummy variable with value of one for firms using Internet for information on government institutions, otherwise zero.	CONCYTEC/INEI (2005), section V, item 5.1
InIE	Natural logarithm of firms' real value of STI investment over the number of workers.	CONCYTEC/INEI (2005), section II, items 2, 3 and 4, Section XI, item 42.a; section II, item 1.b
InIE ^e	Predicted value of InIE from Heckman's estimation of equation (2).	CONCYTEC/INEI (2005), section II, items 2, 3 and 4, Section XI, item 42.a; section II, item 1.b
D _{control}	Dummy variable with value of one for firms with zero k, otherwise zero.	
In(k+1)	Natural logarithm of firms' real value of capital expenditure per worker plus one.	CONCYTEC/INEI (2005) section II, item 31
InProd	Natural logarithm of firms' real value per worker.	CONCYTEC/INEI (2005) section I, items 22 and 23
TI	Dummy variable with value of one for firms having technological innovation, otherwise zero.	CONCYTEC /INEI (2005), section VI.1, item 44.h
NTI	Dummy variable with value of one for firms having non-technological innovation, otherwise zero.	CONCYTEC/INEI (2005), section VI.1, item 44.h

Source: Prepared by the author.

These variables are consistent with several arguments considered in the literature (e.g. Crepon, Duguet and Mairesse, 1998; Braga and Willmore, 1991; Kumar and Aggarwal, 2005; Álvarez, 2001; Cohen and Klepper, 1996; Benavente, 2006; Crespi and Peirano, 2007; Girma and Görg, 2007). Equation (2) is the firm STI investment intensity measured by STI expenditure per worker. If the firm decides to invest, IE^*_i would be the same as the actual STI expenditure per worker IE_i , otherwise IE^*_i would be zero. X_{2i} is the set of factors that influences the firm's STI investment intensity. This set will be equal to X_{1i} plus the following dummy variables: public financial support (PFS), market information

sources ($INFO_1$), scientific information sources ($INFO_2$), government institutions information ($INFO_3$) and the degree of coordination, cooperation, or collaboration between firm i and other entities (D_{coord}).

Such factors are found in several studies for Latin America, for example, for Mexico and Argentina (Raffo, Lhuillery and Miotti, 2008). Although arguments based on size (for example, exploitation of scale and scope economies) point out that size affects the investment intensity equation, empirical evidence demonstrates that it may affect investment decisions but not the intensity of STI investment. For that reason and for identification purposes, in this paper, size is included in equation (1) and excluded from equation (2). The Peruvian evidence shown below for the marginal effects of both equations supports these changes. Finally, the analysis of financial constraints supports the inclusion of this constraint in both equations (1) and (2).

Equations (3) and (4) represent the outcomes of the technological (TI^*i) and non-technological (NTI^*i) innovation process or the expected returns on innovation. The latent variables TI^*_i and NTI^*_i are positive if firms, in fact, have innovation outputs, i.e. if the dummy variable $D_{TI=1}$ or $D_{NTI=1}$.¹⁴ Both outputs are determined by IE^*_i and the set of factors $X_{3i}=X_{4i}$. The variables of this set include size and the two dummy variables of exports and foreign ownership. Hahn and Park (2010), Hanley and Monreal-Pérez (2011) and Ito (2011) present the argument for and evidence of a relationship between exports and innovation; evidence of the other two factors, foreign ownership and size, is provided by Crespi and Zúñiga (2010).

Equation (5) is the labour productivity of a firm (measured by firms' real value added per worker) determined by both technological (TI) and non-technological innovation (NTI) outputs, investment in STI, and X_{4i} , which includes size and the ratio capital stock per worker, $lnki$ (in natural logarithm). Although the measurement of productivity has a variety of shortcomings, not only in products (Tybout, Katayama and Lu, 2009; Syverson, 2011) but also in services (Dean and Kunze, 1992; Griliches, 1992; Crepon, Duguet and Mairesse, 1998; Gallouj and Djellal, 2008; Gallouj and Savona, 2009; Crespi and Zúñiga, 2010; Biege and others, 2011), in this work, labour productivity was measured as the real value added (or net sales)¹⁵ per worker.¹⁶

In the estimations, quantity variables such as size, productivity and investment expenditure are transformed into natural logarithms. The rest of the variables (which are binary) are not transformed. In addition, branch heterogeneity of the four ISIC (Revision 3) groups is introduced through a binary variable $ISIC_n$, where n is the first digit of the ISIC branch. Note that for each group of firms, one ISIC branch is included in the constant to avoid problems of collinearity.

