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A Firm-level Analysis

Ricardo Monge-González
Juan A. Rodríguez-Alvarez
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Ricardo Monge-González
High Technology Advisory Committee (CAATEC)
and Instituto Tecnológico de Costa Rica

Juan A. Rodríguez-Alvarez
High Technology Advisory Committee
and Instituto Tecnológico de Costa Rica

John Hewitt
High Technology Advisory Committee

Jeffrey Orozco
Centro Internacional de Política Económica (CINPE)
and Universidad Nacional de Costa Rica

Keynor Ruiz[1]
Centro Internacional de Política Económica
and Universidad Nacional de Costa Rica

Final version

[1] Contact: Ricardo Monge (rmonge@caatec.org), Juan A. Rodriguez (jara107@gmail.com), John Hewitt (jhewitt@caatec.org), Jeffrey Orozco (jeffrey.orozco@gmail.com) and Keynor Ruiz (keynor@una.ac.cr).

Abstract[*]

This paper studies the degree to which innovation by Costa Rican manufacturing firms creates or displaces employment, how different innovation strategies affect employment, and how these effects vary by firm size and type of employment demand characteristics (skills and gender). In particular the research focuses on the differential effects of product and process innovations on employment growth. Particular attention was paid to identifying innovation impacts on employment generation by SMEs (small and medium-sized enterprises). In doing so, we estimate a model proposed in Harrison, Jaumandreu, Mairesse, and Peters (2008) using an IV approach with data from the Innovation Surveys for Costa Rica for the period 2006–2007. The results show that both product and process innovation are positively related to employment growth. Evidence was found for important differences in impacts by firm size and labor skills. The strategy of in-house innovation is very important as a driver of employment generation. Imported innovation does not seem to have an impact on employment growth. The findings suggest that policies aimed at overcoming challenges faced by Costa Rican firms in becoming more innovative are also very important for generating new employment opportunities in the country.

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1. Introduction

Costa Rica is a small open economy whose recent growth has been associated with the increase of exports, mostly related to high-technology goods. In fact, the country is the fourth leading high-tech exporter in the world, in terms of high-tech exports as a percentage of total exports. Although Gross Domestic Product (GDP) per capita has been growing at 2.5 percent per year during the last three decades, Costa Rica's growth is associated mostly with the availability and use of labor and capital factors, rather than increases in productivity. Recognizing that innovation is a driver for increased productivity, Costa Rican authorities have been designing and implementing policies to encourage firm-level innovation for several years, including some designed especially for small and medium-sized enterprises (SMEs) (Monge-González, Rivera and Rosales, 2010).

The entry of China, India and Central Europe onto the global capitalist stage is the most significant change in today's global economy. As pointed out by Abugattas and Paus (2006), such a situation means a doubling of the global labor force, which poses a fundamental challenge for countries like Costa Rica, since it alters the range of possible strategies for the development of new comparative advantages. Indeed, wages in Costa Rica are too high to allow this country to compete any longer in the production of unskilled-labor-intensive commodities. At the same time, productivity is too low in Costa Rica to compete successfully with more industrialized countries in the production of highly skill-intensive goods by Costa Rican companies.[2]

Given these circumstances, Costa Rican authorities face a double challenge: the country must both move towards an innovation-driven economy in order to increase productivity, and generate enough sources of employment to reduce both poverty and inequality, thus achieving higher economic growth and sustainable development.[3]

Although authorities are trying to move Costa Rica towards an innovation-driven economy, and most public policies take this orientation into account (Villalobos and Monge-González, 2011), the relationship between innovation and employment is a complex one, and the effects of those policies which have already been introduced—both in terms of increasing innovation and in terms of the type of employment that they generate—are not yet clear enough

[2] It should be noted that most high tech products exported from Costa Rica are produced by Multinational Corporations (MNCs) operating in this country.
[3] For a discussion of this topic see Daude (2010).

to provide reliable guides for the selection of future strategies. In fact, evidence from developed countries shows that innovations often destroy jobs, but also stimulate demand for firms' products, and it is unclear to what extent and through what mechanisms overall employment is affected (Harrison, Jaumandreu, Mairesee, et al., 2008). In addition, in the case of developing countries, the impacts of innovation on employment can be different from those in developed countries, for several reasons, which will be further discussed herein. For all of these reasons, a better understanding of the consequences of innovation for employment generation is of critical importance for the near-term future of Costa Rica.

The main focus of this research is on the direct effects of innovation on employment (in terms of both quantity and quality) at the firm level. Several reasons justify such a choice. First, firms are where innovations are introduced and where they have immediate effects on employment. Second, these effects are likely to influence the extent to which different agents within firms resist or encourage innovation and even the types of innovations that are introduced and their subsequent effects on prices, outputs and employment. Third, even at the firm level the problem is complex enough to justify specific consideration (e.g., the effects of different types of innovation, the operation of feedback effects due to compensation processes, etc.). Fourth, the subjects of innovation policies are firms, and knowing how employment in firms responds to innovation (which may be influenced by specific policies) can be valuable for policymakers. Indeed, innovation policy should be able to anticipate the impacts of innovation on employment in order to encounter the best ways to overcome or mitigate the costs of potential displacement effects. Possible strategies might be to include—parallel to any initiatives to increase innovation—unemployment risk mitigation policies that help the economy to reap the benefits of innovation, protecting those who may stand to lose from those changes and training policies that support new skills formation.

This paper assesses how different types of innovations create or destroy employment in Costa Rican manufacturing firms. In particular, the research focuses on the differential effects of product and process innovations on employment growth.[4] The paper also investigates how different types of business innovation strategies influence the capacity of innovation to generate or destroy employment. At least two different types of innovation strategies might be assessed: make (in-house innovation) or buy (externally acquired innovation). The main reason to do so is

[4] As it is explained in Appendix C the definition of process innovation includes organizational change innovation.

that while a make strategy is expected to work with internal formation of human capital, a buy strategy may lead firms to optimize resources and employ less people, particularly skilled labor. Indeed, firms can innovate by investing in Research and Development (R&D), training, acquiring embodied technologies or purchasing codified knowledge (Veugelers and Cassiman, 1999). Particular attention will be paid to identifying the impacts of innovation on employment generation by SMEs.[5]

This paper makes three main contributions to the literature. First, it explores the differential effects of product and process innovations on employment growth for a small developing country. In that sense, the results expand on some of the findings already in the literature, which has been focused primarily on the experience of developed countries. Second, the paper extends the basic Harrison et al. (2008) model to explore whether SMEs behave differently from the rest of firms, as well as assessing how different types of innovations and innovation strategies affect different employment demand characteristics. In particular, the paper evaluates the effects of such strategies on skilled and unskilled employment. A better understanding of how innovation relates to employment growth in Costa Rica can provide useful empirical evidence for policymakers attempting to make better use of existing resources, focusing training policies, targeting innovation policies according to firm size, and promoting particular innovation strategies, etc. This is particularly important in the case of Costa Rica, where the Presidential Council on Competitiveness and Innovation was created in 2010. Its major concern is to promote economic growth and sustainable development based on moving the country from an efficiency-driven economy towards an innovation-driven economy.[6]

The structure of the paper is as follows: Section 2 discusses the relevant literature; Section 3 presents a qualitative analysis of some important characteristics of the Costa Rican innovation system; Section 4 presents the econometric models; Section 5 describes the data used in the estimations; and Section 6 then discusses the evidence provided by simple descriptive statistics on employment and innovation outcomes as well as the main econometric results using firm-level data. A final section summarizes the work presented in the rest of the document.

[5] According to Costa Rican authorities, SMEs are defined as firms with less than 100 employees; however for the purposes of the present research we define SMEs as those firms with more than 10 and less than 50 employees.

[6] The Costa Rican Government has moved to strengthen governance through the creation and adoption of Executive Decree N° 36024-MP-PLAN, which called for the establishment and consolidation of a Presidential Council on Competitiveness and Innovation, as an organ of guidance, advice, coordination and follow-up on public policies, plans, goals and objectives, and their design.

2. Literature Review

Lundvall (2002) discusses the direct and indirect costs of innovation. Direct costs have to do with the development, implementation and use of something new. Indirect costs have an effect on people and organizations that have very little influence on the innovation process. In this sense, employment situation is associated with the *match or mismatch* between the new demand for labor (caused by technological change) and the availability of competences and capabilities (Vivarelli and Pianta, 2000).

As has been pointed out by the Inter-American Development Bank (IDB), innovation may trigger direct (mainly firm-level), partial, and general equilibrium effects on employment, and the relationship between these variables across all these levels depends on many different transmission mechanisms, feedbacks, and institutional factors (Pianta, 2006). For example, organizational innovation is frequently an indispensable complement to the adoption of new technologies that critically affect the productivity and employment consequences of technological innovation, especially in the case of ICTs (Black and Lynch, 2004; Basant, et al., 2006; and Harrison, 2008). There are few studies of the effect of the use of ICTs on the demand for various types of labor, especially at the firm level. Among those that do exist, a comparative analysis from Brazil and India by Basant et al. (2006) found that size and foreign ownership of firms tend to be associated with higher ICT adoption, and that in Brazil there is strong evidence that increasing ICT adoption has been associated with a higher share of educated workers. This study also shows very high returns to the use of ICTs. More recently, Harrison's (2008) study of the same countries shows that ICT use was diffusing rapidly through the manufacturing sectors of Brazil and India, and that ICT use explained up to a third of the average increase in the share of skilled workers in Brazil and up to one half in India. These results are similar to those of earlier studies in developed countries, such as that of Berman, Bound and Machin (1998), which found shifts away from unskilled labor within industries in 12 OECD countries during the 1980s, suggesting pervasive skill-biased technological change.

The complexity of the relationship between innovation and employment also arises from the fact that innovation affects not only employment *quantity* but also *quality*. Innovation might change the skills mix of employment and generate wage polarization. The empirical literature has mainly focused on two related issues: whether the adoption of ICTs is skill-biased (Autor, Katz and Krueguer, 1998; Bresnahan, Bryinjolfsson and Hitt, 2002) and whether skills and organizational innovation complement each other (Caroli and Van Reenen, 2001; Greenan, 2003). As in the case of the quantitative impacts of innovation on employment, feedback effects may be also pervasive.

Evidence on the relationship between innovation and employment is lacking for Costa Rica, where the idiosyncratic nature of innovation means that findings from developed countries cannot be simply extrapolated to this country. Indeed, for Costa Rican firms the acquisition of knowledge from abroad through contacts, trade, collaborations, and joint ventures with industrialized countries is very relevant (Monge-González, 2010), while investment in R&D remains an expensive and rare innovation strategy (confined to few firms). Technological change in developed countries may respond to different objectives, incentives, and factor endowments and move in different directions from technological change in developing countries. Innovations borrowed from developed countries might drive increased production in the Costa Rican context, and may have some impacts in the dynamics of innovation for local firms. There is some evidence in the literature showing that imported innovations may contribute to increased innovation by firms in developing countries, complementing internal technology efforts in certain industries and types of firms (e.g., Hu et al., 2005; Lopez, 2007), however, the empirical evidence about this for the case of Costa Rica is not available.

It may not only be the case that Costa Rican firms produce different types of innovations (based on imitation of the best practice frontier rather than being the first to introduce world-class innovations), but it also may be true that the very nature of the innovation process is different (MICIT, 2009) in Costa Rica as compared to more developed countries, and the effects of innovation on employment generation in this country may also be quite different from those of developed countries. Furthermore, in Costa Rica the structure of production is strongly dominated by SMEs and innovation processes in SMEs show very different characteristics from those of large firms.[7] SME innovation is strongly dominated by informal search routines and learning from available knowledge and technologies, while in large firms innovation processes are more systematic and tend to be formalized in R&D labs (Orozco and Ruiz, 2010).

Nevertheless, firms recognize the importance of innovation processes in facing changes

[7] According to Monge-González, Monge-Ariño and Vargas-Aguilar (2007), 98 percent of all Costa Rican firms can be classified as SMEs (with less than 100 employees).

in business contexts, where technological change, competence building, and organization of work are the core of the acquisition of new knowledge and dissemination of that knowledge within the firm. In that sense, firms have realized that if they want to take advantage of labor force capabilities, they have to invest in developing those capabilities (Ruiz, 2007).

