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Mario D. Tello

ABSTRACT

Based upon a standard Crepon, Duguet and Mairesse (1998), CDM, model and data at firms' level, this paper analyzes the interrelationship between firms' science, technology and innovation (STI) activities and their labor productivity in Peru for the year 2004. The effects of some constraints (i.e., investment innovation risks, market structure distortions and financial constraints) on firms' decision and amount of investment on STI (or STI investment intensity) are also estimated. Subject to data limitations, the analysis suggests that firms' size is an important factor in their decision to invest upon STI activities. In the same way, firms' market share is a key factor in the determination of the level of investment on STI. On the other hand, investment risks and financial restriction seem to affect negatively to firms decision and amount of investment on STI respectively. However, their statistical effects vary among the six ISIC branches considered. The effects of market structure or anticompetitive practices were not clear in sign and statistical significance. Regarding the factors that foster innovation outputs or outcomes (such as new products, processes, commercial and organizational innovations) firms STI investment intensity, their degree of cooperation (collaboration) with other entities and the endowment of STI infrastructure are important factors that promote innovation outputs. Finally, although capital-labor ratio and human capital were determinants factors of firms' labor productivity the effects of innovation outputs on labor productivity were not statistically significant or robust.

RESUMEN

Basa en un modelo estándar modelo CDM (debido a Crepon, Duguet y Mairesse, 1998) y datos a nivel de firmas, este trabajo analiza la interacción entre actividades de ciencia, tecnología e innovación (STI) y la productividad laboral para el año 2004. También se estimaron los efectos de restricciones financieras, riesgos de la innovación y distorsiones en la estructura del mercado sobre las decisiones de actividades STI de las firmas. Las estimaciones indican que el tamaño de las firmas es un importante factor en las decisiones de las firmas en invertir en actividades STI. La participación de la firma en el marco fue otro factor determinante en la intensidad o el monto de inversión en dichas actividades. De otro lado, las restricciones financieras y los riesgos de la innovación afectaron negativamente a las decisiones y montos de inversión en actividades STI. Estos efectos, sin embargo varían de acuerdo al sector CIIU. No fueron claro los efectos de las prácticas anticompetitivas. Los resultados de la innovación (tales como nuevos productos, procesos, formas comerciales y organizaciones novedosas) fueron influenciados por la cooperación de firmas con otras entidades y la infraestructura para las actividades STI. Estos resultados no fueron importantes en influenciar las productividad laboral de las firmas aunque si lo fueron el ratio capital-trabajo y en menor medida el capital humano.

JEL: L6, O31

Key words: Science, technology and innovation, labor productivity and technological innovation, CDM model.

FIRMS' INNOVATION, CONSTRAINTS AND PRODUCTIVITY: THE CASE OF PERU

Mario D. Tello[1]

INTRODUCTION

In contrast to international literature (e.g., Crepon, Duguet and Mairesse, 1998; Crespi & Zuñiga, 2010; Hall, 2011), analysis of the impacts of innovation on firms' performance are scanty for Peruvian economy. In general, innovation studies of Peru have been concentrated on descriptive analysis of science, technology and innovation activities (STI) and information and communications technology (ICT) indicators (e.g., CONCYTEC, 2005, Kuramoto, 2008 and Tello, 2011 and 2010), as well as analysis on STI policy (e.g., CTI, 2012; Kuramoto & Diaz, 2010 and 2011; Kuramoto, 2007; Tello, 2010; Sagasti, 2011 and UNCTAD-ECLA, 2011)[2]. The only study of the role innovation upon firms' economic performance has been reported by Tello (2011b) for manufacturing firms.

Based upon a survey on STI activities at firms level implemented by the National Council of Science and Technology (CONCYTEC) and the National Institute of Statistics and Computation (INEI), this paper analyzes the interrelationship between investment on STI, innovation outputs and (labor) productivity at the level of firms for Peruvian economy for 2004. Further, market failures related to investment risks, financial constraint and anticompetitive practices which may hinder innovation are also analyzed. The availability of the data (CONCYTEC-INEI, 2004) allows that the analysis to include six ISIC groups of branches: knowledge intensive business services (KIBs), primary goods, high and low tech manufacturing, and infrastructure & energy branches.

[1] This paper is based upon an IADB-CINVE project on Productivity and Innovation. The author thanks Gustavo Crespi for his valuables insights on CDM models. Carla Solis provided excellent research assistance. A shortened version of this paper with focus on total factor productivity of manufactured firms would be *forthcoming in the Review of Development Economics*

[2] Tables A1 and A2 and Figure A1 in the annex summarize the National System of Science Technology and Technological Innovation (SINACYT) of Peru, policies, programs and projects on science, technology and innovation which covers all sectors of the economy including services. Policies on ICT are summarized in Tello (2010).

The paper is divided in five sections. Section I, presents a brief literature review on the relationship between innovation and productivity. Section II, a standard CDM[3] structural model of innovation and productivity is formulated. Section III, describes the main data source and report a list of firms' STI indicators coming from the data (CONCYTEC-INEI, 2004). Section IV, describes the estimation strategy and shows the econometric results. The last Section V lists the main conclusions of the paper and provides some STI policy guidance. References and annex tables are attached at the end of the paper.

I. BRIEF LITERATURE REVIEW

As a consequence of surveys undertaking in science, technology and innovation and information & communications technologies at firms' level in some Latin American Countries have emerged a series of studies on the innovation process, their restrictions and its effects on firms' performance[4]. Series of contributions in this area[5] for developed and some developing economies are listed in Mairesse & Sasaenou (1991), Mairesse & Mohnen (2010), Crespi & Zuñiga (2010) and Hall (2011). The dominant methodology in most of these contributions is that proposed by Crepon et al. (1998) called the CDM model[6]. The two main features of the CDM model are, on the one hand, the specification of a structural model in which variables such as R&D expenditures, innovation outputs and firms' (labor) productivity are interrelated. On the other hand, econometric techniques are used to deal with selectivity, simultaneity biases and some statistical features of the available data.

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[3] Named after the work of Crepon et al (1998).

[4] Crespi & Zuñiga (2010) use six data sets from STI surveys in Argentina (period 1998-2001), Chile (period 2004-2005), Colombia (2004), Uruguay (2006) and Costa Rica (2008) to analyze the effects of innovation on firms' productivity. Balboni, Rovira and Vergara (2011) use ITC surveys to analyze the effects of ITC on manufacturing firms' performance in Chile, Argentina, Uruguay, Colombia and Peru.

[5] Initiated by the works of Griliches (1979) and Griliches and Packes (1980).

[6] The alternative methodology is based on estimations of total factor productivity (TFP) or labor productivity (Prod) using panel and/or cross sections data.

Crespi and Zuñiga (2010) point out that CDM model consists of four stages: (i) firms decision to invest in innovation activities. This is the firms' R&D investment[7] decision equation; (ii) firms decision on the amount to invest. This is firms' research intensity equation; (iii) knowledge (technology) is produced as a result of this investment (the "knowledge production" function, e.g., Griliches, 1979 and Griliches & Packes, 1984). This is the firms' innovation output equation; and (iv) output is produced using new knowledge (technological innovation) along with other inputs. This is firms' productivity equation. The same authors also report a list of relevant empirical results on the factors that are included in these four equations. Among others:

i) Firm's decision to invest in innovation (R&D) increases with its size, market share and diversification, and with demand pull and technology push forces;

ii) Firm productivity correlates positively with a higher innovation output, even when controlling for the skill composition of labor;

iii) Technological innovation (product or process) leads to superior firm economic performance[8] in European firms (e.g. Monhen *et al*., 2005)

iv) Firms that invest more intensively in R&D are more likely to develop innovations—products, process innovation or patents—once corrected 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, etc.).

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7 Consistent with the available survey data for Peru instead of using investment in R&D, this paper uses investment in science, technology and innovation (STI). This includes: expenditures in 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 generation, production, dissemination and application of scientific and technical knowledge in all the fields of science and technology. Innovation activities are the actions of firms with the objectives to implement in practice new concepts, ideas, and methods to acquire, assimilate or to incorporate new knowledge.