Given these transformations and dummy variables, the econometric strategy is composed of the following steps: first, investment decision and intensity equations are estimated using a generalized Tobit model estimation (or Heckman maximum likelihood estimation, assuming a normal joint distribution for the error terms of both equations). For the purposes of robustness, the two-step Heckman procedure or Heckit estimator (which assumes conditional normal distributions for the error term) was estimated, although this is not reported owing to space limitations. The size variable included in the ID^* equation and excluded in IE^* equation allows identification of both equations. In addition PPS , D_{coord} and the set of information variables reinforce the identifications of the parameters of both equations. Further,

¹⁴ NTI is a dummy variable equal to one if firms show innovation output results on commercialization and organization, otherwise zero.

¹⁵ Value added is obtained using the average ratio of value added over the value of production of the respective ISIC sector of the input output table for 1994 and 2007, which is provided on a preliminary basis to INEI.

¹⁶ The common problems associated with productivity and output measures are related to the relevant price deflators for computing real values and measures of product quality. In the services sector, measures of output will be restricted to the amount in value (sales or value added) of the transaction (following Griliches, 1992, and Gallouj and Savona, 2009). The characteristics of services output represented by the so called IHIP-criteria (intangibility, I; heterogeneity, H; inseparability, I; and perishability, P) and other considerations (for example in KIBS) pointed out by Biege and others (2011) (such as the innovativeness of the output; the "internal output", input figures and knowledge) will not be taken into account due to restrictions in the data.

to avoid spurious results in equations (1) and (2), firms that did not invest in STI activities and responded that they did not have any restrictions on innovation output were eliminated from the sample.¹⁷

Second, both innovation outputs, which involve equations (3) and (4), are estimated using probit (maximum likelihood estimation, MLE) estimation (when equation errors are assumed to be uncorrelated). Also, no reported bivariate probit (when equation errors are assumed to be correlated) estimation gave similar results to the probit estimation. Further to avoid potential endogeneity of the STI investment intensity, predicted values from the estimated STI investment intensity equation were also used instead of the actual values of *IE*. In such cases standard errors are estimated by bootstrapping.

Third, productivity, equation (5), is estimated using least squares estimations with bootstrap standard errors whenever predicted value for TI, NTI and IE were used as exogenous variables. These estimations are not reported although the results do not vary from those reported in table 7. Finally, to avoid the reduction of the sample size for each sector for firms with no information on k_i , the variable $\ln k_i$ is replaced by $\ln(1+k_i)$ plus a control dummy ($D_{control}$ equal to one when $k_i = 0$, otherwise zero). In addition, collinearity problems were avoided by not including TI, NTI, and IE (actual or predicted value) all together in the estimation of the labour productivity equation.¹⁸

V. Estimation and results

Tables 3 to 7 show the regression coefficients and statistics of the estimation methods implemented for the set equations of the model using the sample described in the data description section.¹⁹ The estimates for equation 1 indicate that only size (in its uncensored version) seems to affect firms' investment decision on STI activities in all the branches, although the marginal or censored effects for firms that decided to invest were not statistically significant. On the other hand, financial constraint²⁰ seems to have limited investment decisions only for traditional services. Nonetheless, once firms decided to invest, the effect of this constraint was not statistically significant.²¹ The coefficients of the rest of factors were not statistically significant.

The econometrics results are more varied for the STI investment intensity, equation (2). Thus, the fact of being an export firm, public financial support, financial constraints and coordination with other entities were statistically important factors in the amount of STI investment for firms in the traditional services branches. The former two factors helped to increase the investment intensity and the last two to reduce it. However, once a firm decided to invest, only the coordination marginal coefficient was statistically significant and helped to reduce the amount of investment in STI activities. For KIBS and low-tech manufacturing branches, public financial support was the most important and statistically significant factor. Once again, the respective marginal coefficients were not significant.

¹⁷ The author wishes to thank Gustavo Crespi for providing insight on this sample reduction. With this elimination, the sample in the selective and investment intensity equations is reduced to 2,896 firms.