Furthermore, human resources have been highlighted as a decisive factor in the creation of innovative advantages (Zúñiga, 2004). In other words, the innovative capacity of firms depends greatly on labor force capabilities. Thus, an investment in human resources aimed at increasing capabilities has a double effect. On the one hand, it increases employability, while on the other hand it has an effect on a firm's performance and competitiveness.

3. Qualitative Analysis of the Costa Rican Innovation System

The microeconomic analysis of employment generation, firm size, and innovation that is carried out in Section 4 is preceded here by an initial qualitative analysis whose results provide a wider context within which the results of the basic microeconomic analysis can be more meaningfully interpreted. The background information includes a series of interviews with key innovation system actors to gather evidence on the current state of the debate on policies related to innovation, labor markets, and other important factors.

a. General Description

As show in Table 1, GDP per capita (PPP) has grown in Costa Rica in the last few years from an average of US$6,450 in the period 1995–2000 to US$10,152 in 2005–2010. The inter-annual rate of growth of the real GDP was about 5 percent in the latest period and somewhat lower in the previous period. As mentioned in the introduction to this document, recent growth has been associated with an increase in exports, mostly related to high-tech goods. The rate of unemployment has been relatively low with respect to other economies, but has increased in the latest period, reaching 7 percent.

Table 1. Costa Rica: Macroeconomic Indicators

Indicator	1995-2000	2000-2005	2005-2009 (or most recent year)
Gross domestic product (GDP) per capita (US$ PPP)	6,450.10	7,735.90	10,152.10?
Gross domestic product (GDP) real growth (inter-annual average)	4.80%	3.72%	4.87%
Labor productivity growth (average growth between period)	3.03%	-1.20%	6.03
Share of the population in the labor force	39.87%	42.49%	45.22%
Share of tertiary educated as a proportion of the labor force	-	22.66%	25.26%
Unemployment	4.51%	2.02%	6.96%
Unemployment of the tertiary educated	-	3.54%	3.70%

Source: Banco Central de Costa Rica (BCCR), Instituto Nacional de Estadísticas y Censos (INEC), Programa Estado de la Nación.
Notes: a The average includes 2010. For the indicators GDP per capita (US$ PPP), unemployment and share of the population in the labor force, the average rate of growth for the period is an average of the annual rates of growth.

One of the main challenges that Costa Rica faces is to move towards an economy driven by innovation. This is not an easy task, since innovation is most commonly incremental and R&D expenditures in the country are relatively low and more frequent in the public sector.[8] R&D expenditures with respect to GDP have been about 0.4 percent in the last few years (Table 2), and are concentrated mostly in public universities. This low investment in R&D could be a relevant factor in understanding the fact that most of the growth of GDP is associated with the growth of investment, rather than increases in productivity.

Table 2. Costa Rica: Investment in Research and Development

	2006	2007	2008	2009
R&D/ GDP	0.43	0.36	0.40	0.49

Source: Ministry of Science and Technology; National Science, Technology and Innovation Indicators 2006-2007, 2008 and 2009.

b. Policy Landscape and Recent Evolution

In June of 1990, the Costa Rican Legislative Assembly passed Law 7169 for the promotion of scientific and technological development, which was intended to promote the creation of a National Science and Technology System (NSTS). This law also created the Ministry of Science and Technology (MICIT) as the governing body of the NSTS. The MICIT is responsible for promoting and coordinating science and technology activities and policies in the country. Although little emphasis was placed on the concept of *innovation* in the original law and

[8] Indeed, public sector represented the 67 percent of total R&D in the country for 2009.

supplementary regulations, the MICIT has since become formally responsible for the promotion of science, technology, and innovation in Costa Rica.

In the recent past, the MICIT has carried out activities aimed at realizing various recommendations contained in the previous National Development Plan (2006–2010) related to the transition of Costa Rica to a knowledge- and innovation-based country; these recommendations were influenced by findings of the multisector *Estrategia Siglo XXI* initiative (www.estrategia.cr) and by recommendations from the National Council of Rectors of public universities (CONARE).

The MICIT also created a Department of Innovation, which compiled an Atlas for Innovation in Costa Rica,[9] and has worked with the International Center for Economic Policy (Centro Internacional de Política Económica, or CINPE) of the National University of Costa Rica to carry out national innovation surveys to collect information and estimate indicators on science, technology and innovation on a continuing basis. It also administers the primary source of funding for science and technology in the country, the Incentive Fund for Scientific and Technological Development, which uses resources from the government budget and from international organizations.

Actors from the public, private, civil society. and academic sectors were brought together by the MICIT in a series of working sessions shortly after President Laura Chinchilla took office in May of 2010 to contribute to the development of a National Science, Technology, and Innovation Plan (2011–2014). The plan that is currently being developed by the MICIT bases many of its recommendations on the results of those sessions—priority areas related to innovation include new sources of financing; creation of technology parks which bring together the public, private, and academic sectors; improved access to intellectual property protection; business incubation; innovation in small businesses; improved cooperation between universities and the private sector; promotion of entrepreneurship; and the creation of a national innovation agency.

The other major actor in the area of innovation has traditionally been the National Council for Scientific and Technological Investigation (CONICIT), which was created as an autonomous institution in 1972, with a council of directors that comes from the largest public

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[9] MICIT. 2007. *Atlas Para la Innovación en Costa Rica.* (www.micit.go.cr/index.php/docman/doc_download/196-atlas-para-la-innovacion-en-costa-rica-2007.html)

universities in the country. It is charged with strengthening the role of science and technology in the country through the promotion of research and the education of investigators. It affects innovation and innovative activities most directly through its administration of the Risk Capital Fund for Investigation (FORINVES) and through grants provided by the Program for Strengthening Innovation Capabilities and Technological Development of SMEs (PROPYME). In the past, it also administered the Technology Development Fund (FODETEC), which was recently discontinued because of low levels of participation by local companies; reasons cited by possible participants for their lack of interest included the small size of loans available, variable interest rates, and requirements for initial business and marketing plans whose creation would have required more resources than the companies could provide without assistance from FODETEC. CONICIT also participates in the governing council of the Incentive Fund for Scientific and Technological Development of the MICIT.

Another of the early actions of the new administration was the creation of several presidential councils, among which is a Presidential Council on Competitiveness and Innovation, whose members include the president, both vice presidents, the ministers of the MICIT, and most other major government ministries, as well as the executive presidents of major government institutions, such as the National Training Institute (INA), the branch of the Ministry of Labor (MTSS) in charge of technical training, and the Costa Rican Electrical Institute (ICE), the government telecommunications and electricity provider.

The creation of this council has for the first time provided a forum in which the highest government authorities regularly discuss innovation and its economic impacts. The Technical Secretariat provides the council diagnostics and other information requested by the members. It also assists in the design of solutions in priority areas and monitors the execution of policies, plans, and actions related to the promotion of innovation.

c. Interactions Between Policy Dimensions

Interaction Between Public Institutions

The MICIT has previously worked in an ad hoc manner with other government institutions due to common interests in areas related to innovation and employment. In the cases of the Ministry of the Economy, Industry, and Commerce (MEIC), the Foreign Trade Promotion Corporation (PROCOMER), and the Ministry of Foreign Trade (COMEX), for instance, the shared interest lies in improving the competitiveness of Costa Rican SMEs through the promotion of science, technology, and innovation, while the INA shares the MICIT's interest in competence building and improving the technical training of the Costa Rican workforce.

The recent creation of the Presidential Council on Competitiveness and Innovation now allows the MICIT to systematically coordinate its activities at a ministerial level with those of other government agencies in areas related to innovation. In addition to coordinating inter-agency activities related to innovation, the council also provides oversight for the MICIT's efforts in the promotion of science, technology, and innovation, and may provide recommendations and assistance in elaborating plans and policies.

Although both the MICIT and the CONICIT have responsibilities related to the promotion of science, technology, and innovation in the country, the CONICIT was neither incorporated into nor made formally a subsidiary to the MICIT when that Ministry was created, and it has argued against recent proposed legislation that would integrate it more tightly with the MICIT on the grounds that this would unduly politicize CONICIT's activities.[10]

This same resistance to perceived government interference has also occurred in areas such as attempts by the government to persuade public universities to more closely align their curricula with labor market demands; at least in the case of the continuing division of efforts between the MICIT and the CONICIT, it appears to constitute a serious impediment to the Costa Rican government's efforts to coordinate and streamline the process of innovation policy formation and execution.

[10] *CONICIT rechaza intervencionismo gubernamental* ("*CONICIT rejects government interventionism*"; http://ns.vinv.ucr.ac.cr/index.php?option=com_content&task=view&id=534&Itemid=68)

Participation of the Private Sector

Relationships between the MICIT and the private sector in areas related to innovation and employment policy formation have, with few exceptions, been based on periodic convocations of representatives of the public, private, civil society, and academic sectors to provide input into the creation of national development plans and national science, technology, and innovation plans.

The CONICIT administers PROPYME funds, which brings it into contact with Costa Rican SMEs, and it has worked in an ad hoc manner to coordinate its activities with the Costa Rican Chamber of Industries, but there is no representation of the private sector in CONICIT's council of directors, and in general no institutionalized participation of the private sector in the activities of the CONICIT.

Although there is not yet an institutionalized channel for the private sector to provide information and suggestions to the Presidential Council on Competitiveness and Innovation, some members of the council, such as COMEX, INA, MEIC and MICIT, have been trying to improve relationships with the private sector.[11]

Labor Market and Learning Capability Building

Many scholars have stressed that the creation of learning capability and competence is essential for a firm's success.[12] Most of them have emphasized the relevance of training on this regard. Furthermore, as it was pointed out before, human resources have been highlighted as a decisive factor in the creation of innovative advantages (Zúñiga, 2004). Thus, the innovative capacity of firms depends in good measure on the labor force's capabilities and competences (Ruiz, 2007).[13]

In the case of Costa Rica, some efforts have been undertaken to create learning capabilities and competences in the productive sector. The technical competence building system is one of the most important institutionalized efforts on this regard. This system has been operating for several decades as a joint effort by the state and the private sector. The system

[11] For example, the Innovation Department of MICIT has been improving its relationship with some private chambers, such as the Chamber of Manufacturers, in order to attend to needs from firms that belong to these chambers.

[12] See for example, Lundvall (1992, 1996, 2002), Edquist (2001, 2004), Johnson (1992), Johnson and Gregersen (2002), Lam (1998), O'Doherty and Arnold (2004), Velásquez (2001).

[13] An investment in labor force aimed at increasing capabilities has a double effect. On the one hand, it increases employability, while on the other hand it has an effect on a firm's performance and competitiveness.

includes the INA, the chamber of industry, some technical secondary schools, and recently a technical university created as a joint project by the public universities of the country.

The functioning of the labor market, on the other hand, has direct and indirect effects on the competence building of firms in Costa Rica. These effects depend on the relationships between institutions and organizations, as well as between organizations and actors (employers and employees) and how they are regulated. The direct effects are through the access to training (intra- or extra-firm training) and the role of the employee within the firm (work organization and participation), while the indirect effects are those reflected in the high quality of the labor force through a good level of health, nutrition, education, and social security that also provide a basic level of stability and confidence (Ruiz, 2007).

The institutional framework of the labor market in Costa Rica is characterized by a complex system of regulations that promote a set of minimal standards and conditions for the labor force. Firms must fulfill the minimal standards and are stimulated to generate extra mechanism to maintain the best workers and to get the best effort from them in terms of productivity and innovation. In that sense, the institutional framework has not only guaranteed minimal conditions for employees, but has also generated incentives to stimulate the creativity of workers. There are other policies in place that also promote the improvement of Costa Rican firms' innovation capabilities, especially the foreign direct investment and the promotion of linkages between local and high-technology multinational firms that operate in the country. The first policy is in charge of COMEX with the support of CINDE, while the second one is in charge of PROCOMER. Thanks to these policies, knowledge transfer from multinationals to local firms as well as knowledge spillovers through workers mobility are two potential mechanisms for improving local companies' learning capabilities (Monge-González, 2010).