8 Measured through labor productivity, sales, profits and so on.

v) Evidence with regard to the ability of firms in developing economies to transform R&D into innovation is much more mixed than in the case of firms in industrialized countries.

vi) The results regarding the impact of innovation on labor productivity are equally 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 mostly based on imitation and technology transfer, e.g., acquisition of machinery and equipment and disembodied technology purchasing. The amount on R&D investment is in many cases very high (both in terms of financial costs and human capital needed) and, due to its cumulative effects, it could require longer time horizons to demonstrate results. In addition to firm characteristics, CDM models also include external forces acting concurrently on the innovation decisions of firms. These are traditionally indicators of demand-driven innovation (i.e., environmental, health and safety regulation), technological push (i.e., scientific opportunities), innovation policy (i.e., R&D subsidies), and spillovers.

One particular force pointed out by Alvarez & Crespi (2011) is financial constraints. That credit constraints could severely harm innovation is a long standing 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 might have important impacts on the financing of innovation. The first one is the semipublic good nature of knowledge that limits innovating firms to exclude others from the use of the innovation they create. Consequently this attribute not only may explain why firms under-invest on innovation but also may explain the constraint of financing innovation. The second one is that knowledge investments produce an intangible asset that might be very difficult to use as collateral. This asset is linked to the human capital (e.g., engineers and technicians) working in the firm. Banks, however, prefer to use physical assets to secure loans and they might be reluctant to lend when the project involves the accumulation of intangible assets, partially embodied in the human capital of firm's employees that can be lost whenever they either quite the organization or they are fired. The third attribute is that knowledge investments have tacit components that are very idiosyncratic to the firm. That means that a potentially substantial share of these investments is sunk and cannot be easily deployable in other activities. The fourth attribute is the uncertainty associated with its outputs. The uncertainty in this case relates to the lack of a very well defined probability distribution of potential impacts. In this context, knowledge investments have an options-like character in the extent that some projects with very small probabilities of great success may be worth to be pursued even if they do not pass an ex-ante cost-benefit analysis. All these attributes may have important impacts for financing innovation.

Although this brief review does not cover all the literature on the subject, it provides a flavor of the factors involved in the estimations of CDM models. Additional factors included in the CDM model reported for Peru are analyzed in the next section.

II. A STRUCTURAL MODEL OF INNOVATION AND PRODUCTIVITY

This paper extends the Latin American literature on STI investment, innovation, their constraints and labor productivity[9] to analyze their interrelations at firms level of six ISIC groups of branches: primary goods (agriculture, fishing and mining), high-tech and low-tech manufacturing, knowledge intensive business services (including financial services), traditional services and the infrastructure & energy branches (which includes construction, transport, electricity and water). Firms' data was obtained from the National Survey of Science, Innovation and Technology (ENCYT04), implemented by the National Institute of Statistics and Computation (INEI) and the National Council of Science and Technology (CONCYTEC). The structural simultaneous equation model shown below is based upon Crepon et al. *(*1998) or CDM model (called after these authors) and Savignac's (2008) model.

[9] Among others: Álvarez & Crespi (2011), Crespi &Zuñiga (2010), and Benavente (2006).

The structural model is composed by the following equations:

[1] $g^*_i = X_{1i}.\alpha_1 + R_i.\beta_1 + \varepsilon_{1i}$; where if $g^*_i > \mu_i$ then $D_{gi}=1$; otherwise $D_{gi}=0$;

[2] $Ig^*_i = X_{2i}.\alpha_2 + FC_i.\beta_2 + \varepsilon_{2i}$; where $Ig^*_i = Ig_i$ if $g^*_{i\,i} \geq \mu_i$, i.e., when $D_{gi}=1$; otherwise $Ig^*_i=0$; i.e., $D_{gi}=0$

[3] $INN^*_i = \delta.Ig^*_i + X_{3i}.\alpha_3 + \varepsilon_{3i}$; where $D_{INNi}=1$ if $INN^*_i > 0$, $D_{INNi}=0$ otherwise;

[4] $Prod_i = \varphi_0.INN^*_i + X_{5i}.\alpha_5 + \varepsilon_{5i}$;

Wherein[10]:

g^*_i is the decision variable for the ith firm to invest on STI activities. It assumed that firm decide to invest if g^*_i is greater than zero or a threshold, μ_i. Note this latent variable is positive if a firm has in fact invested in STI activities, i.e., if the dummy variable $D_{gi}=1$;

X_{1i} is the set of factors that affects the appropriability aspect of firms' decision to invest on STI. This set of factors is composed by: firms' size and market share, and the rate of growth of the real valued added of the branch which belong the firm, g_i[11].

R_i is the set of constraints which limit firms' decision to invest or influence the amount of STI investment. Two constraints are considered: market structure or anticompetitive practices (D_{MSi}) and STI investment risks (D_{RISKi})[12].

[10] The detailed list of variables and their sources of data is presented in Table A1 of the annex tables.

[11] This variable is assumed to be a proxy of the demand pull and/or technological push factors that induce to firms to invest on R&D.

[12] Regressions results when other restrictions factors were considered yielded inconsistent results. This could mean that firms do not select actual restrictions but rather complains on the innovation environment they face. In all the cases restrictions variables are considered when firms' responses were that the respective factor imposed a high restriction for the firm (See Table 2).

Ig^*_i is the firm STI investment intensity which is measured by the SIT expenditure per worker. If the firm decide to invest then Ig^*_i would be the same as the actual STI expenditure per worker, Ig_i otherwise Ig^*_i would be zero.

X_{2i} is the set of factors that influences the firm STI investment intensity. Following to Benavente (2006) this set of factors will be equal to X_{1i}. In addition financial constraint is considered in this equation.

INN^*_i is the outcome of innovation process (as in Benavente, 2006) or the expected returns of innovation (as in Alvarez & Crespi, 2011). This latent variable is positive if a firm has in fact had innovation outputs[13], i.e., if the dummy variable D_{INNi}=1. INN^*_i is determined by Ig^*_I, firms financial constraints, FC_i and the set of factors X_{3i}.

X_{3i} is a set of factors which also determine the innovation output and includes the following variables: i) D_{COOR}, firms' degree of coordination (or cooperation) with other firms, research institutions or government; ii) firm's export market orientation, D_X=1 if domestic the D_X=0; iii) D_{INFRAi} the availability or not of research infrastructure; and iv) the availability of ICT instruments, i.e., D_{ITCi}=1.

FC_i is a dummy variable. FC_i=1 means that a firm faces financial constraint, otherwise is zero.

X_{4i} is the set of factors which affect the latent financial constraint variable. Three factors are considered: firms' total capital, equity or wealth, K_i, net profits, π_I, and an index of (refinanced or overdue) debt, $Debt_i$.

[13] Innovation outcomes may be technological (such as product and processes innovation) or non-technological (such as organizational, trade or marketing innovation).

$Prod_i$ is a firm' labor productivity (measured by total real sales or value added[14] per worker) and,

X_{5i} is the set of factors which includes capital stock per worker, k_i, and the share of firms' human capital out of the total workers..

Equation [1] represents the decision to invest (i.e., $D_{gi}=1$) or not (i.e., $D_{gi}=0$) on STI activities for firm 'i', wherein g^*_i is a criterion (and latent) variable that may be the expected present value of profits generated by innovation activities. Firm 'i' will invest on innovation activities if g^*_i is greater than a fixed threshold, μ_i. The vector X_{1i} is composed by a set of factors which influence firms' innovation activities decision. Following Crepon et al. (1998) and Benavente (2006), this vector is composed by variables that determine R&D in the Schumpeterian tradition such as: size (D_{sji}), market share (S_{Mi}), demand conditions and technological opportunities (g_i). Market structure (or anticompetitive practices) and STI investment risks as important factors that restrict innovation considered by Peruvian firms are also introduced in this equation.

Equation [2] represents the firms' effort or intensity of research, Ig^*_i, which occurs when a firm decides to invest in STI activities (i.e., when $D_{gi}=1$). This equation is the amount that firms wish to invest. X_{2i} is a set of variables that affects Ig^*_i. It is assumed that $X_{2i}=X_{1i}$. Consistent with the arguments listed in the literature review, financial constraint (i.e, FC_i) is also considered in this equation[15]

Equation [3] represents the outcome or production function of innovation or the knowledge that is produced by firms and is denoted by the latent variable INN^*_i. This outcome will be produced if firms respond that in fact innovate (i.e., $D_{INNi}=1$)[16]. The

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[14] Value added are obtained using the average ratio of value added over value of production of the respective ISIC sector of the input output matrix of 1994 and 2007 provided preliminarily by the INEI.

[15] In this case, it is assumed that limited access to financial resources affect the amount that firms invest on STI rather than firms decision to invest on such activities.