¹⁸ It should be noted that in the KIBS ISIC group, 10.2% firms produced only TI, 13% produced only NTI and 18% produced both TI and NTI. In traditional services, the respective shares were 6%, 16% and 17%. In high-tech manufacturing, the respective shares were 15%, 7% and 35%, and in low-tech manufacturing, 16%, 7% and 24%.

¹⁹ The sample is biased towards medium-sized and large firms with an average of 68 workers each for the basic model and 79 for the extended model. Because, in general, these firms may have a higher probability of investing in STI activities, the estimated coefficients could be overestimated with respect to coefficients coming from a sample with larger firms.

²⁰ The shares of firms with financial constraints (reporting these as a major obstacle to innovation) out of total firms for each ISIC group were 21.2% for KIBS, 18.5% for traditional services, 34.3% for high-tech manufacturing firms, 29.4% for low-tech manufacturing firms, and 22.9% for services and manufacturing overall.

²¹ The results using the Heckman two-step procedure estimation (i.e. Heckit) not reported were much better for the investment decision equation. Thus, the censored and uncensored coefficients of firm size were statistically significant for all the sectors. On the other hand, the censored or marginal coefficients of public financial support and patent protection were statistically significant for all the sectors. The exporter and foreign ownership dummy variables were either not significant or of doubtful statistical significance. Finally, the coefficient of financial constraint was also statistically significant for traditional services.

In addition, for KIBS, the respective censored and uncensored coefficients were statistically significant for firms using the Internet for information searches on products and processes (INFO₁), research activities (INFO₂) and information on government institutions (INFO₃). For the first two uses of the internet, firms using that information had a higher level of investment intensity, and for the third one, firms using this information had spent less on investment on STI activities.

Table 3

Censored (C) and uncensored (U) coefficients of the selective (observed) equation (1) on firms' decision to invest in STI, by firm type: generalized Tobit (Heckman selection)

Sectors Var.	KIBS		Traditional services		High-tech manufacturing		Low-tech manufacturing	
	C	U	C	U	C	U	C	U
Dx	0.033	0.083	-0.001	-0.001	-0.037	-0.318	0.022	0.065
FO	-0.046	-0.116	-0.1054	-0.136	-0.079	-0.508	0.057	0.170
ISIC ₁							-0.008	-0.023
ISIC ₂					-0.005	-0.041	-0.028	-0.080
ISIC ₃			-0.460	-5.832				
ISIC ₄			-0.058	-0.147				
ISIC ₅			-0.012	-0.031				
ISIC ₇	-0.046	-0.116	-0.128	-0.332**				
ISIC ₈			0.170	0.430*				
FC	-0.077	-0.193	-0.125	-0.321***	-0.024	-0.192	-0.025	-0.070
PFS	0.563	6.158	0.601	5.406	0.333	6.522	0.488	6.377
PatenP	0.483	5.468	0.588	6.413	0.143	6.354	0.395	6.484
lnSize	0.112	0.282***	0.103	0.260***	0.071	0.607***	0.072	0.208***
Const.		-0.99***		-0.914***		-1.67***		-0.86*
Observ.	539	539	1 411	1 411	178	178	768	768
ρ		0.610**		0.873***		0.221		0.158
σ		2.171		2.512		1.630		1.960
λ		1.326		2.193		0.361		0.309
Pred. V.	0.541		0.453		0.941		0.701	
Obs. V.	0.445		0.393		0.567		0.465	

Source: Prepared by the author.

Note: * 10% level of significance; **5% level of significance; *** less than 1% level of significance.

Table 4

Censored (C) and uncensored (U) coefficients of the STI investment intensity output (observed) equation (2), by firm type: generalized Tobit (Heckman selection)

Sectors Var.	KIBS		Traditional services		High-tech manufacturing		Low-tech manufacturing	
	C	U	C	U	C	U	C	U
Dx	0.555	0.621	0.670	0.668**	0.100	0.076	-0.121	-0.111
FO	0.232	0.136	0.435	0.233	-0.615	-0.663	0.375	0.401
PFS	1.748	2.943***	0.676	2.796***	0.447	0.644	0.486	0.727*
Dcoord	-0.560	-0.560	-0.475**	-0.475**	0.450	0.450	0.313	0.313
INFO ₁	1.136**	1.136**	0.178	0.178	-0.612	-0.612	0.443	0.443
INFO ₂	0.723**	0.723**	0.278	0.278	0.779*	0.779*	-0.055	-0.055
INFO ₃	-1.066**	-1.066**	0.240	0.240	-0.098	-0.098	-0.441	-0.441
ISIC ₁							-0.244	-0.247
ISIC ₂					-0.036	-0.039	0.128	0.116
ISIC ₂			13.969	2.501				
ISIC ₄			0.550	0.332				
ISIC ₅			0.047	0.002				