Policy Assessment Mechanisms

The Presidential Council on Competitiveness and Innovation currently functions primarily as a policy coordination and monitoring mechanism. However, its members are aware of the necessity to develop capabilities to evaluate the impact of policy execution, and are beginning to consider how such evaluations should be carried out. If successfully implemented, this would constitute first significant instance of a policy evaluation mechanism in the Costa Rican government's efforts to promote innovation in the country.

Table 3. Costa Rica: Level of Influence, Interaction and Consultation Mechanism, Private-Public Partnership, and Policy Assessment Mechanisms in Relation to Innovation, Employment Creation, and the Upgrading of Labor Force Skills Policies

	Responsible agency(ies)(policy development)	Level of influence (design and implementation of policies) [a]	Interactions and consultation mechanisms [a]	Private- public partnerships. Participation of the private sector	Policy assessment mechanisms [b]
Innovation	Ministry of Science and Technology (MICIT)	4	3	2	1
	National Council for Scientific and Technological Investigation (CONICIT)	2	2	1	2
	Presidential Council on Competitiveness and Innovation	4	4	2	2
Employment policies (emphasis on R&D, skilled employment)	Ministry of Labor and Social Security (MTSS)	2	2	2	1
Higher education (universities, vocational education)	National Council of Rectors of public universities (CONARE)	4	2	2	2
	Ministry of Public Education (MEP)	3	3	1	2
Training policies (on the job, lifelong learning, etc.)	National Training Institute (INA)	4	2	2	2

Source: Results of interviews and consultation of secondary sources including Costa Rica's Innovation Survey for 2006–2007.

[a] 1: Nonexistent; 2: Low; 3: High; 4: Very high

[b] 1: Nonexistent; 2: Some assessment (non compulsory) exist; 3: Assessments are inherent part but the results are not necessary taken into account in the (re)design of the program; 4: Assessments are made and results imply redesign/abandon of programs.

Table 3 summarizes the level of influence, interaction and consultative mechanisms, private-public partnerships, and policy assessment mechanisms in relation to innovation, employment creation, and the upgrading of labor force skills policies. The high level of influence of some public institutions on policy design and implementation is clear, as is a low level of interaction and consultative mechanisms, private-public partnerships and policy assessment mechanisms in these types of policies. In addition, Table 4 summarizes the main challenges, strengths, and actions taken in relation to innovation, employment creation, and the upgrading of labor force skills. Among the main challenges are both the fact that Costa Rican products compete internationally through low salaries or high productivity rather than through innovation, and the lack of alignment between universities, technical schools, and other creators of skilled human resources, and the private sector. As pointed out in Table 4, Costa Rica is facing important institutional challenges in its evolution toward an innovation-driven economy. Fortunately, actions are already being taken to overcome some of these problems.

Table 4. Costa Rica: Perceptions on Challenges, Strengths, and Actions in Relation to Innovation, Employment Creation, and the Upgrading of Labor Force Skills

	Main challenges	Institutional/policy challenges	Main strengths	Actions taken/ to be taken
Innovation	Costa Rica cannot compete with other countries based on low salaries or high productivity; must rather compete on innovation	Efforts to define innovation policies are supply-driven, rather than demand-driven	High-level commitment to innovation from the office of the President, through the Presidential Council on Competitiveness and Innovation	Design of a national policy on Science, Technology, and Innovation
		Inefficiently organized government funding sources with few resources; little access to angel or venture capital; legal restrictions on who can receive government funds	Competitiveness in strategic sectors, including agriculture; biodiversity and bioassay; ICTs; shared service centers	Focus on innovation in competitive sectors
		Lack of proper training and staffing for government IP protection agency		Improve organization of government funding sources
		Low private sector investment in R&D and other systematic efforts to innovate		Improve funding and organization of government IP protection agency
		Need to improve telecommunications infrastructure		Successfully carry out opening of cellular telephony market; continue efforts to increase penetration of broadband Internet connectivity
Employment creation	Lack of alignment between universities, technical schools, and other creators of skilled human resources, and the private sector	Align educational system output with private sector demand	Good investment climate for high-tech foreign investment	Institutionalize interaction and improve communication between private and other sectors
			Flexible labor market regulations	
Upgrading of labor force skills	Shortage of graduates in S&T - especially mid-level/technical workers	Improving the efficiency of the National Training Institute (INA) through increased outsourcing of investigation, program design and implementation	In process of forming a national training institute	Initiate subcontracting of tasks from the INA to outside organizations
	Shortage of trained researchers (facilitating innovation)		Good training initiatives in ICT use	Improve supply of skilled bilingual workers
	Lack of bilingual (English and Spanish language) workers in science- and technology-related areas			Facilitate access to highly-skilled workers by SMEs
	SMEs lack access to highly-skilled workers			Modify immigration policy to facilitate entry of highly-skilled workers

Source: Authors' elaboration, based on deep interviews with selected stakeholders.

d. Innovation and Employment – Interview Results

As a first step to improve our understanding of the nature of the innovative activities undertaken by manufacturing firms operating in Costa Rica, we interviewed managers from four companies to produce short case studies. Selection of the firms was based on the results of conversations with members of the research team and with other experts in the area of innovation in the country. The companies vary widely in size and the sectors in which they operate, from a label manufacturing company with 80 employees, to a cooperative specializing in aircraft maintenance services with 750 employees, to a fish processing and canning company with 1700 employees, to a multinational high-technology company with 6500 employees primarily dedicated to providing services to corporate clients.[14] The main purpose of this effort is to compare and contrast results of case studies with those from the econometric analysis in Section 4.

There was a near-universal consensus among interviewees that Costa Rican firms must make the strongest possible efforts to improve their competitiveness and the employment that they generate through systematic innovation in the products and services they provide, in the productive processes they use, and the way that they are organized to carry out their activities. All of the representatives of firms discussed in the case studies (see Appendix B) were emphatic in stating that the continued existence and growth of their companies depended critically on innovation in the face of strong competition.

At the most general level, interviewees think that innovation is likely to maintain or increase employment levels and to increase the quality of employment. When asked to comment in more detail, they clearly recognized the possibility of differential impacts of innovation on employment. Changes in organization and processes intended to make a firm more efficient and/or reduce costs were seen as obviously having the potential to reduce total employment, with automation as an extreme case. The creation of new products and services, on the other hand, was regarded as much more likely to increase total employment. These two results are confirmed by the econometrics findings discussed later in this paper.

Other qualifications emerged in further discussion. The probability that the introduction of a new product or service would actually contribute to the continuing commercial success of a firm, with a sustained positive effect on employment, was seen to depend on factors such as preliminary market research and effective marketing techniques, as well as how quickly

[14] See Appendix A for the list of interviewees and Appendix B for cases studies.

competitors were able to respond with new products or services of their own. Likewise, evaluation of processes using methodologies such as ISO 9000 was mentioned as a factor that could improve the likelihood of successful implementation of new processes, and resistance from affected workers was mentioned as a possible barrier to implementing new processes aimed at improving efficiency. No mention of barriers to innovation by labor legislation was made. Only one firm was concerned about the higher wages that must be paid in Costa Rica to workers that have to work night shifts, because this was inconvenient for an outsourcing company with numerous clients in different time zones. However, this is not a serious barrier to innovation.

The likelihood of *any* innovation taking place was considered to be very highly influenced by the level of entrepreneurship shown by owners and/or high-level managers of firms, and when asked under what circumstances innovation was most necessary to maintain or increase employment levels, the most common responses were related to the need for innovation to maintain competitiveness in international markets.

There was no general perception that levels of innovation were higher in certain sectors of the economy than others, or that they necessarily varied with firm size, although several comments were made concerning lower expectations of successful innovation and consequent increases in employment opportunities among firms with limited financial resources—a situation which may occur more frequently in smaller firms than larger ones.

As mentioned previously, interviewees think that most types of innovation should lead to a higher quality of employment, since when a new product or service is more sophisticated than a previous one, new competences or capabilities have to be created. On the other hand, one interviewee observed that if a new product or service is no more sophisticated than a previous one, the quality of employment related to the new product or service should remain the same. Although all interviewees tended to agree that the effects of process innovations on quality of work should be positive, it should be remembered that there is a perception that such innovation may reduce the total number of workers. Among the opinions expressed in interviews about general barriers to innovation by Costa Rican firms, the most frequently mentioned include:

- Existing government efforts to promote research, development, and innovation are not systematically organized and integrated, with a consequent lack of overall effectiveness.[15]

[15] In fact, 43 percent of Costa Rican firms that innovate agree with this statement, according to the most recent national innovation survey (2009).

- There is a shortage of technical workers and skilled researchers, and the creation of such workers is hampered by a lack of coordination between universities, technical schools, and other creators of skilled human resources, on one hand, and the private sector, on the other hand.[16]
- Financial resources for research, development, and innovation are difficult to obtain, and the amount of resources awarded is small.[17] This situation is exacerbated by an almost complete lack of access to private sector angel and venture capital funding.[18]
- Costa Rican firms are unfamiliar with the mechanisms and benefits of formal methods of intellectual property (IP) protection,[19] and a lack of staff and staff training in the Registry of Intellectual Property makes the process of obtaining a Costa Rican patent unduly lengthy and complicated.[20]
- The fact that the national telecommunications market is only now opening to competition means that telecom infrastructure in general, and penetration of broadband Internet connectivity for Costa Rican firms in particular, does not yet provide optimal levels of Internet access to information that would facilitate innovation, for example through better connectivity to partners, suppliers, or clients.[21]

4. Econometric Models

In order to assess how different types of innovations create or displace employment in Costa Rican manufacturing firms, the first part of this section presents the basic model developed by Harrison et al. (2008). The second part discusses extensions of the basic model to explore how different types of innovations and innovation strategies affect skilled and unskilled employment demand.

[16] According to the 2009 innovation survey, 45 percent of the firms that innovate consider that a lack of trained personal is an obstacle to innovation.

[17] A perception supported by findings of Monge-González, et al. (2010), who reported that the Propyme program has not been successful in allocating significant amounts of resources to Costa Rican SMEs.

[18] According to the 2009 innovation survey, 42.5 percent of firms mentioned difficulties in accessing credit as a barrier to investment in R&D.

[19] In the case of Costa Rican ICT firms, Monge-González and Hewitt (2010) found that almost 90 percent of the firms that did not make use of IP protection were not familiar with the necessary procedures for obtaining such protection

[20] It is worth mentioning that during the year 2009, only 9 percent of manufacturing firms claimed to have obtained a patent for their innovations (MICIT, 2009).

[21] It should be noted that 93 percent of Costa Rican manufacturing firms have access to Internet and 62 percent claim that this technology is one of the main sources of information used for innovation (MICIT, 2009).

a. The Basic Model

The literature suggests that the effect of innovation on employment generation depends on the relative intensity of the displacement and compensation effects that it generates on labor demand. Assuming a two-goods production function and two different years, Harrison et al. (2008) derive a production function in which firm productivity levels are influenced by *individual productivity effects* (i.e., all unobservable factors which make a firm more or less productive than the average firm using the same technology[22]) and (non-technological) *productivity shocks* (i.e., all the unobservable shifts in the production function for reasons other than the development of technology[23]). The authors claim that employment and other decisions about inputs are made based on cost minimization given these individual productivity effects and productivity shocks. From this framework they derive a labor demand function, and conclude that in trying to distinguish between the employment-creation versus displacing effect of innovation on this demand, a distinction between product and process innovation is useful.