[16] An alternative to this dummy variable is to use the number of patents produced by firms as in Crepon et al. (1998)

innovation outcome depends on the firms´ effort or intensity of research, Ig* and others factors, X_{3i}. These factors includes: firms' degree of coordination or cooperation with other firms, government or research centers (i.e., D_{COORi}=1), whether the firms sell to foreign markets (i.e, D_{Xi}=1), firms use of information and communication technology (i.e., D_{ICT}=1) such as internet, mobile and fixed phones, and computers, and whether firms has STI infrastructure (i.e., D_{INFRA}=1) such as labs, centers of research and so on.

Regarding the role of cooperation, Surroca and Santamaría (2007), Galende & de la Fuente (2003), Miotti & Sachwald (2003) and Belderbos et al. (2004) argue that sometimes firm internal resources will not be enough to develop innovations. In other words, firms may lack necessary resources and capabilities to develop technological activities. In this perspective, it is necessary to have access to resources and capabilities which are external to the firm. As a result, cooperation, collaboration or technological coordination may become relevant tools. For example, collaboration agreements may solve problems of market contracting and at the same time they can allow the firms to have access to other lacking resources or resources that are complementary to their own. Therefore, the complementary between internal and external resources provided by technological partners is what triggers success of cooperation agreements and development of product, processes, marketing or organization innovations[17]. On the other hand, Hahn & Park (2010), Hanley & Monreal-Perez (2011) and Ito (2011) present the argument and evidences between the links of exports and innovation. Lastly, theoretical arguments about the role of R&D infrastructure and use of ICT tools upon innovation are reported in Tello (2011b).

Finally, equation [4] represents the determinants of firms' productivity, $Prod_i$. This variable depends upon innovation outcome, INN^*_i and traditional factors of the production function such as capital per worker, k_i, the share of human capital out of the total worker, S_{H1i} (employees with graduate studies) and S_{H2i}[18] (employees with

[17] The author´s proposal (Tello, 2011) has presented evidence of the role of cooperation on the profitability of manufacturing firms from Peru.

[18] An alternative set of determinants includes: firms degree of market protection, market shares, managerial endowment and so on (Syverson, 2011).

undergraduate o technical degrees). Although the measurement of productivity has a variety of shortcomings not only in products (e.g., Syverson, 2011, Tybout, Katayama, y Lu 2009) but also in services (e.g., Biege et al., 2011; Dean & Kunze, 1992; Griliches, 1992; Gallouj & Savona, 2009; and Gallouj & Djellal, 2008), as in the work of Crespi & Zuñiga (2010), Crepon et al. (1998) as many others this project will measure labor productivity as the real value added (or net sales) per worker[19].

III. DATA SOURCES AND FIRMS STI INDICATORS

The main data source at firms' level used in this paper is the National Survey of Science, Technology, and Technological Innovation (ENCYT-04) of 2004 implemented by CONCYTEC and INEI between October and November of 2005[20]. ENCYT-04 provides information on science, technology and technological innovation activities for 4898 firms from 44 sectors of the ISIC classification (Revision 3). However, the sample used contains STI information of 4845 firms. The number of firms with formal employment and sales data was 4828 representing in 2004 close to 32% of the value added of Peruvian economy. The sample was divided in 6 ISIC groups of branches: knowledge intensive business services (Kibs), traditional services, high-tech and low-tech manufacturing[21], primary goods branches, and infrastructure and energy branches[22].

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

20 Another survey of the same features of ENCYT 2004 has been recently implemented by the same institutions gathering data for 2009 and only manufacturing firms.

21 High tech manufacturing ISIC branches have ratios investment in STI over sales higher than the average ratio of the manufactures. Low tech manufacturing ISIC branches have ratios lower or equal than such as average.

22 Kibs include telecommunications (642), computer and related activities (72), R&D (73), others business activities (74), and financial intermediation (65) and auxiliary activities (67). Traditional services include: building of complete constructions or parts thereof; civil engineering (4520), wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (5), post and courier activities (6410),

The respective representative values for the services, manufactures, primary goods and infrastructure & energy industrial branches were 30%, 39%, 36% and 21% in terms of output. The employment of the 4828 firms represented close to 13% of the total formal economic active population of the economy. The respective values for the groups of branches are: 14% for services, 27% for manufactures, 22% for primary goods and 18% for infrastructure and energy branches. The average number of workers per firm (that responded to the employment question) was 71.

The respective averages for services, manufactures, primary goods and infrastructure & energy industrial branches were 63, 86, 109 and 51. The main features of the set of STI indicators obtained from ENCYT-04 and described in Table 1 are the following:

i) About 34% of firms had innovation results (technological and/or non-technological) in 2004. The share of these innovative firms was greater for manufacturing firms (42%, in particular low-tech manufacturing firms, 43%) and the lowest for traditional services and infrastructure and energy firms (around 30%). On the other hand, the share of firms producing non technological innovation was a bit higher than the respective share for technological innovation. However, these shares are reversed for the Kibs, manufacturing and primary goods ISIC branches.

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real estate, renting and business activities (7, except 72, 73 and 74), health and social work (85), Other community, social and personal service activities (90-93), High-tech manufacturing includes: some branches of manufacture of food and beverages (i.e., 1549, 1551, and 1553), tobacco (16), some branches of textiles (1712, 1730), tanning and dressing of leather (1911), paperboard and of containers of paper and paperboard (2102), manufacture of man-made fibers (2430), manufacture of other non-metallic mineral products (except ISIC 2695-99), manufacture of basic iron and steel (2710), manufacture of cutlery, hand tools and general hardware (2893) and other metals (2899), manufacture of machinery for food, beverage and tobacco processing (2925), some branches of manufacture of office, accounting and computing machinery (i.e, 3210, 3599, 3699). Low tech manufacturing includes the rest of manufactures. Primary goods ISIC branches include agriculture and forestry, mining, and extraction of crude petroleum and natural gas. Finally the last ISIC group includes: electricity, gas and water supply, construction, transport, and supporting and auxiliary transport activities; activities of travel agencies.

ii) About 63% of firms undertaking STI activities did not have any cooperation from other entities and used their own resources. These shares of 'in house' firms were higher for Kibs (66%) and low tech manufacturing firms (65%) and lower for firms from high tech manufacturing (51%) and infrastructure and energy (60%) ISIC group. On the other hand, close to 82% of the firms that produced innovation output used their own resources. These figures suggest the isolated firms' behavior in STI activities.

iii) Investment in STI activities as a percentage of firms' sales were rather low: 3.6% of all firms sample. Firms from high-tech manufacturing (6.4%) and Kibs (5.7%) had the highest investment STI per dollar of sales and firms from traditional services (2.6%) and low-tech manufacturing had (3.7%) the lowest ratios. In terms of investment per worker or STI investment intensity, firms from the sample only invested 3.4% of the labor productivity. High tech manufacturing firm had the highest ratio 27.3% and traditional services firms the lowest ratio 1.7%

iv) Although more than 50% of employees working in the firms had a bachelor or technical degree, only 1.5% of them worked on STI activities. Kibs firms had the highest share of employees working on STI activities (about 8.7%) and traditional services firms had the lowest share (0.24%).

v) Except for traditional services[23], the rank of labor productivity of the sample of firms is relative consistent with other estimations of this indicator (i.e., Tello, 2012d). Thus, firms from primary goods, Kibs, infrastructure and energy and high tech manufacturing ISIC branches had the highest levels of labor productivity. The capital expenditure per worker is not related to labor productivity since a large number of firms of the sample did not reported data on capital expenditure.

vi) Most of the firms used ICT tools in all the ISIC branches.

[23] The highest level for this ISIC group is explained because value added in this group is dominated from firms of wholesale trade related to exports.

vii) Only 5.2% of the firms coordinated or collaborated with other entities, in particular with national firms to carry out innovation activities. This share was the highest for primary goods (8.2%) and high tech manufacturing firms (7.8%) and the lowest for traditional services.

viii) In general, the share of firms with innovations results that faced constraints[24] for their STI activities was higher than the respective share for all the firms (with and without innovation results). In terms of this share, the constraints that had higher impact were: financial constraint, lack of STI policy, low development of STI institutions, high cost of training, and anticompetitive practices or market structure constraint.

The set of STI firms indicators for 2004 is consistent with aggregate data for Latin American Countries (i.e, Tello, 2012a) that points out that Peru has one of the lowest ratio of R&D over GDP in the region and that its STI policy is not existent and without an articulated set of institutions. On the other hand, most firms STI activities were undertaken an isolated way without collaboration with other entities and using their own resources.