Table 4 (concluded)

Sectors Var.	KIBS		Traditional services		High-tech manufacturing		Low-tech manufacturing	
	C	U	C	U	C	U	C	U
ISIC ₇	-0.115	-0.210	-0.121	-0.621				
ISIC ₈			-0.207	0.374				
FC	-0.372	-0.532	-0.243	-0.722**	0.129	0.114	-0.244	-0.255
PatenP ^a	0.540	1.561	-2.070		0.587	0.682	-0.197	
lnSize	-0.229		-0.378		-0.046		-0.033	
Const.		4.516***		3.381***		6.090***		5.910***
Obser.	539	539	1 411	1 411	178	178	768	768
Pred. V.	5.786		5.637		6.062		5.978	

Source: Prepared by the author.

Note: *10% level of significance; **5% level of significance; ***less than 1% level of significance.

^a The patent protection variable (PatenP) was excluded from traditional services and low-tech manufacturing owing to concavity problems in the log-likelihood function.

Finally, for high-tech manufacturing firms, only the censored and uncensored coefficients of Internet use for research activities were statistically significant for investment in STI activities.

Those firms that used this kind of information show higher investment amounts.²² In the case of the estimates of innovation, equations (3) and (4), the results were more uniform across branches than they were for equation (2).

Table 5
Marginal coefficients of the (observed) technological innovation output equation (3),
by firm type: Probit method

	KIBS		Traditional services		High-tech manufacturing		Low-tech manufacturing	
lnIE	0.108***		0.062***		0.169***		0.146***	
lnIE ^a		0.139***		0.125***		0.348**		0.368***
lnSize	0.055***	0.087***	0.039***	0.041***	0.175***	0.166***	0.068***	0.064***
Dx	0.022	-0.044	0.025	-0.028	-0.091	-0.051	0.062	0.100***
FO	0.041	-0.040	0.014	0.008	-0.167	-0.017	0.028	-0.115*
ISIC ₁							0.028	0.081
ISIC ₂					0.073	0.008	0.027	-0.043
ISIC ₃			0.059	-0.170***				
ISIC ₄			-0.019	-0.026				
ISIC ₅			-0.052	-0.092**				
ISIC ₆				-0.343***				
ISIC ₇	0.049	0.068	-0.033	-0.006				
ISIC ₈			0.193*	0.131				
Obser.	539	586	1 411	1 534	178	200	768	874
Pred. Prob	0.172	0.334	0.144	0.340	0.397	0.412	0.279	0.305

Source: Prepared by the author.

Note: *10% level of significance; **5% level of significance; ***less than 1% level of significance.

^a Predicted with the Heckman method and with bootstrapping standard errors for the independent variable.

²² Estimations not reported using the Heckit method produced more robust coefficients for public financial support. Other factors were also more important under the Heckit estimation. Thus, coefficients of financial constraint were statistically robust for both ISIC services branches (and manufacturing and services sectors as a whole). Analogously, the effect of the patents protection variable on STI investment intensity was statistically significant for traditional services, services as a whole, low-tech manufacturing, manufacturing as a whole, and for all sectors (manufacturing and services as a whole). Finally, the fact of being an export firm affected STI investment intensity positively. The rest of the factors were either not robust or not statistically significant.

Table 6
Marginal coefficients of the (observed) non-technological innovation output equation (4),
by firm type Probit method

	KIBS		Traditional services		High-tech manufacturing		Low-tech manufacturing	
lnIE	0.097***		0.133***		0.169***		0.082***	
lnIE ^a	0.064***		0.151***		0.128**		0.081	
lnSize	0.030**	0.065***	0.062***	0.054***	0.175***	0.114***	0.034***	0.060***
Dx	-0.094*	-0.086	-0.095***	-0.101***	-0.091	-0.082	-0.046	-0.014
FO	-0.119**	-0.118*	-0.166***	-0.110***	-0.167	0.020	0.070	0.103
ISIC ₁							-0.061	-0.048
ISIC ₂					0.073	-0.048	-0.115	-0.103
ISIC ₃								-0.313***
ISIC ₄			-0.012	-0.083				
ISIC ₅			0.0896*	0.022				
ISIC ₆								
ISIC ₇	-0.0635	-0.048	0.011	0.010				
ISIC ₈			0.044	0.019				
Obser.	539	586	1 407	1 534	178	200	768	874
Pred. Prob	0.230	0.334	0.199	0.340	0.397	0.412	0.200	0.305

Source: Prepared by the author.