This analysis starts by using the Harrison et al. (2008) basic model in which two types of products are distinguished: existing products and new products. The change in employment is then decomposed into the part due to increased efficiency in production of old products (which could be related to process and organizational innovations) and the part due to introduction of new products (product innovations). Hence, the exploration of the effects of innovation on employment growth is built on the estimation of different variations of the following basic equation (see Harrison et al., 2008):

$$l_{it} = \alpha_0 + \alpha_1 d_{it} + y_{1it} + \beta y_{2it} + u_{it} \qquad (1)$$

Where **l** stands for the rate of employment growth over a specific period (t) for firm i, $\mathbf{y_1}$ and $\mathbf{y_2}$ are the corresponding rates of output growth of old and new products (product innovations) for the same period and the same firm. The parameter $\boldsymbol{\alpha_0}$ represents the average efficiency growth in production of the old product,[24] and a binary variable **d**, equal to one if the firm has implemented a specific process innovation not associated with a product innovation, picks up the effects of such "process innovation only" through parameter $\boldsymbol{\alpha_1}$. The parameter $\boldsymbol{\beta}$

[22] For example, it is because the firm has a superior ability to manage innovation, higher absorptive capacity, or more efficient organization.
[23] For example, unobserved investments, bursts in capacity utilization, labor and temporary organizational problems.
[24] See Harrison et al. (2008, pp. 10–11) for a detailed explanation why the parameter $\boldsymbol{\alpha_0}$ captures the change in efficiency associated with production of the old products and why it should be negative.

captures the relative efficiency of the production of new products. Notice that the variable $\mathbf{y_1}$ has a coefficient equal to one and can thus be subtracted from l on the left-hand side of the equation for estimation.

Equation (1) identifies two effects of major interest for the proposed research. By enabling the measurement of the growth of output due to the introduction of new products, it for the estimation of the gross effect of product innovation on employment, while the observation of process innovations related to the production of old products allows for the estimation of the gross productivity or "displacement" effect of process innovation. It should be noted that equation (1) has some limitations, since the variable **y1** embodies three different employment effects which cannot be separated without additional (demand) data: i) the possible "autonomous" increase in firm demand for the old products (for example, due to cyclical or industry effects); ii) the "compensation" effect induced by any old product price decrease following a process innovation; and iii) the cannibalization of old product demand resulting from the introduction of new products either by the firm or by its competitors (Harrison et al., 2008). In what follows, the problems involved in the identification and estimation of the parameters of equation (1) are presented in detail.

b. Identification Issues

The identification and consistent estimation of the parameters $\boldsymbol{\alpha_0}$, $\boldsymbol{\alpha_1}$ and $\boldsymbol{\beta}$ of equation (1) depend on the lack of correlation between the variables representing product and process innovations ($\mathbf{y_2}$ and **d**) and the error term **u** or, at least, on the availability of instruments correlated with these variables and uncorrelated with **u**.

Harrison et al. (2008) claim that innovations are the result of the success of "technological investments," mainly R&D, which have to be decided upon by firms in advance and depend on their individual productivity effects. Therefore, innovations are likely to be correlated with these effects. However, as shown by the authors, they are differentiated out in equation (1) and do not enter into **u**. On the other hand, the unobserved productivity shocks (ω) remain in **u**, and their correlations with **d** and $\mathbf{y_2}$ depend on the assumptions, which can reasonably be made about both their characteristics and the timing of the firm's technological investments. If the firm is assumed to make its technological investment decisions in advance and the shocks are considered unpredictable, innovations will not be correlated with ω and **u** and an OLS estimator would suffice to estimate equation (1) consistently. On the contrary, if firms are assumed to make these investments within the period affected by the shocks ω, the resulting innovations will be correlated with these shocks, even if they were unpredictable before. In this case, however, lagged values of the included variables could be considered to be uncorrelated with ω and $\mathbf{u}$ and used as valid instruments. Finally, if ω is assumed to be autocorrelated, the timing of the investment decisions becomes irrelevant because the current value of $\mathbf{u}$ depends on its past values and innovations will likely be correlated with past values of u as well as with its current value. In this case, both $\mathbf{d}$ and $\mathbf{y_2}$ and their past values are endogenous and identification should rely on the use of (external) instrumental variables which can be claimed to be exogenous with respect to ω (Harrison et al., 2008).

The authors make a series of general observations about the identifiability of the model. First, there are good reasons to think that in fact productivity shocks are not predictable or very poorly predictable by firms at the moment of deciding upon and starting their technological investments; hence, consistent estimation of model (1) by OLS can be carried out. For example, it seems rather unrealistic to assume that firms can forecast their future labor or organizational problems or demand shocks when deciding upon R&D investments, which to a large extent are made well in advance of the innovations they eventually generate. On the other hand, if technological investments were positively related to productivity shocks ω (e.g., if they are stimulated by an anticipated burst in firm capacity utilization and the resulting increase in labor productivity), and hence negatively with the overall error $\mathbf{u}$, we would expect a downward bias in the coefficients of $\mathbf{d}$ and $\mathbf{y_2}$. In other words, we would estimate employment displacement effects of process innovation that are too large and an impact of the introduction of new products that is too low.

Taking into account the above discussion, the next section shows that our estimates are free of such biases after controlling for the measurement problems and using some instrumental variables.

c. Measurement Problems

In order to estimate equation (2), we have to face a difficult issue. In this equation, we must substitute the growth in nominal sales, which is what we observe, for the growth in real production. The problem that prices are unavailable at the firm level to deflate changes in nominal sales is in fact common in nearly all firm productivity data analyses. This problem is particularly relevant here, since we are attempting to estimate the relative efficiency of producing old and new products, which may be sold at different prices.

Denoting $\mathbf{g_1}$ as the nominal growth rate of sales due to old products, we can approximately write $\mathbf{g_1 = y_1 + \pi_1}$, where $\boldsymbol{\pi_1}$ is the rate of increase of the prices of old products. Similarly, we can define $\mathbf{g_2}$ as the nominal growth in sales that is due to new products and write $\mathbf{g_2 = y_2(1 + \pi_2) = y_2 + \pi_2 y_2}$, where $\boldsymbol{\pi_2}$ is the proportional difference of the prices of new products with respect to the prices of the old products. Substituting $\mathbf{g_1}$ and $\mathbf{g_2}$ for $\mathbf{y_1}$ and $\mathbf{y_2}$ in equation (1), and moving $\mathbf{g_1}$ to the left-hand side of the equation, we obtain:

$$l_{it} - g_{1it} = \alpha_0 + \alpha_1 d_{it} + \beta g_{2it} + v_{it} \qquad (2)$$

where the new unobserved disturbance is now $\mathbf{v = -\pi_1 - \beta\pi_2 y_2 + u}$. In case of a non-zero mean of $\boldsymbol{\pi_1}$, the model will include $-\mathrm{E}(\boldsymbol{\pi_1})$ in the intercept and $-(\boldsymbol{\pi_1} - \mathbf{E}(\boldsymbol{\pi_1}))$ in the disturbance. To estimate the parameters of (2) consistently, we thus have to take into account two additional problems. First, $\mathbf{g_2}$ (i.e., $\mathbf{y_2 + \pi_2 y_2}$) will be correlated with the composite error term $\mathbf{v}$ (i.e.,$\mathbf{-\pi 1 - \beta\pi 2 y2 + u}$). According to Harrison et al. (2008), one can hope that this only happens because $\mathbf{\pi_2 y_2}$ is obviously correlated with $\mathbf{\beta\pi_2 y_2}$, and that the term $\mathbf{y_2}$ is uncorrelated with both $\boldsymbol{\pi_1}$ and $\mathbf{\beta\pi_2 y_2}$. If this condition is met, the problem amounts to finding an instrumental variable for $\mathbf{g_2}$ that is correlated with the real ratio $\mathbf{y_2}$ and uncorrelated with $\mathbf{\pi_2 y_2}$. We accordingly tested several possible instruments (see next section) in the estimation of equation (2) to solve this problem. As pointed out by Harrison et al. (2008), the likely bias in $\boldsymbol{\beta}$ in the absence of instrumentation is an "attenuation" bias.

Second, the composite error term $\mathbf{v}$ includes $\boldsymbol{\pi_1}$ as long as we cannot control for the change in the prices of the old products. This creates a problem for isolating one of the structural effects of interest. We know that any increase in efficiency decreases marginal cost by the same proportion. Therefore, if firms are pricing their products competitively or by setting a markup on marginal cost, price variations are likely to be proportional to the efficiency increase (with an opposite sign). If we suppose, for example, that the price change $\boldsymbol{\pi_1}$ depends on the marginal cost change c according to the rule $\mathbf{\pi_1 = \pi_0 + \gamma c}$, where $\boldsymbol{\pi_0}$ is a constant and $\boldsymbol{\gamma}$ is the pass-through parameter (with $\mathbf{0 < \gamma < 1}$), and that marginal cost changes themselves are related to process innovation efficiency gains according to $\mathbf{c = \alpha_1 d}$, we can write that $\mathbf{\pi_1 = \pi_0 + \gamma\alpha_1 d}$. Thus, in equation (2), we will only be able to estimate an attenuated effect $\mathbf{(1 - \gamma)\alpha_1}$. In other words, in the absence of firm price information, we can only identify an effect of process innovation on employment net of (direct) compensating price variations. As such, compensating movements can be important (with $\boldsymbol{\gamma}$ close to 1), we might even find that process innovation has no effect on employment (Harrison et al., 2008). To deal as best as we can with this problem in our econometric analysis, and following Harrison et al. (2008), we take the corresponding industry price indexes $\boldsymbol{\pi}$ as a rough proxy for $\boldsymbol{\pi_1}$, available at a 2 digit-level of the Standard Industrial Classification (SIC) for Costa Rica and assigned to firms according to their main activities (the main products they produce).[25] Therefore, in practice we use $\mathbf{l} - (\mathbf{g_1} - \boldsymbol{\pi})$ as the dependent variable, which will leave the term $-(\boldsymbol{\pi_1} - \boldsymbol{\pi})$ in the error term. We may hope that, to the extent the firm prices do not deviate much from industry prices, especially in a small open economy, this adjustment at least partly corrects the attenuation bias in the estimated $\boldsymbol{\alpha_1}$. Given the foregoing discussion, equation (2) can be rewritten as follows:

$$l_{it} - (g_{1it} - \pi) = \alpha_0 + \alpha_1 d_{it} + \beta g_{2it} + \tau_{it} \qquad (3)$$

In short, to consistently estimate the parameters of interest in our model, we have to address the endogeneity problem created by the possible correlation of $\mathbf{y_2}$ with productivity shocks and by its necessary replacement by $\mathbf{g_2}$ for lack of firm-level price information and we have to consider that **d** could also be correlated with productivity shocks. Our strategy thus relies on a choice of instrumental variables that can be considered to be correlated with **g2** and **d**, and uncorrelated with productivity shocks.

d. Innovation and Employment Quality

This section follows the earlier approach and use a variation of equation (3) for assessing the innovation impact on employment quality as it is explained bellow. Based on equation (3) and data availability in the waves of innovation surveys for Costa Rica, we can split the growth rate of employment in both skilled (l^s) and unskilled workers (l^{us}). Therefore, we can study the impact of both process and product innovation on skilled and unskilled labor growth.

$$l_{it}^{s} - (g_{1it} - \pi) = \alpha_0^{s} + \alpha_1^{s} d_{it} + \beta^{s} g_{2it} + \varepsilon_{it} \qquad (4)$$
$$l_{it}^{us} - (g_{1it} - \pi) = \alpha_0^{us} + \alpha_1^{us} d_{it} + \beta^{us} g_{2it} + \eta_{it} \qquad (5)$$

[25] Even in those cases where Costa Rican firms export most of their production, especially when they operate under the free zone regime, it is valid to used domestic price indexes since Costa Rica is a small open economy and tariffs are very low and have not changed during the last decade.

In doing so, l^s can be estimated as the rate of growth of the sum of employees with technical and professional education, while l^{us} as the rate of growth of the sum of employees with only basic education or less. In short, through equations (4) and (5) we can assess the extent to which innovation, both in process and product separately, affect employment generation when we consider employment quality and not only total employment. Once again, we will use instrumental variables as discussed before in order to address the identification problem related to correlation between **d** and **g2** and the error term. We will report results for total sample and for SMEs.

e. Innovation Strategies and Employment

We adopt as a working hypothesis that since innovation strategies are firm control variables they should be influenced by the relative factor endowments of the place where they are implemented. If that is correct, and given that capital intensity is higher in frontier technology countries, imported innovations should have a more damaging effect on employment than the locally generated ones. In other words, "make" strategies should be more labor generating (and less skills intensive) than "buy" innovation strategies (Harrison, 2008; Harrison et al., 2008). For the models considering "buy" and "make" innovation strategies, we will use a definition of variables very similar to the one suggested by Veugelers and Cassiman (1999). The variables are defined as follows:

Make = 1, if firm carries out R&D and/or other innovative activities (in-house training, in-house engineering and industrial design, in-house management) and report a non-negative budget for these activities, and 0 otherwise.