Based upon the CDM model described in the previous section, next section presents the estimation of factors that determine the relationship between innovation and labor productivity and to what extent some of features shown in Table 1 restrict or promote innovation and productivity at the level of firms in Peruvian economy.

[24] The responses taken were when firms perceived that these constraints were very important for innovation.

Table 1 *STI Indicators*

Indicators	All	Services			Manufacturing			Primary	Infra-Energy
		KIBS	Trad.	Total	H-Tech	L-Tech	Total		
Sample number of firms	**4845**	**471**	**1991**	**2462**	**231**	**1074**	**1305**	**178**	**700**
1. Technological Innovation (Share of firms that introduced a)									
Product innovation	18.20	21.23	12.00	13.77	25.11	28.03	27.51	21.16	14.86
Process innovation	17.96	19.53	12.61	13.93	25.11	28.77	28.12	16.14	14.14
Both (innovative firms)	11.50	16.13	7.43	9.95	15.58	19.93	20.45	10.58	8.00
In-house innovation[1]	22.89	24.63	19.89	20.80	22.51	30.07	28.74	23.28	19.14
Technological Innovation	24.66	27.39	17.18	19.13	34.63	36.87	36.48	26.72	21.00
New-product-inn international	1.51	0.85	0.70	0.73	3.46	3.26	3.30	1.32	1.00
New-product-inn national	14.49	16.14	10.35	11.45	18.18	22.99	22.07	12.70	12.00
National Patents in Products	0.56	0.21	0.30	0.28	3.03	1.02	1.38	0.53	0.00
International Patents in Products	0.06	0.00	0.05	0.04	0.00	0.19	0.15	0.00	0.00
National Patents in Process	0.06	0.00	0.00	0.00	0.44	0.19	0.23	0.00	0.00
International Patents in Process	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Firms with Innovation activities of any kind(product, process, marketing, organization)	36.47	37.37	31.84	32.90	44.16	46.09	45.75	36.24	31.86
Firms with innovation results of any kind(product, process, marketing, organization)	34.04	34.61	29.78	30.71	38.10	43.02	42.15	33.86	30.71
Investment in innovation activities and scientific and technological activities	29.37	29.72	26.22	26.89	32.90	36.22	35.63	29.37	26.43

Table 1 *STI Indicators*

Indicators	All	Services			Manufacturing			Primary	Infra-Energy
		KIBS	Trad.	Total	H-Tech	L-Tech	Total		
Innovation in any activity without a reported investment	5.72	6.58	4.42	4.83	7.36	7.91	7.82	5.82	4.86
Sample and number of firms	**4845**	**471**	**1991**	**2462**	**231**	**1074**	**1305**	**178**	**700**
2**. Non-Technological Innovation** (Share of firms that introduced a)									
Marketing Innovation	14.98	12.74	16.88	16.08	12.99	17.23	16.48	8.20	12.00
Organizational Inn.	21.78	21.44	20.69	20.84	16.88	25.70	24.14	19.58	21.86
Either M/O inn	25.47	23.35	25.46	25.06	20.78	29.42	27.89	21.16	24.71
Sample of Firms	**1399**	**134**	**518**	**652**	**72**	**382**	**454**	**109**	**184**
3. Inputs of STI (averages or %)									
Inv_{STI}/Sales	3.58	5.68	2.59	3.23	6.36	3.16	3.66	4.51	4.11
$Inv_{R\&ED}$ /Sales	0.24	0.80	0.05	0.20	1.21	0.20	0.36	0.38	0.02
Inv_{HK} /Sales	0.05	0.22	0.01	0.06	0.27	0.02	0.06	0.10	0.02
Inv_{TS} /Sales	0.05	0.22	0.02	0.07	0.01	0.03	0.03	0.10	0.01
Inv_{INN}/ Sales	3.24	4.43	2.51	2.90	4.87	2.91	3.22	3.94	4.07
% Firms performed INNa[2]	10.71	12.74	8.79	9.55	12.55	14.25	13.95	8.73	9.86
% Firms with Research Infrastructure[3]	14.80	11.89	5.98	7.11	31.60	30.07	30.34	25.40	7.14
% Firms with any Research Infrastructure	60.47	72.19	56.50	59.50	65.80	65.83	65.82	58.99	54.71
Sample and number of firms	**1649**	**163**	**593**	**756**	**88**	**462**	**550**	**128**	**215**
43.Outputs (averages)									
N_{PAT}	0.16	0.06	0.10	0.09	0.27	0.34	0.33	0.06	0.00

Table 1 *STI Indicators*

Indicators	All	Services			Manufacturing			Primary	Infra-Energy
		KIBS	Trad.	Total	H-Tech	L-Tech	Total		
N_{NPAT}	0.11	0.01	0.06	0.05	0.23	0.25	0.24	0.06	0.00
$N_{NPATINT}$	0.02	0.01	0.04	0.03	0.03	0.01	0.01	0.00	0.00
Sample of Firms	**4768**	**463**	**1962**	**2425**	**227**	**1062**	**1289**	**367**	**687**
4. Firms Characteristics (averages)									
L	71	116	50	63	92	84	86	109	51
S_{H1}	1.74	4.47	1.60	2.15	1.36	1.09	1.14	1.66	1.48
S_{H2}	53.14	70.80	53.58	56.87	47.11	46.06	46.25	41.09	59.33
S_{STI}	1.51	8.70	0.24	1.86	0.63	1.03	0.96	1.44	1.35
Prod[4]	71133.43	45752.77	116853.10	103369.00	28164.73	22623.05	23598.70	73355.42	45018.15
(Number of firms)	(4746)	(458)	(1957)	(2415)	(225)	(1053)	(1278)	(367)	(686)
k[5]	19004.17	21508.27	13986.04	15887.57	14444.24	14995.84	14910.07	27567.56	37666.46
(Number of firms)	(1133)	(136)	(402)	(538)	(58)	(315)	(373)	(93)	(129)
S_X	22.97	14.44	14.57	14.54	46.75	41.71	42.61	38.62	7.57
(Number of firms)	(4845)	(471)	(1991)	(2462)	(231)	(1074)	(1305)	(378)	(700)
Ig	2386.58	2852.54	2009.76	2165.59	7688.11	1778.81	2790.21	3151.32	1933.48
(Number of firms)	(1787)	(164)	(723)	(887)	(89)	(431)	(520)	(130)	(250)
Market share (firm average)	0.32	0.36	0.05	0.11	0.76	0.78	0.78	0.46	0.16
(Number of firms)	(4828)	(467)	(1986)	(2453)	(231)	(1066)	(1297)	(378)	(700)
Output Representativity	31.56	20.01	22.65	29.99	14.90	31.89	39.17	35.82	20.84
Employment Representativity	2.42	3.85	1.60	2.47	2.90	7.05	8.67	0.72	2.85
F. Employment (represent.)	12.79	12.39	9.41	14.09	11.24	22.24	27.42	21.98	18.46
Sample number of firms	**4845**	**471**	**1991**	**2462**	**231**	**1074**	**1305**	**178**	**700**
5. ICT Indicators (firms share)									
D_{ICT}	95.81	97.45	95.38	95.78	97.84	97.02	97.16	93.92	94.43