Note: *10% level of significance; **5% level of significance; ***less than 1% level of significance.

^a Predicted with the Heckman method and with bootstrapping standard errors for the independent variable.

Thus, the coefficients of investment intensity and size were positive and statistically significant for the four groups of branches and both types of innovation.²³ Furthermore, among low-tech manufacturing firms, export firms seemed to have a higher probability of producing TI innovation than domestic-market-oriented firms. Conversely, foreign firms are less likely to produce TI innovation than national firms within this category of manufacturing. In the case of KIBS and traditional services, domestic and national firms seemed to have a higher probability of producing NTI innovation than exporter and foreign firms.²⁴

Finally, the estimates of the last equation, (5), produced one robust result for practically all the ISIC groups; the capital-labour ratio was the most important and statistically significant factor for firms' labour productivity. Investment intensity was also more important for the ISIC groups than the high-tech manufacturing firms.²⁵

²³ Practically the same results were obtained with the predicted values of *lnIE* using the Heckit method.

²⁴ Note that traditional services include export traders of primary export goods. When the predicted values of *lnIE* were estimated with the Heckit method, the results of size and investment intensity for NTI and TI equations were similar. However, for the NTI equation, the negative effect of exporters was not robust statistically and foreign ownership also affected firms in KIBS.

²⁵ The effects of TI and NTI for all the ISIC services branches and low-tech manufacturing were statistically robust and positive when predicted values of the TI variables were estimated with the Heckit method for the extended model. The statistical significance of the rest of the factors is similar to the results found using the Heckman method.

Table 7

Regression coefficients of labour productivity equation (5), with bootstrap standard errors for predicted values using Heckman estimation: extended model

	KIBS				Traditional services			
lnSize	-0.022	-0.025	-0.008	-0.037	-0.183***	-0.180***	-0.183***	-0.190***
ln(k+1)	0.138***	0.138***	0.139***	0.119***	0.231***	0.229***	0.230***	0.236***
D _{control}	0.646**	0.639**	0.643**	0.496	1.374***	1.359***	1.373***	1.475***
TI	0.214*	0.153			-0.006	0.033		
NTI	-0.142		-0.056		0.081		0.079	
lnIE				0.034**				0.039***
ISIC ₃					0.568	0.558	0.567	0.345
ISIC ₄					1.217***	1.218***	1.217***	1.137***
ISIC ₅					1.445***	1.450***	1.445***	1.453***
ISIC ₇	-0.282***	-0.273***	-0.264**	-0.207*	0.168	0.165	0.169	0.186
ISIC ₈					-0.454*	-0.453*	-0.455*	-0.477*
Const.	9.247***	9.231***	9.239***	9.374***	8.550***	8.571***	8.550***	8.407***
Obs.	570	570	570	524	1 474	1 474	1 474	1 357
Adj- <i>R</i> ²	0.0455	0.0447	0.0420	0.0440	0.234	0.234	0.234	0.240
<i>R</i> ²	0.0556	0.0531	0.0504	0.0532	0.239	0.238	0.239	0.245
	High-tech manufacturing				Low-tech manufacturing			
lnSize	0.033	0.031	0.034	0.012	-0.001	0.002	0.001	-0.011
ln(k+1)	0.104*	0.103*	0.103*	0.087	0.187***	0.184***	0.187***	0.198***
D _{control}	0.758*	0.753*	0.755*	0.648	1.062***	1.043***	1.059***	1.170***
TI	0.006	-0.027			0.053	0.094		
NTI	-0.062		-0.059		0.092		0.119	
lnIE				0.002				0.039***
ISIC ₁					-0.163	-0.169	-0.160	-0.260
ISIC ₂	0.123	0.125	0.123	0.177	0.153	0.143	0.157	0.049
Const.	8.862***	8.860***	8.864***	8.996***	8.253***	8.283***	8.259***	8.244***
Obs.	189	189	189	167	836	836	836	735
Adj- <i>R</i> ²	-0.00886	-0.00410	-0.00336	-0.0124	0.0978	0.0977	0.0984	0.114
<i>R</i> ²	0.0233	0.0226	0.0233	0.0181	0.105	0.104	0.105	0.121

Source: Prepared by the author.