Buy=1, if a firm acquired technology through licensing, external R&D, hardware, software, consultancies, and machinery or equipment, and 0 otherwise.

Following Elejalde, Giuliodori and Stucchi (2011), we use two approaches to estimate the impact of innovation strategies on employment growth. The first of these is a reduced form approach, which is an extension of the innovation-employment model allowing for different innovation strategies; the second is a structural approach modeled as a two-step process. In the first step, innovation inputs (innovation strategies) affect innovation outputs (product and process innovations), and in the second step, innovation outputs affect employment growth.

In the reduced form approach, we estimate the econometric model

$$l - (g_1 - \pi) = \alpha_0 + \alpha_m make + \alpha_b\ buy + \alpha_{mnb} make\&buy + v, \quad (6)$$

Where make is an indicator of whether the firm follows a make only strategy, buy is an indicator of whether the firm follows a buy only strategy, and make&buy is an indicator of whether the firm follows both a mix of make and buy strategies. In the structural approach, we carried out a regression of innovation strategies on product and process innovations and growth sales of old products, after which we used the results of the innovation-employment model to decompose the impact of innovation strategies on employment growth in different channels: a product innovation effect, a process innovation effect, and a sales of old products effect.

The econometric model for the first stage of the structural approach is

$$\begin{aligned} d &= \delta_0 + \delta_m make + \delta_b\ buy + \delta_{mnb} make\&buy + error, \\ g_2 &= \gamma_0 + \gamma_m make + \gamma_b\ buy + \gamma_{mnb}\ make\&buy + error, \\ g_1 &= \rho_0 + \rho_m make + \rho_b\ buy + \rho_{mnb}\ make\&buy + error. \end{aligned}$$

These equations measure the impact of different innovation strategies on process and product innovations, and sales of old products.

The second stage is simply the innovation-employment model of HMJP, which was already estimated:

$$l = \alpha_0 + \alpha_1 d + g_1 + \beta g_2 + v.$$

To decompose the impact of different innovation strategies on employment growth, we can use the estimates of the first and second stage. For example, the expected impact of a buy innovation strategy (vs. no innovation strategy) on employment growth is

$$\begin{aligned} &E[l|buy = 1, x] - E[l|buy = 0, x] \\ &\qquad = \beta\ (E[g_2|buy = 1, x] - E[g_2|buy = 0, x]) \\ &\qquad + \alpha_1(\Pr(d = 1|buy = 1, x) - \Pr(d = 1|buy = 0, x)) \\ &\qquad + (\mathrm{E}(g_1|buy = 1, x) - \mathrm{E}(g_1|buy = 0, x)) \\ &= \alpha_1 \delta_b + \beta\ \gamma_b + \rho_b. \end{aligned}$$

The first term measures the impact of a buy strategy on employment through process innovations, the second term measures the impact through product innovations, and the third term measures the impact through the growth in sales of old products. As usual, we replace unknown parameters with their sample estimates to estimate these effects.

5. Data

The main source of data used in the study is the Costa Rican Innovation Survey for the years 2006–2007. This survey is based on a statistically representative sample of the manufacturing, energy, and telecommunications sectors. According to the official data of the National Institute of Statistics and Census (INEC), these sectors comprised a total of 2,285 firms. In the case of the 2006–2007 survey, the INEC provided a sample of 566 firms distributed over all sectors. Using this sample, it was possible to obtain responses from 376 firms. After eliminating firms from energy and telecommunications sectors, and also any manufacturing firms with less than 10 employees for comparability reason with other international studies, we ended with a sample of 208 firms. The survey was conducted by CINPE for the MICIT.

The data from the innovation survey include most of the variables we need to estimate equations from (2) to (7), such as total sales, sales of both old and new products, amount of workers (skilled and unskilled; permanent and temporary), and traditional information on the results of innovation (product, process, organizational, and commercialization innovations). The data from the innovation survey were combined with official data from the Costa Rican Social Security System (CCSS) and the Central Bank of Costa Rica related to total amount of workers and total production value for each industry sector (2-digit codes from the ISIC), respectively. Finally, the definitions of all variables used in the estimation of equation (2) through (7) are presented in Appendix C. Although two other innovation surveys were available for the years 2008 and 2009, we decided not to use them because of data compatibility problems with the survey for 2006–2007. First of all, the three samples were not selected using criteria, which would permit the creation of a panel; each sample was selected using a random sample of the total population of manufacturing firms in the country. Second, some key questions for this research, such as sales of products or innovations that were new for the firm or new for the market, were included only in the 2006–2007 survey.

6. Econometric Results

a. Estimation Strategy

To consistently estimate the parameters of interest in our model, we address the endogeneity problem created by the possible correlation of $\mathbf{y_2}$ with productivity shocks and by its necessary replacement by $\mathbf{g_2}$ for lack of firm-level price information, and we must take into consideration that **d** could also be correlated with productivity shocks. Our strategy thus relies on the choice of instrumental variables that can be considered to be correlated with both **d** and **g2**, and uncorrelated with productivity shocks. After several trials, we finally choose two valid instruments for $\mathbf{g_2}$ the *increased range of goods* indicator (which is the one used by Harrison et al. 2008) and the *increase in productive capacity*. These two variables assess the impact of innovation on the range of goods produced by firm and on its productive capacity, respectively, as reported by the firms in the innovation survey.[26] The first variable is coded as zero if innovation is not relevant for the range of goods produced by the firm, one if the impact of innovation on the range is low, two if it is medium, and three if it is high. As a result, we expect this instrument to be uncorrelated with changes in the price of new products compared to old products. It also seems unlikely to be correlated with productivity shocks. The second instrumental variable is coded in a similar way as the first one; the indicator is coded as zero if innovation is not relevant for an increase in the productive capacity, one if the impact of innovation is low, two if it is medium, and three if it is high. Based on the accelerator theory, we could argue that before an increment in the demand of the goods produced, the firm has the option to increase his production by incrementing its productive capacity, thus the production of new goods would be related to the increase in the productive capacity, but the increase in productive capacity would not necessarily be correlated to the productivity shocks.

The original instrumental variables were converted to dummy variables, which produced a larger number of IVs to work with. However, only two of these dummies functioned well as IVs in all of the regressions.

b. Innovation by Costa Rican Manufacturing Firms

This section presents descriptive statistics and discusses the results of the initial exploration of the data. Details on variable definitions can be found in Appendix C. Table 5 presents descriptive

[26] We could not find any valid instrument for d based on the available data from the innovation survey.

statistics for the manufacturing sector in Costa Rica. For each variable, the sample is split into five subgroups according to whether the firm reports that, over the whole study period 2006–2007, it had introduced product and/or process innovations, had introduced product, process and/or organizational change innovations, had introduced only process innovations (nonproduct innovations), had introduced only organizational innovations (nonproduct innovations) or had introduced product innovations.

Table 5 shows that product or process innovators represent about 78 percent of manufacturing firms. Firms that carry out only process innovations account for 4 percent of the sample, which indicates that in most cases product and process innovations occurs simultaneously in these firms. Finally, firms that are product innovators account for 74 percent of the sample, of which 57 percent carry out process and product innovations simultaneously. Compared to results from other countries, the previous figures seem to be high for a developing country like Costa Rica.[27] A possible explanation of this result is that perhaps firms in Costa Rica understand innovation and novelty more broadly.

Employment growth of all firms is about 3.3 percent. Few firms are noninnovators (no process or product innovations) and show an employment growth rate equal to 3.5 percent, with the employment growth for product innovators being less than half that of process innovators only (3.0 percent versus 7.4 percent). Productivity gains tend to be higher in product innovators than in process innovators (20.4 and 4.3 percent, respectively).

The average increase in sales over the period 2006–2007 was 23.7 percent. Average sales growth is positive even when deflated by the corresponding rate of price increase, which is relatively high in Costa Rica for that period (14.6 percent).[28] Sales growth is consistently higher (even if only slightly) for innovators than for noninnovators, with a significant difference between firms that only introduce process innovations and those that introduce organizational or product innovations. For product innovators, sales of new or significantly improved products introduced during the period 2006–2007 are a very important component of total sales growth. In fact, while these sales grew at a rate of 78.6 percent in 2007, sales of old products decreased by

[27] For example, Harrison, et al. (2008) found that innovators represent between about 40 percent (the UK) and 60 percent (Germany) of manufacturing firms in four countries (France, Germany, Spain, and UK), and that about more than three-fourths of them have introduced product innovations (half of them together with process innovations). We tried to "deflate" the share of innovator firms by redefining the innovation variables in terms of "novelty", that is we focus only on new to market product and process innovators, but the results still remained relatively high.
[28] That is, the increase in the manufacturing prices index without fuels, from 2006 to 2007 (source, Central Bank of Costa Rica).

54.8 percent, which may be interpreted as sales of new products cannibalizing sales of old products in Costa Rica.

To summarize, the data show that employment grows more in innovative firms, but not more intensely in firms with product innovations than in firms with process innovations. For firms with product innovations, demand for old products always decreases, but the increase in sales of new products is greater than this decrease (i.e., new products contribute to an increase in demand). This suggests that compensation effects of all kinds are prevalent, and that there is no reasonable way to assess the relative roles played by process and product innovations without estimating Harrison et al.'s model. Finally, it appears that the introduction of new products and their relative importance in total sales is very high in the Costa Rican manufacturing sector.

Given the emphasis on firm size when estimating the impact of innovation on labor growth, we estimate the descriptive statistics for SMEs (see Table 6) and contrast them with those obtained for the whole sample (Table 5). With the exception that in the case of SMEs there are somewhat more non-innovators than in the whole sample (29 percent versus 22 percent) the rest of the descriptive statistics do not allow us to claim that there are important differences by firm size regarding employment, sales, and productivity growth.

Table 5. Manufacturing Firms: Process and Product Innovators, Growth of Employment, Sales, and Prices and Sources of Information

	Mean	Median	Standard deviation	Minimum	Maximum
Number of observations	208				
Distribution of firms (%)					
Noninnovators (no process or product innovations)	22				
Process only innovators (non product innovators)	4				
Product innovators	74				
Number of employees at the beginning of (each) survey					
2006	177	43	397	10	3575
2007	182	44	405	10	3575
Foreign Ownsership -10% or more-(%)	14.9	0.0	35.7	0.0	100.0
Located in the capital of the country (%)	57.7	100.0	49.5	0.0	100.0
Employment growth (%) (yearly rate)					
All firms	3.3	0.0	10.9	-36.4	63.6
Noninnovators (no process or product innovations)	3.5	0.0	12.9	-36.4	57.1
Process only innovators (non product innovators)	7.4	4.3	9.9	0.0	28.2
Product innovators	3.0	0.0	10.4	-36.0	63.6
Growth wage bill per worker (%) (yearly rate)	n.d.	n.d.	n.d.	n.d.	n.d.
Sales growth (%)[1] (nominal growth) (yearly rate)					
All firms	23.7	19.1	25.9	-41.4	134.7
Noninnovators (no process or product innovations)	27.3	22.6	25.9	-10.0	106.7
Process only innovators (non product innovators)	11.7	10.8	16.4	-8.4	46.2
Product innovators	23.4	18.8	26.2	-41.4	134.7
of which:					
Old products	-54.9	-100.0	55.9	-100.0	106.7
New products	78.6	99.5	58.5	0.0	234.7
Labor productivity growth (%)[1] (yearly rate)					
All firms	20.5	15.4	26.0	-55.8	106.8
Noninnovators (no process or product innovations)	23.8	20.9	30.3	-55.8	106.7
Process only innovators (non product innovators)	4.3	5.4	18.7	-20.4	46.2
Product innovators	20.4	15.0	24.8	-41.4	106.8
Prices growth (%) [2]					
All firms	14.3	16.0	7.1	-4.0	23.1
Noninnovators (no process or product innovations)	14.1	16.0	7.8	-4.0	23.1
Process only innovators (non product innovators)	11.8	10.8	6.8	3.2	19.3
Product innovators	14.6	16.0	7.0	-0.5	23.1

Source: Costa Rica Innovation Survey for 2006–2007.