Table 1 *STI Indicators*

Indicators	All	Services			Manufacturing			Primary	Infra-Energy
		KIBS	Trad.	Total	H-Tech	L-Tech	Total		
D_{PC}	89.85	96.82	88.25	89.89	93.51	91.71	92.03	89.15	86.00
D_{Pho}	80.37	84.71	79.81	80.75	85.28	83.43	83.75	72.22	77.14
D_{Cel}	79.61	84.71	75.94	77.62	80.09	82.31	81.92	78.84	82.71
D_{net}	78.08	91.51	74.74	77.94	81.82	82.40	82.30	73.54	73.14
Sample number of firms	**4845**	**471**	**1991**	**2462**	**231**	**1074**	**1305**	**378**	**700**
7. Policy Relevant Features									
S_{Coor_For}	0.60	1.49	0.25	0.49	0.87	0.84	0.84	0.79	0.43
S_{Coor_N}	4.87	4.88	3.52	3.78	7.79	6.24	6.51	7.41	4.29
S_{Coor_U}	2.75	3.18	1.71	1.99	3.03	4.00	3.83	5.29	2.00
S_{Coor_G}	0.95	1.27	0.55	2.12	1.73	0.93	2.36	2.12	1.00
S_{Coor}	5.16	5.52	3.67	4.02	7.79	6.61	6.82	8.20	4.43
S_{FG}	0.23	0.42	0.30	0.32	0.00	0.09	0.08	0.26	0.14
S_{FFI}	0.25	0.64	0.10	0.20	0.43	0.28	0.31	0.53	0.14
S_{FO}	28.67	29.30	24.01	25.02	32.47	38.08	37.09	32.28	23.86
S_{O}	1.44	0.85	1.46	1.34	4.76	1.77	2.30	0.26	0.86
S_{PAT}	2.97	2.55	2.26	2.32	7.36	5.40	5.75	1.85	0.71
S_{FC}	18.04	13.80	12.91	13.08	28.57	24.30	25.06	22.75	19.86
S_{MS}	11.91	10.19	10.85	10.72	14.72	14.71	14.71	12.70	10.43
$S_{INSTSTI}$	13.48	10.19	12.46	12.02	12.99	17.69	16.86	14.02	12.00
S_{Q}	12.07	9.55	10.95	10.68	12.55	14.90	14.48	13.76	11.57
S_{RISK}	12.43	9.13	12.91	12.19	11.69	12.85	12.64	11.90	13.14
S_{POL}	14.47	12.95	12.91	12.95	18.18	18.25	18.24	14.81	12.71
S_{TRN}	17.07	13.16	15.12	14.74	19.48	22.07	21.61	17.99	16.29
Sample number of firms	**1649**	**163**	**593**	**756**	**88**	**462**	**550**	**128**	**215**

Table 1 *STI Indicators*

Indicators	All	Services			Manufacturing			Primary	Infra-Energy
		KIBS	Trad.	Total	H-Tech	L-Tech	Total		
6. Policy Relevant Features with innovation results									
S_{Coor_For}	1.70	4.29	0.84	1.59	2.27	1.95	2.00	1.56	1.40
S_{Coor_N}	13.52	13.50	10.96	11.51	19.32	13.42	14.36	21.88	13.49
S_{Coor_U}	7.70	9.20	5.23	6.08	7.95	8.87	8.73	14.84	6.51
S_{Coor_G}	2.67	3.68	1.69	2.12	4.55	1.95	2.36	6.25	3.26
S_{Coor}	14.25	15.34	11.47	12.30	19.32	14.07	14.91	23.44	13.95
S_{FG}	0.67	1.23	1.01	1.06	0.00	0.22	0.18	0.78	0.47
S_{FFI}	0.67	1.84	0.17	0.53	1.14	0.65	0.73	1.56	0.47
S_{FO}	81.75	80.98	79.09	79.50	80.68	85.50	84.73	92.19	75.81
S_{O}	3.88	2.45	4.55	4.10	10.23	3.90	4.91	0.78	2.33
S_{PAT}	5.70	3.68	4.38	4.23	11.36	9.52	5.75	3.91	1.40
S_{FC}	20.68	15.34	14.00	14.29	27.27	27.06	27.09	25.78	23.72
S_{MS}	14.01	11.04	13.49	12.96	18.18	18.18	18.18	11.72	8.37
$S_{INSTSTI}$	19.71	14.72	19.06	18.12	18.18	23.38	22.55	18.75	18.60
S_{Q}	13.95	12.88	12.14	12.30	13.64	16.67	16.18	13.28	14.42
S_{RISK}	10.98	10.43	12.65	12.17	10.23	10.17	10.18	10.94	8.84
S_{POL}	21.35	18.40	19.73	19.44	28.41	23.59	24.36	19.53	21.40
S_{TRN}	18.86	14.72	15.01	14.95	19.32	23.59	22.91	20.31	21.40

Source: Table A1. Author's own elaboration based on CONCYTEC-INEI (2004), SUNAT (2012), Peru Top 10 000 (2004), INEI (2012). [a] Includes Transport, Construction, Water and Electricity. [1] This firms produced innovation of any kind (product, process, marketing and organization), with their own funds and without any collaboration from other entities. [2] Firms that invested on innovation for three consecutive years (2002, 2003 and 2004). [3]Includes Labs, Center of R&D, Pilot plants, experimental field. Other research facilities include: library and information equipment. [4]Labor productivity real value added (in dollar of 1994) per worker. [5] Real Value of capital expenditure per worker (in dollars of 1994).

IV. ESTIMATION STRATEGY AND ECONOMETRIC RESULTS

The econometric strategy follows that of Crepon et al. (1998), Alvarez & Crespi (2010) and Crespi &Zuñiga (2011) with some adjustments related to firms' Peruvian data. Except for the dummy variables, the rest of quantitative variables are transformed in natural logarithms. The estimation strategy has the following steps:

i) Equations [1], [2], [3] and [4] define the CDM model. In this model financial constraint is assumed to be exogenous for STI investment intensity (i.e., equation [2])[25]. Since firms in the sample that did not undertake STI activities neither faced (in terms of relative importance) innovation constraints may contaminate the effects of these constraints on firms' decision to invest and their expenditures, then these firms were eliminated from the sample.

ii) The dependent variables of equation [1] and [2] taken separately are censored from below and consequently they are estimated using standard Tobit maximum likelihood estimation (MLE) method assuming a normal distribution for the error terms. Also, equation [1] and [2] are estimated simultaneously using a Generalized Tobit or the Heckman Sample Selection Method (see details in Cameron and Trivedi, 2005). In this case, it is assumed that there exists a correlation between the errors of both equations and their joint distribution is a normal standard. As robustness check, Heckman two step estimator (called also Heckit) was estimated (see details in Cameron & Trivedi 2005).

iii) Equation [3] is estimated by MLE Probit method and use observed and predicted values for STI investment intensity[26]. In this case, a reduction in sample size is avoided since predicted values are not necessarily equal to zero.

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25 The case of endogeneity of FC cannot be assessed due to data limitations in the determinants of firms financial constraints.

26 Following Alvarez & Zuñiga (2010) this estimation strategy is used when firms do not necessarily reports the amount invested on STI activities, which are assumed cero in survey (CONCYTEC –INEI 2004. The output of these not declared investment efforts produces knowledge, and it is possible to have an estimate of innovation efforts for a greater number of the firms. However, this strategy is debatable, as this approach assumes that the process describing STI efforts and innovation output for firms that do not report investment STI activities is the same as for reporting firms.

The standard errors for the regression coefficients when estimations use predicted values are obtained using the bootstrap (Cameron & Trivedi, 2005). Also equation [4] is estimated with Probit method.

iv) The productivity equation [4] is estimated using standard least squares (LS) and bootstrap standard errors whenever the estimated of INN^*_i of equation [3] is used instead of dummy variable of innovation output D_{INN}. Since some firms did not reported capital expenditure data, then two variables are generated instead of using the variable lnk. One is ln(k+1) when k is not zero and the other is $D_{Control}$ (=1) when k=0[27].

Tables from 2 to 6 report the coefficients and statistics of the estimations methods implemented for the set of five equations. The figures of the estimations indicate:

i) For all the ISIC groups of branches, firms size in a key determinant of firms decision to invest on STI activities. Further, firms' market share also affected in a robust way the STI investment intensity for all the ISIC branches. In contrast, market share only affect to firms decision to invest in low tech manufacturing branches. On the other hand, STI investment risk seem to reduce firm decision to invest in STI activities in all ISIC branches except to firms from Kibs and high tech manufacturing branches. Market structure or anticompetitive practices seems to reduce the motivation for invest in STI activities for firms from low-tech manufacturing, primary goods and infrastructure & energy branches. Finally, market growth promoted both firms decision to invest on STI and the amount of investment only for low tech manufacturing firms.

ii) Financial constraint, although in almost all the ISIC groups of branches affected negatively to firms STI investment intensity, its effects were statistically significative only for traditional services and high tech manufacturing. This result was not robust for all the estimations implemented.

[27] The autor thanks Gustavo Crespi for this suggestion avoiding the reduction of the size of the simple.

iii) Given the not significant correlation coefficient between errors of equation [1] and [2], then investment intensity on STI was a key determinant for firms (technological and non-technological) innovation outcomes. Also, firms' degree of coordination with other entities, use of ICT tools and to less extent availability of STI infrastructure affected positively firms' innovation output for all the ISIC groups of branches. Except for traditional, low tech manufacturing and infrastructure & energy ISIC groups, export firms did not have a higher probability for producing innovation results.

iv) Capital intensity and availability of human capital (in that order) were the most important factors that affected (in a robust way) firms labor productivity. The capital per worker source of firms productivity result is consistent with the results of Tello (2012c) that points out that major determinant of total factor productivity in Peruvian economy is capital accumulation. In contrast, innovation results did not seem to foster firms' labor productivity. Moreover, in some ISC groups the effects have been (statistically) negative. These results are consistent with the ambiguous effects of innovation upon labor productivity found in some studies on Latin American Countries.