Note: *10% level of significance; **5% level of significance; ***less than 1% level of significance.

VI. Conclusions

The area of science, technology and technological innovation in the Peruvian economy has been of low priority for institutional policymakers over the past decade. The STI system, the National System of Science Technology and Innovation (SINACYT), has been institutionally disjointed, focusing on particular programmes and funds aimed at fostering firms' innovation activities in primary and manufacturing sectors without a specific and previously designed innovation strategy. STI in services was directed mainly towards providing ICT infrastructure under the principles of universal access, affordability, fostering private competition, and technological convergence in concordance with the evolution and development of ICT.

Based on data from a 2004 STI survey of firms (CONCYTEC/INEI, 2005a), robust evidence of the positive effects of firms' science, technology and innovation activities on the labour productivity of services and manufacturing firms in Peru was presented. Affording greater priority to STI policy

and its effective implementation in Peru could thus improve the poor performance of the past decade and spur productivity growth (Tello, 2012b). Two CDM models were estimated with methods that overcome selection and endogeneity problems.

The statistical results in general partially support some of the hypotheses found in the literature. Specifically, firm size seems to be a key determinant for decisions to invest in STI activities in all the seven ISIC groups considered in the analysis. However, for those firms motivated to invest, patent protection, particularly for manufacturing firms, was a determining factor for effective investment. At the same time, financial constraints influenced firms' decisions to invest or not in STI activities only in the traditional services ISIC group. Further, for those firms that decided to invest in STI activities, the statistical significance of financial constraints vanished, implying that the financial factor was a major restraint only for firms that ultimately did not invest. Second, although public financial support seems to increase the latent variable of firms' investment intensity for most of the ISIC groups (with the exception of firms from high-tech manufacturing branches), the effect on the actual investment intensity (measured through the expenditures on STI activities per worker) was not statistically significant for firms that invested in STI activities. This means that public support policies seem to have more of an inducement effect (making non-spending firms spend) than an intensive margin effect (increasing intensity by firms already spending). The same result is obtained for financial constraints in the traditional services ISIC group. The effect of other factors on firms' STI investment intensity was also statistically robust for some ISIC groups. Specifically, Internet information on products and processes for KIBS and services as whole and for all (manufacturing and services) firms in the sample; Internet information on research activities for KIBS, high-tech manufacturing, traditional services and both sectors (services and manufacturing) overall; and firms' coordination with other entities on innovation purposes for traditional services and total services.

Third, across all the ISIC groups, firm size and investment intensity were the key determinants for producing both technological and non-technological innovation outputs. In some ISIC groups (such as services and low-tech manufacturing), domestic-market-oriented and national firms had a higher probability of producing technological and non-technological innovation outputs than did exporters and foreign-owned firms. This result may indicate a greater need to produce technological changes in order to compete with export and foreign firms in the first group of firms. Last, capital per worker and STI investment intensity affected the labour productivity of firms positively for most of ISIC groups (with the exception of the high-tech manufacturing group).

From the perspective of economic policy, these results suggest that horizontal STI policies (at least for services and manufacturing branches) that encourage firms to increase their STI investment intensity may well produce some gains in firms' labour productivity. However, given that innovation outputs showed no statistical effect on productivity, it appears necessary to conduct a detailed, micro-level analysis of what firms consider innovation output and to obtain information about the kinds of innovation outputs that can increase labour productivity. Finally, the fact that most firms' STI activities are undertaken in an isolated fashion —i.e. production of innovation of any kind, whether product, process, marketing or organizational, is carried out with firms' own funds and without collaboration from other entities— and the statistical non-significance of the effect of firms' coordination with other entities on STI investment intensity indicate the need to exploit firms' interactions with other firms, research institutions and government in order to increase the probability of producing innovation²⁶ and reducing firms' STI expenditure per worker.

²⁶ See this result in Tello (2011).

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