Note: [1]Sales growth for each type of firm is the average of variable g and averages for old and new products are the

[2] Prices computed for a set of industries and assigned to firms according to their activity

n.a= not available.

Table 6. Small Manufacturing Firms: Process and Product Innovators, Growth of Employment, Sales, and Prices and Sources of Information

	Mean	Median	Standard deviation	Minimum	Maximum
Number of observations	119				
Distribution of firms (%)					
Noninnovators (no process or product innovations)	29				
Process only innovators (non product innovators)	6				
Product innovators	65				
Number of employees at the beginning of (each) su					
2006	26	24	12	10	49
2007	26	23	12	10	60
Foreign Ownsership -10% or more-(%)	6.7	0.0	25.1	0.0	100.0
Located in the capital of the country (%)	63.9	100.0	48.2	0.0	100.0
Employment growth (%) (yearly rate)					
All firms	3.6	0.0	13.5	-36.4	63.6
Non-innovators (no process or product innovations	3.7	0.0	14.4	-36.4	57.1
Process only innovators (non product innovators)	5.4	4.3	6.6	0.0	17.6
Product innovators	3.3	0.0	13.6	-36.0	63.6
Growth wage bill per worker (%) (yearly rate)	n.d.	n.d.	n.d.	n.d.	n.d.
Sales growth (%)[1] (nominal growth) (yearly rate)					
All firms	20.0	15.5	25.9	-41.4	134.7
Noninnovators (no process or product innovations)	23.1	19.2	24.7	-10.0	96.8
Process only innovators (nonproduct innovators)	12.8	10.8	16.3	-2.7	46.2
Product innovators	19.3	15.2	27.3	-41.4	134.7
of which:					
Old products	-46.1	-66.8	57.2	-100.0	96.8
New products	66.1	86.6	58.4	0.0	234.7
Labor productivity growth (%)[1] (yearly rate)					
All firms	16.5	12.2	26.2	-55.8	103.5
Noninnovators (no process or product innovations)	19.4	17.6	30.1	-55.8	96.8
Process only innovators (nonproduct innovators)	7.4	6.5	20.4	-20.4	46.2
Product innovators	16.0	11.1	24.8	-41.4	103.5
Prices growth (%) [2]					
All firms	13.5	15.3	7.1	-4.0	23.1
Noninnovators (no process or product innovations)	14.1	16.0	7.4	-4.0	23.1
Process only innovators (non product innovators)	9.7	9.4	6.2	3.2	19.3
Product innovators	13.6	15.3	7.0	-0.5	23.1

Source: Costa Rica Innovation Survey for 2006–2007.

Note: [1] Sales growth for each type of firm is the average of variable g and averages for old and new products are the

[2] Prices computed for a set of industries and assigned to firms according to their activity

n.a= not available.

c. The Basic Model

i. Econometric Results for all Firms

Table 7 presents the results of estimating equation (2) using OLS (Ordinary Least Squares), while considering the rate of growth of total employment as a dependent variable. No relationship was found between innovation in products (d2) or processes (d) and the rate of employment growth, or between this last variable and a combination of the two types of innovation (TPP: product and process innovations). Similarly, there does not seem to be any relationship between the rate of growth of the production of old products (g1-π) and the employment rate of growth, nor between this variable and the company being located in the capital city. The results show a significant relationship only between the rate of growth of employment and foreign ownership (FO). That is, the rate of growth of employment in Costa Rican manufacturing firms is higher in those companies with participation of foreign capital. In general, the results are not surprising given the identification problems discussed in previous sections, which have yet to be addressed.

Table 7. Dependent Variable: l (Yearly Employment Growth)-OLS Estimation with Robust Errors

Regression	Sector: Manufacturing			
	1-OLS: basic estimation	2-OLS: basic estimation	2-OLS: basic estimation	2-OLS: basic estimation
Constant	2.339	3.606	5.229	3.776
(se)	(3.291)	(2.335)	(4.128)	(2.598)
TPP (product or process innovator)	1.577			
(se)	(3.443)			
Product innovator (d2)		-2.730		-2.783
(se)		(3.949)		(3.905)
Process innovator (d)		3.386		3.214
(se)		(4.244)		(4.350)
TPP wide (product or process innovator) + org change			-2.022	
(se)			(4.469)	
Organizational change (only)				-0.204
(se)				(1.732)
Real sales growth *(g1-Π)*	0.011	-0.015	0.005	-0.015
(se)	(0.016)	(0.022)	(0.015)	(0.022)
Time (if pooled)	No	No	No	No
(se)				
2-digit industry dummies	yes	yes	yes	yes
(se)				
Located in the capital (capreg)	-0.086	0.117	-0.040	0.128
(se)	(1.517)	(1.604)	(1.557)	(1.594)
Foreign owned (10% or more)	2.165	2.883*	2.379	2.936*
(se)	(1.586)	(1.603)	(1.572)	(1.628)
Standard error	11.09	11.077	11.094	11.106
Number of firms	208,00	208,00	208,00	208,00

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

For the whole sample, Table 8 presents the results of estimating equation (3) by OLS as well as the results of using IV, using the two instruments discussed in a previous section for **g2** the *increased range of goods* and the *increase in productive capacity* indicators. The dependent variable is employment growth minus the growth of sales due to unchanged or old products. As discussed above, we control for changes in the prices of old products by subtracting an industry price growth index from the nominal sales growth of unchanged products (i.e., the dependent variable is $\mathbf{l - (g_1 - \pi)}$). The value of the constant is therefore an estimate of the (negative) average real productivity growth in the production of old products for the two-year period 2006–2007. Following Harrison, et al. (2008), in all regressions we include a full set of industry dummies, with their coefficients constrained to sum to zero to preserve the interpretation of the constant. The key explanatory variables are the "process innovation only" dummy **d** and "sales growth due to new products" $\mathbf{g_2}$ variables. We also include other explanatory variables such as the location of the firm in the capital city and the participation of foreign investors in the firm (see definitions in Appendix C.)

The first two columns of Table 8 present the OLS estimates for manufacturing using two specifications of the basic model or equation (3). The first column shows the results for the original equation (3), and the second one includes the two additional explanatory variables (located in the capital and foreign owned). Both the constant $\boldsymbol{\alpha_0}$ and the coefficient for **d** are not significant in both specifications.

As shown by Harrison, et al. (2008), the estimated coefficient $\boldsymbol{\beta}$ of sales growth due to new products ($\mathbf{g_2}$) is an estimate of the relative efficiency of the production process for new products compared with that for old products. The fact that this coefficient is statistically different from zero, and less than one in the two specifications, may suggest that new products are produced more efficiently than old products. However, as discussed above, any endogeneity (due to unobserved price changes or correlation with nontechnological productivity shocks) is likely to produce a downward bias in this coefficient, exaggerating the productivity gains associated with the production of new products. In fact, the results in the third and fourth columns of Table 8 where we use IV estimates confirm this claim.

Table 8. Dependent Variable: l -(g1-Π)-OLS and IV Estimation

Regression	Sector: Manufacturing			
	1-OLS: basic estimation	2-OLS + controls	IV: basic	IV + controls
Constant	2.380	-1.616	-8.779*	-12.160**
(se)	(3.955)	(5.241)	(4.591)	(5.170)
Process innovation only *(d)*	8.017	8.175	18.855*	18.413*
(se)	(6.363)	(6.539)	(10.126)	(10.076)
Sales growth due to new products *(g2)*	0.887***	0.887***	1.023***	1.015***
(se)	(0.042)	(0.042)	(0.051)	(0.050)
Foreign owned (10% or more)		0.950		1.361
(se)		(5.161)		(5.503)
Located in the capital (capreg)		6.672*		6.680*
(se)		(3.884)		(3.843)
2-digit industry dummies	yes	yes	yes	yes
Time (if pooled)	No	No	No	No
Standard error	25.198	25.114	26,327	26,125
Number of firms	208	208	208	208
F test, g2			75,386	78,160
p-value			0,000	0,000
Sargan test			2,178	2,654
p-value			0,140	0,103
Davidson-MacKinnon test of exogeneity			14,913	13,790
p-value			0,000	0,000
Stock and Yogo´s test of weak instruments				
Cragg-Donald critical value			75,386	78,160
SY estadistic (10%)			19,930	19,930
List of instrument(s) used			Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.

Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

The third and fourth columns in Table 8 take the "sales growth due to new products" variable as endogenous using two instruments. As pointed out before, any valid instrument for **g2** must be related to growth in sales of new products but not to any change in the price of new products compared to old products and to productivity shocks. Among the possible variables we evaluated as potential instruments, we prefer both the "increased range of goods" and "the increase in productive capacity" indicators, which assess the impact of innovation on the range of goods produced by firm and on its productive capacity, respectively, as reported in the common innovation survey questionnaire for Costa Rica. As mentioned before, the first variable is coded as zero if innovation is not relevant for the range of goods produced by the firm, one if the impact of innovation on the range is low, two if it is medium, and three if it is high. The second instrumental variable is coded in a similar way to the first one. The indicator is coded as zero if innovation is not relevant for an increase in the productive capacity, one if the impact of innovation is low, two if it is medium, and three if it is high.

We verified that in practice, both instruments will not be weak instruments since both appear to be clearly positively and significantly correlated with the endogenous variable **g2** in the first-stage reduced form regression, as well as not correlated with the residuals. In fact, we used the following procedure to determine the validity of the instruments and the necessity of incorporating them in equation (3). First, we used the F test to evaluate if a statistically significant relation between the instruments and the endogenous variable **g2** really existed. Second, we used the Sargan overidentification test to verify that the residuals are not correlated with the instruments if the latter are really exogenous.[29] Third, we employed the test suggested by Sotck and Yogo (2002) to evaluate the existence of a *strong* and statistically significant relation between the instruments and the endogenous variable—that is, to determine if the instruments were weak or not. In this case, the confirmation of the null hypothesis established that the instruments were weak. The null hypothesis is rejected if the Sotck and Yogo statistic is smaller than the Cragg-Donald critical value. Finally, the use of instruments for **g2** is required, as shown by the result of the Davidson-Mackinnon test for the appropriateness of the IV estimators (see Table 8).

The IV estimates of the constant differ noticeably from the OLS estimates, showing faster average productivity growth (and a corresponding decrease in employment) in the production of old products. As shown in columns three and four in Table 8, the coefficient is negative and significant both in the reduced form and in the one where two additional explanatory variables are included. It is important to remember that the constant $\boldsymbol{\alpha_0}$ of the regression shows detectable average productivity growth, which implies constantly decreasing employment for a given old products output.

Three additional important results arise from the last two columns in Table 8. First, the coefficient for process innovation (d) is significant, showing that this type of innovation activity seems to create employment, at least during the period under consideration. However, we must be careful with this result since the significance is very low. Second, the coefficient for g2 (product innovation) is significant but no longer less than one (in fact, it is equal to one), so new products are not necessarily being produced more efficiently than old products. Third, it seems

[29] In this case, we should not reject the null hypothesis, since it says that instruments are not correlated with the error term.

that firms located in the capital city show higher growth of employment than those operating elsewhere. This may be the case because many people that are qualified for manufacturing tasks live in this area of the country.

In general, one can conclude that Costa Rican firms involved in product innovation are those that generate more employment opportunities. This is a very important result for policymakers since it shows that appropriate policies to promote innovation activities, such as facilitating the supply of people with higher education levels (technical and professional), is the best way to keep creating jobs opportunities in the future. It is also important to point out that since Costa Rican manufacturing firms are on average experiencing productivity growth, jobs related to old products are decreasing. This last result implies that policies are required to improve the capabilities of workers engaged in the production of old products, so they can be involved in innovation activities or in the production of new goods, thus avoiding losing their jobs. Retraining activities, for example, must be a priority in this situation.

ii. Econometric Results for SMEs

The estimation of equation (3) was done using a sample of SMEs (defined as those with less than 50 employees), but also using the same procedures used for the estimation of equation (3) for the whole sample (see tables 9 and 10). Table 9 presents the results of estimating equation (2) using OLS, but considering the rate of growth of total employment as a dependent variable. All results are not significant as in the case of the whole sample, which may be related to the identification problems discussed in previous sections.