Table 2

Coefficients of Peruvian Firms Decision to Invest on STI Activities, 2004

Dependent: DI	KIBS			Traditional			Low Tech		
	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit
Constant	-0.005	-0.219	-0.215	-0.108	-0.498	-0.628	-0.076	-0.486**	-0.502**
lnSm	0.033	0.083	0.085	0.043*	0.051*	0.040	0.045**	0.108***	0.106***
lnSize	0.107**	0.154**	0.154**	0.144***	0.183***	0.192***	0.131***	0.205***	0.206***
Growth	-0.001	-0.002	-0.002	-0.005	0.015	0.035	0.017***	0.024**	0.024**
D_{MS}	-0.109	0.008	0.010	-0.064	-0.213**	-0.163	0.129*	0.179	0.209*
D_{RISK}	-0.051	-0.375	-0.354	-0.283***	-0.245***	-0.339***	-0.325***	0.439***	-0.438***
N	349	314	314	1,417	1,305	1,305	890	785	785
ρ		-0.0928	-0.305		0.792**	0.226		0.242	0.231
σ	0.877***	1.829	1.879	0.955***	2.279	1.776	0.785***	1.774	1.771
λ		-0.170			1.805			0.428	
Mills- λ			-0.573			0.402			0.408
Pseudo-R^2	0.0346			0.0366			0.0633		
χ^2	25.25***	31.34***	30.00***	105.1	55.85***	78.51***	119.3	39.37***	39.61***
Log Likelihood	-352.6			-1385	-1840.848		-882.9	-1230.817	

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance.

Table 2 (Cont.)

Coefficients of Peruvian Firms Decision to Invest on STI Activities, 2004

Dependent: DI	High Tech			Primary			Infra+Energy		
	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit
Constant	-0.040	-0.417	-0.418	-0.238	-0.478	-0.484	-0.235	-0.848**	-0.856**
lnSm	-0.008	0.034	0.032	0.019	0.055	0.047	0.009	0.010	0.011
lnSize	0.166**	0.229**	0.224**	0.163***	0.206***	0.211***	0.191***	0.288***	0.292***
Growth	-0.046*	-0.057	-0.055	-0.015	-0.030	-0.033	-0.031	-0.001	-0.002
D_{MS}	-0.104	-0.040	-0.035	-0.351**	-0.269	-0.406*	-0.436***	-0.438**	-0.471**
D_{RISK}	-0.132	-0.339	-0.371	-0.333*	-0.432*	-0.535**	-0.534***	-0.658***	-0.615***
N	179	155	155	293	267	267	495	457	457
ρ		0.298	0.308		0.844	0.285		-0.388	-0.310
σ	0.806***	1.901	1.905	0.910***	2.822	2.144	0.906***	2.038	2.002
λ		0.566			2.383			-0.791	
Mills- λ			0.586			0.611			-0.621
Pseudo-R^2	0.0391			0.0539			0.0744		
χ^2	14.83	16.45***	15.43***	32.44	5.32	7.59***	74.94	20.59***	19.91***
Log Likelihood	-182.2	-249.697		-284.6	-397.632		-466.0	-648.459	

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance.

Table 3

Coefficients of Peruvian Firms Investment Intensity on STI Activities, 2004

	KIBS			Traditional			Low Tech		
	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit
Constant	2.154	11.698***	12.075***	-0.113	7.888***	9.766***	-0.522	8.209***	8.233***
lnSm	0.670**	0.451***	0.430***	0.489***	0.533***	0.513***	0.651***	0.370***	0.369***
lnSize	0.342	-0.855***	-0.891***	0.651***	-0.537***	-0.722***	0.621***	-0.576***	-0.579***
Growth	-0.081	-0.075**	-0.074*	-0.080	0.069	0.034	0.141***	0.067***	0.067***
D_{FC}	-1.071	-0.120	-0.107	-1.847***	-0.139	-0.104	0.073	-0.215	-0.219
σ	6.442***			6.495***			5.651***		
N	314	314	314	1,305	1,305	1,305	785	785	785
Pseudo-R^2	0.0238	-0.0928	-0.305	0.0178	0.792	0.226	0.0310	0.242	0.231
χ^2	27.69	1.829	1.879	78.52	2.279	1.776	94.18	1.774	1.771
Log Likelihood	-567.9	-0.170		-2163	1.805**		-1470	0.428	
Mills- λ			-0.573			0.402			0.408

Source: CONCYTEC-INEI (2004). Author’s own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance.

Table 3 (Cont.)

Coefficients of Peruvian Firms Investment Intensity on STI Activities, 2004

Dependent:	High Tech			Primary			Infra+Energy		
lnIg	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit	Tobit	Heckman	Heckit
Constant	0.304	9.585***	9.564***	-1.979	5.468***	7.570***	-3.525*	10.852***	10.586***
lnSm	0.471	0.638***	0.639***	0.414	0.325**	0.308**	0.206	0.433***	0.432***
lnSize	1.076*	-0.536*	-0.532	0.906**	-0.192	-0.423	1.368***	-0.701***	-0.667***
Growth	-0.314	0.081	0.079	-0.106	0.043	0.090	-0.027	-0.036	-0.034
D_{FC}	-2.100*	-0.178	-0.191	-0.186	0.022	0.168	-1.251	-0.468	-0.492
σ	6.607***			6.626***			6.264***		
N	155	155	155	267	267	267	457	457	457
Pseudo-R^2	0.0303	0.298	0.308	0.0229	0.844	0.285	0.0349	-0.388	-0.310
χ^2	18.75	1.901	1.905	21.36	2.822	2.144	54.57	2.038	2.002
Log Likelihood	-299.6	0.566		-455.0	2.383		-753.7	-0.791	
Mills- λ			0.586			0.611			-0.621

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance.

Table 4

Coefficients of Peruvian Firms Financial Constraints, 2004

Dependent: FC	KIBS		Traditional		Low Tech		High Tech		Primary		Infra+Energy	
Constant	1.753	1.959	-0.440	-0.417	2.620**	2.576**	-1.445	-1.208	-1.451	-0.779	-0.091	0.930
lnProfits	-0.103	-0.113	-0.001	0.007	-0.130***	-0.116***	-0.270***	-0.268***	-0.022	0.009	0.004	-0.006
lnEquity	-0.129	-0.148	-0.055	-0.066	-0.114	-0.121*	0.238	0.223	0.055	-0.021	-0.043	-0.116
lnDebt[1]	0.003		0.072		0.159**		-0.003		0.009		0.175*	
lnDebt[2]		-0.127		-0.028		0.044		0.063		-0.056		-0.108*
N	43	43	175	175	175	175	34	34	53	53	61	61
Pseudo-R^2	0.0828	0.154	0.0139	0.00660	0.115	0.0830	0.274	0.279	0.00235	0.0221	0.0835	0.0786
χ^2	2.560	4.765	1.672	0.793	23.97	17.22	10.77	10.98	0.121	1.135	5.489	5.168

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance. Debt[1] is amount of refinanced debt / sales and Debt[2] is the amount of overdue debt / sales

Table 5

Coefficients of Peruvian Firms Innovation Output, 2004

Variables	KIBS				Traditional				Low Tech			
	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit
Constant	-1.954***	-1.088***	-0.119	0.079	-3.261***	-1.220***	-1.359***	-0.704**	-2.122***	-0.925***	-0.851	-0.834
lnIg	0.629***				0.690***				0.672***			
$lnIg^{e1}$		0.219**				0.188***				0.197***		
$lnIg^{e2}$			-0.139*				0.031				-0.013	
$lnIg^{e3}$				-0.157*				-0.090**				-0.016
D_{COORD}	0.662	1.854***	1.898***	1.887***	1.165***	1.706***	1.706***	1.699***	-0.178	1.215***	1.266***	1.266***
D_X	-0.271	-0.133	0.087	0.083	-0.080	0.156*	0.263***	0.280***	0.205	0.047	0.316***	0.315***
D_{ICT}		0.734**	0.794**	0.772**	1.255**	0.854***	0.898***	0.875***	0.184	0.512	0.570*	0.571**
D_{INFRA}	-0.434	0.371**	0.383*	0.378*	0.074	0.325**	0.375***	0.336***	0.007	0.457***	0.576***	0.576***
N	315	349	349	349	1,326	1,417	1,417	1,417	796	890	890	890
Pseudo-R^2	0.788	0.111	0.0874	0.0903	0.810	0.0745	0.0670	0.0689	0.794	0.126	0.100	0.100
χ^2	337.4	72.30	98.68	171.6	1424	116.4	86.81	65.16	872.7	81.49	100.4	122.4

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance. Bootstrapping standard errors were used when independent variables were predicted values. [e1] Predicted with the Tobit method; [e2] Predicted with the Heckman method; [e3] Predicted with Heckit method.