Table 9. Dependent Variable: l (Yearly Employment Growth)-OLS Estimation with Robust Errors

Regression	Sector: Small firms in Manufacturing			
	1-OLS: basic estimation	2-OLS: basic estimation	2-OLS: basic estimation	2-OLS: basic estimation
Constant	1.292	3.284	4.526	3.261
(se)	(4.540)	(3.508)	(5.046)	(3.766)
TPP (product or process innovator)	1.582			
(se)	(4.340)			
Product innovator (d2)		-5.837		-5.830
(se)		(6.185)		(6.109)
Process innovator (d)		-0.026		-0.003
(se)		(4.556)		(4.625)
TPPwide (product or process innovator) + org change			-2.605	
(se)			(5.007)	
Organizational change (only)				0.032
(se)				(2.745)
Real sales growth *(g1-Π)*	0.000	-0.048	-0.009	-0.048
(se)	(0.024)	(0.041)	(0.023)	(0.041)
Time (if pooled)	No	No	No	No
(se)				
2-digit industry dummies	yes	yes	yes	yes
(se)				
Located in the capital (capreg)	1.066	1.322	1.070	1.318
(se)	(3.262)	(3.358)	(3.352)	(3.354)
Foreign owned (10% or more)	4.585	4.745	4.587	4.735
(se)	(4.104)	(4.232)	(4.162)	(4.347)
Standard error	13.844	13.854	13.843	13.924
Number of firms	119	119	119	119

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.

Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

Table 10. Dependent Variable: l -(g1-Π) OLS and IV Estimations

Regression	Sector: Small firms in Manufacturing			
	OLS: basic estimation	OLS + controls	IV: basic estimation	IV + controls
Constant	0.832	-0.845	-7.612	-7.571
(se)	(4.899)	(6.650)	(5.315)	(6.088)
Process innovation only *(d)*	5.462	5.726	15.111	15.415
(se)	(9.045)	(8.770)	(12.485)	(12.655)
Sales growth due to new products *(g2)*	0.937***	0.932***	1.057***	1.051***
(se)	(0.060)	(0.059)	(0.066)	(0.068)
Foreign owned (10% or more)		10.083		7.194
(se)		(8.525)		(11.113)
Located in the capital (capreg)		2.112		-0.319
(se)		(5.949)		(6.049)
2-digit industry dummies	yes	yes	yes	yes
Time (if pooled)	No	No	No	No
Standard error	26.057	26.199	26,907	27,039
Number of firms	119	119	119	119
F test, g2			54,230	51,120
p-value			0,000	0,000
Sargan test			0,217	0,251
p-value			0,641	0,616
Davidson-MacKinnon test of exogeneity			7,737	7,147
p-value			0,007	0,009
Stock and Yogo´s test of weak instruments				
Cragg-Donald critical value			54,230	51,120
SY estadistic (10%)			19,930	19,930
List of instrument(s) used			Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.

Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

The first two columns from Table 10 show the OLS results of equation (3) when using two additional explanatory variables, while the last two columns show the results for the same equation but under IV. The results from OLS shows that the only significant coefficient and with the right sign is that associated with **g2** (growth of the production of new products). However, given the problems associated with endogeneity, we decided to use the same two instrumental variables for **g2** we used in Table 8.[30] Having done so, we found that the coefficient for g2 (product innovation) is significant but no longer less than one, so new products are not necessarily being produced more efficiently than old products. So, no difference was found between the results for SMEs and larger ones regarding the impact of product innovation on employment growth. However, unlike the case for all firms, in the case of SMEs no evidence was found regarding faster average productivity growth (and a corresponding decrease in employment) in the production of old products (the constant is not significant in the last case).

[30] See in Table 10 all the tests for the appropriateness of the instruments.

Finally, in the case of SMEs process innovation is not associated with employment changes (either generation or destruction of employment).[31]

In short, we can conclude that considering firm size when analyzing innovation impact on labor is useful. First, the analysis led us to conclude that product innovation generates employment in all cases, without respect to size. Second, SMEs are not on average experiencing productivity growth, which implies they are not suffering constantly decreasing employment for a given level of output of old products. Therefore, it seems that large firms should be more focused on policies such as retraining workers.

d. Innovation and Employment Quality

i. Econometric Results for all Firms

This section presents the results using the Harrison, et al. (2008) basic model, dividing employees into two categories: skilled and unskilled employees. We define skilled employees as in the categories of technicians and professionals, while unskilled employees are those with basic or inferior education level. Before discussing the results of the econometric models, it is important to explore the relative importance of skilled labor in different types of firms, depending on their involvement in innovative activities. Table 11 shows that one-third of the labor force in all Costa Rican manufacturing firms are skilled workers. As an unexpected result, we found that this share is smaller in the case of process innovators (25.1 percent).

[31] It is important to keep in mind that because we have only few SMEs that are process innovators (see Table 6) this last result could face a problem of power. Therefore, such a conclusion must be taken with some precaution.

Table 11. Descriptive Statistics for Employment Composition

	Mean	Median	Standard deviation	Minimum	Maximum
Share of skilled labor 2006					
All firms	32.3	25.5	25.6	0.0	100.0
Non-innovators (no process or product innovations)	33.0	25.0	27.5	3.0	100.0
Process only innovators (non product innovators)	25.2	16.7	27.9	0.0	84.5
Product innovators	32.5	25.8	25.0	0.0	100.0
Employment growth (%) (yearly rate)					
All firms	3.3	0.0	10.9	-36.4	63.6
Non-innovators (no process or product innovations)	3.5	0.0	12.9	-36.4	57.1
Process only innovators (non product innovators)	7.4	4.3	9.9	0.0	28.2
Product innovators	3.0	0.0	10.4	-36.0	63.6
Skilled labor growth (%)					
All firms	4.5	0.0	17.7	-50.0	133.3
Non-innovators (no process or product innovations)	6.1	0.0	18.5	-25.0	100.0
Process only innovators (non product innovators)	3.5	0.0	6.9	0.0	18.3
Product innovators	4.1	0.0	17.9	-50.0	133.3
Unkilled labor growth (%)					
All firms	4.4	0.0	20.5	-40.0	185.7
Non-innovators (no process or product innovations)	2.2	0.0	11.9	-37.5	45.5
Process only innovators (non product innovators)	13.0	0.0	26.6	0.0	81.8
Product innovators	4.5	0.0	21.9	-40.0	185.7

Source: Authors' calculations based on Costa Rica Innovation Survey for 2006–2007.

When we analyze labor growth among the different type of firms, process innovators show the higher rate following by noninnovators. However, the results show important differences when we split the labor force according to labor capabilities (skilled and unskilled). In fact, in the case of process innovators, the proportion of unskilled labor grows faster than that of skilled workers. Finally, in the case of product innovators, the proportion of unskilled workers grew slightly more quickly than that of skilled workers from 2006 to 2007, but both rates are relatively high (4.5 percent and 3.9 percent, respectively).

Table 12 shows the results of OLS analysis for equations (4) – *skilled employees*- and (5) - *unskilled employees*. The results for the first column (skilled labor) show a positive and significant relationship only between qualified employment growth and the production of new products (product innovation), while the second column (unskilled labor) shows a significant relationship between unskilled job growth and both product innovation and process-only innovation.

Table 12. Dependent Variables: Column (1) l^s -(g1-Π) and Column (2) l^{us} -(g1-Π)
Effect of Innovation on Employment Quality, OLS Estimates

Regression	Sector: Manufacturing			
	l^s-(g1-π) Type 1-OLS	l^{us}-(g1-π) Type 2 -OLS	l^s-(g1-π) Type 1-OLS + controls	l^{us}-(g1-π) Type 2-OLS + controls
Constant	6.972	0.774	1.594	-3.581
(se)	(4.656)	(3.936)	(5.514)	(5.326)
Process innovation only (d)	-3.254	17.834*	-2.327	17.810*
(se)	(6.602)	(9.334)	(6.907)	(9.753)
Sales growth due to new products (g2)	0.849***	0.915***	0.850***	0.914***
(se)	(0.048)	(0.046)	(0.047)	(0.046)
Capital stock (if available)			7.755*	7.605*
(se)			(4.334)	(4.281)
Foreign owned (10% or more)			5.516	-0.125
(se)			(5.907)	(5.473)
2-digit industry dummies	Yes	Yes	Yes	Yes
Standard error	28.428	30.323	28.284	30.245
Number of firms	208	208	208	208

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

With the inclusion of two control variables (capital and fo), the last two columns from Table 12 shows very similar results to those from the first two columns, except that in this case the coefficient of **capital** is significant in both specifications. Consistent with the results of the Harrison et al. basic model, the use of instrumental variables proves to be necessary (see Table 13). In addition, including control variables with instrumental variables make the result more robust. In fact, as the last two columns of Table 13 show, not only do the results from the first two columns continue to be valid, but also the constant coefficient becomes significant and with the correct sign, showing that firms on average are experiencing productivity growth.

Table 13. Dependent Variables: Column (1) l^s -(g1-Π) and Column (2) l^{us} -(g1-Π)
Effect of Innovation on Employment Quality, IV Estimates

Regression	Sector: Manufacturing			
	l^s -(g1-Π) Type 1 IV: basic estimation	l^{us} -(g1-Π) Type 2 IV: basic estimation	l^s -(g1-Π) Type 1 IV: + controls	l^{us} -(g1-Π) Type 2 IV: + controls
Constant	-7.332	-8.482	-11.580**	-12.283**
(se)	(5.243)	(5.402)	(5.873)	(6.099)
Process innovation only *(d)*	10.638	26.824**	10.465	26.260**
(se)	(11.562)	(11.914)	(11.446)	(11.887)
Sales growth due to new products *(g2)*	1.024***	1.027***	1.010***	1.020***
(se)	(0.058)	(0.060)	(0.057)	(0.059)
Capital region			7.765*	7.612*
(se)			(4.365)	(4.534)
Foreign owned (10% or more)			6.029	0.214
(se)			(6.252)	(6.492)
2-digit industry dummies	Yes	Yes	Yes	Yes
Standard error	30.063	30.977	29.680	30.823
Number of firms	208	208	208	208
F test, g2	75.390	75.390	78.160	78.160
p-value	0.000	0.000	0.000	0.000
Sargan test	1.817	1.242	2.587	1.495
p-value	0.178	0.265	0.108	0.221
Davidson-MacKinnon test of exogeneity	19.704	6.804	17.268	6.233
p-value	0.000	0.010	0.000	0.013
Stock and Yogo´s test of weak instruments				
Cragg-Donald critical value	75.390	75.390	78.160	78.160
SY estadistic (10%)	19.930	19.930	19.930	19.930
List of instrument(s) used	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

In short, these results point out that skilled labor is needed when a firm is involved in product innovations, while unskilled labor is required by companies that are involved in both process and product innovations, meaning that process innovations are not necessarily related to a demand for skilled labor. In addition, being located in the capital city is important to be able to obtain both skilled and unskilled labor.

ii. Econometric Results for SMEs

Table 14 presents the OLS results for the basic model and using control variables (last two columns. The results of the analysis of the relationship between innovation and job creation in

SMEs do not differ from those obtained for all companies for the original specification (first two columns).

Table 14. Dependent Variables: Column (1 and 3) l^s -(g1-Π) and Column (2 and 4) l^{us} -(g1-Π) SMEs: Effect of Innovation on Employment Quality, OLS estimates

Regression	Sector: Small Manufacturing			
	(1)	(2)	(1)	(2)
	Type 1-OLS	Type 2 -OLS	Type 1-OLS + controls	Type 2-OLS + controls
Constant	4.495	-1.475	0,004	-2.799
(se)	(5.268)	(4.960)	(6.296)	(7.247)
Process innovation only (d)	-6.452	11.648	-6.408	11.237
(se)	(8.378)	(9.166)	(8.034)	(8.768)
Sales growth due to new products (g2)	0.892***	0.994***	0.879***	0.991***
(se)	(0.064)	(0.069)	(0.063)	(0.067)
Capital región			6.348	2.312
(se)			(6.006)	(6.653)
Foreign owned (10% or more)			19.662**	1.132
(se)			(8.809)	(12.218)
2-digit industry dummies	Yes	Yes	Yes	Yes
Standard error	28.079	32.664	27.895	32.973
Number of firms	119	119	119	119

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

Using control variables (capital and fo), the results are slightly different from those obtained in the basic model. That is, in the case of skilled workers participation of foreign capital shows a positive impact on the generation of qualified employees for SMEs. The use of instrumental variables is required according to the results of the Davidson-Mackinnon test only in the case of skilled labor (see Tables 15). We found that the coefficient for g2 (product innovation) is significant but no longer less than one, so new products are not necessarily being produced more efficiently than old products. Contrasting this last result with that for the case of unskilled labor based on the OLS estimation (Table 14), one can conclude that product innovation generates more employment growth in the case of skilled labor than in the case of unskilled labor.