Table 5 (Cont.)

Coefficients of Peruvian Firms Innovation Output, 2004

	High Tech				Primary				Infra+Energy			
Variables	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit
Constant	-2.094***	-1.566***	-1.612**	-1.632**	-2.138**	-1.326***	-1.510*	0.068	-2.769**	-1.675***	-0.478	-0.591
lnIg	0.506***				0.696***				0.782***			
$lnIg^{e1}$		0.184**				0.202**				0.211***		
$lnIg^{e2}$			0.072				0.071				-0.187**	
$lnIg^{e3}$				0.076				-0.282**				-0.174**
D_{COORD}		1.897***	1.791***	1.790***	0.412	2.035***	2.047***	2.073***		2.022***	2.067***	2.066***
D_X	0.603	-0.318	-0.052	-0.054	-0.289	-0.088	0.026	0.094	0.539	-0.013	0.361*	0.371*
D_{ICT}		1.076***	0.726***	0.725**	0.343	0.819**	0.776**	1.039***	0.630	1.293***	1.422***	1.416***
D_{INFRA}	-0.502	0.659**	0.772***	0.772***	-0.667	0.521***	0.508***	0.489**	-0.460	0.557**	0.668**	0.679***
N	143	179	179	179	275	293	293	293	440	495	495	495
Pseudo-R^2	0.684	0.161	0.135	0.136	0.782	0.158	0.145	0.157	0.835	0.128	0.116	0.114
χ^2	131.6	80.66	63.48	74.29	285.2	104.5	215.0	115.2	475.7	129.3	221.8	243.1

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance. Bootstrapping standard errors were used when independent variables were predicted values. [e1] Predicted with the Tobit method; [e2] Predicted with the Heckman method; [e3] Predicted with Heckit method.

Table 6

Coefficients of Peruvian Firms Labor Productivity Equation, 2004

Dependent	KIBS				Traditional				Low Tech			
lnProd	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit
Constant	8.273***	7.578***	8.880***	8.953***	8.941***	9.177***	8.947***	9.824***	8.315***	7.816***	8.010***	8.015***
ln(k+1)	0.185***	0.198***	0.174***	0.170***	0.235***	0.235***	0.236***	0.226***	0.144***	0.130***	0.135***	0.135***
D_{inn}	-0.032				-0.104				0.078			
$D_{inn}^{Ep(e1)}$		1.111***				-0.675**				1.145***		
$D_{inn}^{Ep(e2)}$			-1.048**				-0.169				0.782***	
$D_{inn}^{Ep(e3)}$				-1.127**				-2.090***				0.769***
DC_{ONTROL}	0.849**	1.031***	0.730**	0.700**	1.652***	1.643***	1.684***	1.543***	0.752***	0.754***	0.719***	0.719***
S_{H1}	1.241***	1.232*	1.210	1.195	1.210**	1.262	1.214	1.359**	3.628***	3.431***	3.483***	3.488***
S_{H2}	0.667***	0.688***	0.628***	0.617***	0.204**	0.218**	0.196**	0.275***	0.625***	0.619***	0.618***	0.618***
N	342	342	342	342	1,368	1,368	1,368	1,368	857	857	857	857
Adjusted-R^2	0.117	0.141	0.134	0.137	0.0362	0.0396	0.0353	0.0751	0.118	0.161	0.134	0.133
R^2	0.130	0.153	0.147	0.150	0.0397	0.0431	0.0389	0.0785	0.123	0.166	0.139	0.138
χ^2	.	166.6	46.71	70.87	.	54.06	60.98	82.74	.	228.9	147.0	192.3

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance. Bootstrapping standard errors were used when independent variables were predicted values. $^{Ep(e1)}$ estimated variable using Probit method wherein lnIg is estimated with Tobit method. $^{Ep(e2)}$ estimated variable using Probit method wherein lnIg is estimate with Heckman method. . $^{Ep(e3)}$ estimated variable using Probit method wherein lnIg is estimate with Heckman method.

Table 6(Cont.)

Coefficients of Peruvian Firms Labor Productivity Equation, 2004

lnProd	High Tech				Primary				Infra+Energy			
	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit	Observed	Tobit	Heckman	Heckit
Constant	7.137***	6.730***	6.728***	6.719***	7.418***	7.364***	7.240***	7.885***	8.554***	8.380***	8.896***	8.859***
ln(k+1)	0.294***	0.307***	0.306***	0.306***	0.334***	0.337***	0.336***	0.329***	0.190***	0.186***	0.191***	0.191***
D_{inn}	-0.019				-0.091				0.083			
$D_{inn}^{Ep(e1)}$		0.673*				-0.040				0.544		
$D_{inn}^{Ep(e2)}$			0.722*				0.257				-0.733*	
$D_{inn}^{Ep(e3)}$				0.743*				-1.015***				-0.654
DC_{ONTROL}	1.984***	2.107***	2.082***	2.084***	2.311***	2.345***	2.348***	2.248***	1.078***	1.057***	1.089***	1.092***
SH_1	0.254	0.334	0.328	0.329	0.693	0.659	0.655	0.668	3.059***	2.823**	3.442***	3.413*
SH_2	0.693***	0.634**	0.623***	0.621***	1.155***	1.160***	1.156***	1.122***	0.257***	0.262	0.247	0.249
N	173	173	173	173	281	281	281	281	473	473	473	473
Adjusted-R^2	0.135	0.153	0.153	0.154	0.192	0.191	0.192	0.211	0.0942	0.100	0.104	0.102
R^2	0.160	0.178	0.178	0.179	0.206	0.205	0.206	0.225	0.104	0.110	0.114	0.112
χ^2	.	30.33	28.26	31.59	.	142.0	154.7	128.0	.	68.80	48.97	65.15

Source: CONCYTEC-INEI (2004). Author's own work. * 10% level of significance; ** less than 5% of the level of significance; *** less than 1% level of significance. Bootstrapping standard errors were used when independent variables were predicted values. $^{Ep(e1)}$ estimated variable using Probit method wherein lnIg is estimated with Tobit method. $^{Ep(e2)}$ estimated variable using Probit method wherein lnIg is estimate with Heckman method. . $^{Ep(e3)}$ estimated variable using Probit method wherein lnIg is estimate with Heckman method.

V. CONCLUSIONS

Based upon the estimation of standard and basic CDM model, this paper has analyzed the interrelationship between innovation and productivity at firms' level for Peruvian economy estimated. In addition, the effects of some constraints (such as firms' investment risk, financial restrictions and market structure or anticompetitive practices) on firms' decision and amount to investment in STI activities were estimated. The model was applied for six ISIC groups: Kibs; traditional services; low-tech manufacturing, high-tech manufacturing, primary goods and infrastructure and energy (which include transport, construction, electricity and water).

Despite of the firms data limitations for the year 2004, a set of robust statistical results are drawn from the methods implemented. First, firms' size is an important factor in their decision to invest upon STI activities. On the other hand, firms' market share is the key factor in the determination of STI investment intensity.

Second, investment risks and financial restriction seem to affect negatively to firms decision and amount of investment on STI respectively. However, their statistical effects vary among the ISIC branches. The effects of market structure or anticompetitive practices were not clear in sign and statistical significance.

Third, firms STI investment intensity, their degree of cooperation (collaboration) with other entities and the endowment of STI infrastructure affected positively to firms´ innovation outputs. However, the statistical significance and degree of robustness was greater for the firms' investment intensity and lower for firms' endowment of STI infrastructure.

Fourth, capital-labor ratio was the factor that in all ISIC groups affected positively firms' labor productivity and its coefficient was statistically significative. To less extent and depending upon the ISIC group, human capital (i.e., personal with postgraduate and pre-graduates or technical degrees) was also a factor affecting firms productivity. The effect of the innovation output on labor productivity was not statistically robust[28].

The overall analysis of the interrelationship between STI activities and productivity and their firms' indicators in Peru suggest the urgent need to devote political attention and respectable amount of resources to foster firms' innovation as a mean to sustain increasing rates of growth of total factor productivity. Potential gains in the probability that firms invest on STI activities may be obtained by reducing distortions in the markets or STI investment risks. On the other hand, providing financial resources may be a way to increase firms STI investment intensity. Innovation outcomes pay offs could also be higher if STI policy promotes coordination among firms and with research and knowledge intensive services entities (firms, universities and non-governmental organizations). Finally, the mechanisms by which innovation output affects total factor productivity at the level of the firms require a detailed line of analysis.

28 This latter result is consistent with the low rate of growth total factor productivity at the macro level and for manufacturing firms and that capital growth was the main source of growth of the rate of growth of the real value added of Peruvian economy in period 2002-2007 (Tello, 2012c).

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Table A1

Definition of variables

Variable	Description	Source
Inv_{STI}/Sales	Real investment on science and technological activities (dollars of 1994) includes investment on: i) research and experimental development ($Inv_{R\&ED}$) ; ii) training and technical formation (Inv_{HK}) , iii) technological services (Inv_{TS})	Section II, item 31; Section I, item 23. TOP 10 000
$Inv_{R\&ED}$ /Sales	Real investment (dollars of 1994) on Research & Development= $Inv_{R\&ED}$+$Inv_{R\&Dinnv}$	Section II, item 31; Section I, item 23. TOP 10 000
Inv_{HK} /Sales	Real Investment in human capital (in dollars of 1994):	Section II, item 31; Section I, item 23. TOP 10 000
Inv_{TS} /Sales	Real Investment on science, technological and Innovation activities (in dollars of 1994): Inv_{ST} +Inv_{INN}	Section II, item 31; Section I, item 23. TOP 10 000
Inv_{INN}/ Sales	Real investment on innovation activities (dollars of 1994) over net sales. This investment includes: i) research and development ($Inv_{R\&Dinnv}$) , ii) capital goods for innovation, iii) hardware and software, iv) technological contracts, v) engineering and industrial design, vi) training, vii) management, and viii) consultancy services	Section II, item 31; Section I, item 23. TOP 10 000
N_{PAT}	Average total number patents= N_{NPAT}+ N_{PATINT}	Section VI.1, item 48
N_{NPAT}	Average number of national patents	Section VI.1, item 48
$N_{NPATINT}$	Average number of international patents	Section VI.1, item 48
L	Firm number of workers and employees	CONCYTEC-INEI (2004), Section I, item 22
S_{H1}	Firm share of workers with Doctoral and Master degree	Section IV, item 37
S_{H2}	Firm share of workers with bachelor degree, professional title or technical formation	Section IV, item 37
S_{STI}	Firm share of workers related to STI activities	Section IV, item 36
Prod	Real gross value added sales per worker (in dollars of 1994 per worker)	CONCYTEC(2004) Section I, item 22 and 23,
k	Real value of capital expenditure per worker (in dollars of 1994 per worker)	CONCYTEC(2004) Section II, item 31
S_X	=1 if a firm is an exporter (i.e., exported in more than 2 years since 1993), otherwise 0	SUNAT(2012)
Ig	Investment on STI per worker (in real dollars of 1994)	CONCYTEC-INEI (2004),Section II, item, 2, 3 and 4, Section XI, item 42.a; Section II, item 1.b
D_{ICT}	=1 if firms use any ICT tool, otherwise zero	Section V, items V.1
D_{PC}	=1 if firms use personal computers, otherwise zero	Section V, items V.1
D_{Pho}	=1 if firms use fixed telephones, otherwise zero	Section V, items V.1
D_{Cel}	=1 if firm use mobile telephones, otherwise zero	Section V, items V.1
D_{net}	=1 if firms use internet, intranet, extranet or have a local red, otherwise zero	Section V, items V.1
S_{Coor_For}	Share of firms which coordinated or collaborated with foreign firms to implement innovation activities, otherwise zero	Section VI, item 49

S_{Coor_N}	Share of firms which coordinated or collaborated with national firms to implement innovation activities	Section VI, item 49
S_{Coor_U}	Share of firms which coordinated or collaborated with universities or research centers to implement innovation activities, otherwise zero	Section VI, item 49
S_{Coor_G}	Share of firms which coordinated or collaborated with government entities to implement innovation activities otherwise zero	Section VI, item 49
S_{Coor}	Share of firms which coordinated or collaborated with other entities to implement innovation activities, otherwise zero	Section VI, item 49
S_{FG}	Share of firms which STI activities were financed partly from government resources, otherwise zero	CONCYTEC-INEI (2004),Section II, item, 2, 3 and 4, Section XI, item 42.a; Section II, item 1.b
S_{FFI}	Share of firms which STI activities were financed partly from international organizations resources, otherwise zero	CONCYTEC-INEI (2004),Section II, item 33; Section IV, item 42
S_{FO}	Share of firms which STI activities was financed from its own resources	CONCYTEC-INEI (2004),Section II, item 33; Section IV, item 43
S_{O}	Share of firms which STI activities was financed from other resources	CONCYTEC-INEI (2004),Section II, item 33; Section IV, item 44
S_{PAT}	Share of firms that obtained patents	Section VI.1, item 48
S_{FC}	=1 if a firm reported that financial constraint was of high importance as an obstacle for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
S_{MS}	=1 if a firm reported that a competitive market structure imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
$S_{INSTSTI}$	=1 if a firm reported that a low level of development of STI institutions imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
S_{Q}	=1 if a firm reported that a scarcity of qualified workers imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
S_{RISK}	=1 if a firm reported that risk of innovation imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
S_{POL}	= if a firm reported that lack of public policies for science and technology imposed a constraint of constraint of high	CONCYTEC-INEI (2004), Section VI.1, item 46
S_{TRN}	=1 if a firm reported that the costs of training imposed a constraint of constraint of high	CONCYTEC-INEI (2004), Section VI.1, item 46
D_{gi}	Firm decided to invest in scientific and technological activities, training in scientific and technological matters and R&D	CONCYTEC-INEI (2004),section II, item, 2, 3 and 4; Section XI, item 42.a
lnSize	Natural Logarithm of Firm number of workers and employees	CONCYTEC-INEI (2004), Section I, item 22
gr_i	Rate of growth of the value added of the firm's economic branch	INEI(2012)

$lnSm_i$	Percentage of value added in relation to the value added from the whole economic branch the firm belongs to.	Peru TOP 2002-2006
D_{MS}	=1 if a firm reported that a competitive market structure imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
D_{RISK}	=1 if a firm reported that risk of innovation imposed a constraint of high importance for innovation, otherwise zero	CONCYTEC-INEI (2004), Section VI.1, item 46
Ig_i	Percentage of the firm's expenditure in scientific and technological activities, training in scientific or technological matters and innovation activities (R&D, capital goods, software, hardware, technology hiring, engineering and industrial design, management, training and consulting) per worker.	CONCYTEC-INEI (2004),Section II, item, 2, 3 and 4, Section XI, item 42.a; Section II, item 1.b
D_{INNi}	Outcome of innovation, ,which can be by types(product, process, organization and marketing) and by novelty degree (firm only, local markets, international markets)	CONCYTEC (2004), Section VI.1, item 44.h
D_{COORDi}	Firm's coordination with suppliers and/or customers, universities or research institutes, higher education or government institutions, foreign partners	CONCYTEC-INEI (2004), Section VI, item 49
D_{Xi}	Firm has carried out export activities	SUNAT (2012)
D_{INFRA}	Firm's infrastructure for R&D (labs, centers of research and experimental design, and experimental plants or fields)	CONCYTEC-INEI (2004), Section V.2
$Prod_i$	Total real value of net sales per worker	CONCYTEC-INEI (2004), Section I, items 22 and 23
ln(k+1)	Natural logarithm of firms real value of capital expenditure per worker plus one	CONCYTEC(2004) Section II, item 31
S_{H1}	Employees with a doctoral degree divided by the amount of total workers	CONCYTEC-INEI (2004), Section IV, item 37
S_{H2}	Employees with a higher education degree divided by the amount of total workers	CONCYTEC-INEI (2004), Section IV, item 37

Source: Author´s own work.

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