Table 15. Dependent Variables: Columns (1 and 3) l^s -(g1-Π) and Columns (2 and 4) l^{us} -(g1-Π) SMEs: Effect of Innovation on Employment Quality, IV Estimates

Regression	Sector: Small Manufacturing			
	l^s -(g1-Π) Type 1 IV: basic estimation	l^{us} -(g1-Π) Type 2 IV: basic estimation	l^s -(g1-Π) Type 1 IV: + controls	l^{us} -(g1-Π) Type 2 IV: + controls
Constant	-5.148	-6.726	-7.479	-7.132
(se)	(5.749)	(6.505)	(6.500)	(7.487)
Process innovation only *(d)*	4.566	17.648	4.371	17.478
(se)	(13.504)	(15.279)	(13.512)	(15.563)
Sales growth due to new products *(g2)*	1.028***	1.068***	1.012***	1.068***
(se)	(0.071)	(0.080)	(0.072)	(0.083)
Capital region			3.642	0.746
(se)			(6.458)	(7.439)
Foreign owned (10% or more)			16.448	-0.729
(se)			(11.866)	(13.667)
2-digit industry dummies	Yes	Yes	Yes	Yes
Standard error	29.104	32.929	28.871	33.253
Number of firms	208	208	208	208
F test, g2	54.230	54.230	51.120	51.120
p-value	0.000	0.000	0.000	0.000
Sargan test	1.038	0.004	1.396	0.005
p-value	0.308	0.951	0.238	0.944
Davidson-MacKinnon test of exogeneity	8.770	1.800	7.856	1.777
p-value	0.004	0.183	0.006	0.186
Stock and Yogo´s test of weak instruments				
Cragg-Donald critical value	54.230	54.230	51.120	51.120
SY estadistic (10%)	19.930	19.930	19.930	19.930
List of instrument(s) used	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity	Increased range of goods; increase in productive capacity

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.

Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

Robustness Checks

We again estimated (2) for both the whole sample (manufacturing) and for the subsample of SMEs, using a different strategy. We instrumentalized **d** using the same set of instruments used for g2, to determine if the variable **d** is or is not correlated with productivity shocks that are in the error term—that is, if our assumption that **d** is exogenous is valid. It is worth mentioning here that we did not check for changes in the slope of product innovation when these innovations are introduced jointly with process innovations, since we did not have firms in the sample that meet such a condition.

Based on the results presented in Table 15A, we cannot reject the null hypothesis that **d** is exogenous in any of the regressions under the headings of manufacturing and small firms, based on the Davidson-MacKinnon test of exogeneity. Therefore, we can remain fairly confident of the results found in the previous subsections.[32]

Table 15A. Effects of Innovation on Employment Quantity – IV Estimations Robustness Checks Dependent Variable: l-(g1-π)

Regression	Sector					
	Manufacturing			Small firms		
	1	2	3	1	2	3
Constant	-17.36**	-21.19**	-22.52**	-10.87	-9.26	-10.35
(se)	8.40	8.78	9.57	9.11	8.33	8.58
Product innovator (g2)	1.11***	1.10***	1.10***	1.09***	1.09***	1.08***
(se)	0.08	0.08	0.09	0.10	0.10	0.10
Process only innovator (non product innovator) (d)	75.24*	77.85*	83.08*	36.98	35.50	38.15
(se)	44.91	45.00	47.99	50.55	48.96	49.54
Located in the capital (capreg)		6.54	7.01		-2.37	-1.34
(se)		4.35	4.46		6.44	6.61
Foreign owned (10% or more)			4.89			7.95
(se)			6.87			11.59
Time (if pooled)	No	No	No	No	No	No
2-digit industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
F test, d	14.57	14.56	13.56	7.17	7.53	7.12
p-value	0.00	0.00	0.00	0.00	0.00	0.00
F test, g2	87.31	87.29	90.15	62.28	60.95	58.64
p-value	0.00	0.00	0.00	0.00	0.00	0.00
d Davidson-MacKinnon test of exogeneity	1.95	2.19	2.33	0.21	0.18	0.23
p-value	0.16	0.14	0.13	0.65	0.67	0.63
g2 Davidson-MacKinnon test of exogeneity	13.80	13.07	12.55	7.38	7.37	6.75
p-value	0.00	0.00	0.00	0.01	0.01	0.01
R square	0.73	0.73	0.49	0.79	0.80	0.80
Standard error	29.61	29.61	41.97	27.49	27.41	27.39
Number of firms	208	208	208	119	119	119

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Notes: Instrumented d and g2 by "increased range of goods" and "increase in productive capacity" indicators.
All regressions include industry and time dummies. F test denotes de F of excluded instruments in the first stages regressions. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

e. Innovation Strategies and Employment

Firms can use different strategies to innovate. Considering the concept of a knowledge production function (Griliches, 1979), firms can innovate by investing in R&D, training, acquiring embodied technologies (through the purchasing of new machinery and equipment), or

[32] We did not estimate the Sargan test since the equation is not over-identified.

purchasing codified knowledge (e.g. through technological licenses). Veugelers and Cassiman (1999) have categorized these channels into two types of innovation strategies: “make” or “buy”. We estimate equations (6) and use the second approach discussed previously in order to explore how different innovation strategies affect the employment outcomes of innovation. For the models used to investigate buy and make innovation strategies, we use a definition of variables that is similar to the one suggested by Veugelers and Cassiman (1999), as defined previously.

Table 16 shows some descriptive statistics for the sample of firms regarding innovation strategies. It is important to point out that only product innovators are involved in “make-only” innovation strategies (86 percent). Some of these firms are also involved in “buy-only” innovation strategies (55 percent). Many of the product innovators are involved in both make and buy innovation strategies (77 percent). As shown in the second part of Table 16, the results do not change significantly when we analyze only the case of SMEs. Therefore, it seems that firm size does not affect the participation of firms in “make” and/or “buy” innovation strategies.

Table 16. Descriptive Statistics for Firms Regarding Innovation Strategies

	Buy only	Make	Make & Buy
All Firms			
Number of observations	**20**	**14**	**137**
All Firms	100	100	100
Noninnovators (no process or product innovations)	30	14	20
Process only innovators (non product innovators)	15	0	3
Product innovators	55	86	77
Small Firms			
Number of observations	**14**	**11**	**64**
All Firms	100	100	100
Noninnovators (no process or product innovations)	36	18	30
Process only innovators (nonproduct innovators)	14	0	5
Product innovators	50	82	66

Source: Authors’ calculations based on Costa Rica Innovation Survey for 2006–2007.

i. Econometric Results for all Firms and SMEs

Table 17 presents the results of equations (6) –reduced form- for all firms in the sample, while Table 18 shows the results for SMEs. The results in column (1) of Table 17 suggest that the make only strategy has a larger effect on employment than both make and buy and buy only strategies. In fact, the former is the only coefficient that is significant (make only). Column (1) in table 18 shows similar results for SMEs. It also shows that in the case of SMEs the effect of the make only strategy on employment seems to be larger than for the sample as a whole.

Table 17. Innovation Strategies: Results for all Firms

Regression	Sector: Manufacturing			
	Reduced form l -(g1-Π) 1-OLS	First stage g2 2-OLS	First stage d 3-OLS	First stage g1 4-OLS
Constant	70.01***	64.10***	0.06	-51.94***
(se)	9.65	9.34	0.04	9.68
Make only (dummy)	28.17*	40.38**	-0.07	-30.42*
(se)	16.15	17.39	0.04	16.20
Buy only (dummy)	-7.04	8.02	0.08	1.85
(se)	17.70	18.25	0.09	17.56
Make & Buy (dummy)	1.87	16.70	-0.02	-1.62
(se)	10.97	10.91	0.04	11.00
2-digit industry dummies	Yes	Yes	Yes	Yes
R-squared		0.11	0.09	0.08
Standar error		57.81	0.20	56.19
Number of firms	208	208	208	208

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

Table 18. Innovation Strategies: Results for SMEs

Regression	Sector: Small in Manufacturing			
	Reduced form l -(g1-Π) 1-OLS	First stage g2 2-OLS	First stage d 3-OLS	First stage g1 4-OLS
Constant	63.11***	54.41***	0.06	-45.46***
(se)	10.16	9.74	0.05	10.31
Make only (dummy)	33.35*	42.96**	-0.06	-35.40**
(se)	17.79	18.68	0.06	17.90
Buy only (dummy)	-23.47	3.47	0.03	15.91
(se)	20.42	22.14	0.10	20.08
Make & Buy (dummy)	-0.58	13.60	0.00	1.45
(se)	12.87	12.89	0.06	12.93
2-digit industry dummies	Yes	Yes	Yes	Yes
R-squared	0.12	0.14	0.15	0.12
Standar error	60.08	58.52	0.24	58.04
Number of firms	119	119	119	119

Source: Authors calculations based on Costa Rica's Innovation Survey for 2006–2007.
Note: * Coefficient is statistically significant at the 10 percent level; ** at the 5 percent level; *** at the 1 percent level; no asterisk means the coefficient is not different from zero with statistical significance.

Columns (2), (3) and (4) in Table 17 show the results of the first stage (the second approach discussed previously) between innovation strategies, product and process innovations, and sales of old products. The results suggest that a make only strategy accelerates the introduction of new products by 40 percentage points, while no effect was found in the case of the other two strategies (the coefficients are not statistically significant from zero). A make only strategy decreases the sales of old products by 30 percentage points, while no effect was found in the other two strategies. Columns (2), (3) and (4) from Table 18 show similar results, with similar precision, hold for SMEs.

Table 19. Effect of Different Innovation Strategies on Employment

Strategy	Effects on employment growth							
	Manufacturing Sector				Small in Manufacturing Sector			
	Product innovations	Process innovations	Sales of old products	Total	Product innovations	Process innovations	Sales of old products	Total
Make only	41.32	-1.31	-30.42	9.59	45.39	-0.93	-35.40	9.06
Buy only	8.21	1.43	1.85	11.49	3.66	0.40	15.91	19.97
Make & Buy	17.10	-0.42	-1.62	15.06	14.37	0.05	1.45	15.87

Source: Authors' calculations based on Costa Rica's Innovation Survey for 2006–2007 and results from Tables 17 and 18.

In Table 19, we quantify the total effect of different innovation strategies on employment growth. Since the only valid result is that for the make only strategy we analyze only this case.[33] In short, columns (2), (4) and (5) show that higher employment growth due to the product innovation effect (41.32) more than compensates for the decrease of employment due to the sales of old products (-30.42). The first specification shows that the "make only strategy" has a positive impact on labor generation. This means that the firms with "make only" strategies have much larger impacts on labor generation than firms that do not use that strategy. The result is very similar when we analyze the case of SMEs, as shown by the results from columns (6), (8) y (9) from Table 19.

To summarize, based on the preceding discussion on innovation strategies and employment generation, we can conclude that in-house innovations are positively related to the creation of labor in Costa Rican manufacturing firms, while "buy" strategies seem have no impact on employment in these firms. No differences were found when we controlled for firm size.

[33] The results from tables 17 and 18 show that only the coefficients associated with the "make only strategy" (in first stage regressions) for g2 and g1, are statistically different from zero.

8. Concluding Remarks

This document has presented the results of the estimation of Harrison, et al.'s (2008) basic model and some extensions of this model for the case of Costa Rica, using a cross-sectional data set for the manufacturing sector of this country for the period 2006–2007.

The results of using the Harrison et al. model show that both product innovation and process innovation are positively related to employment growth. This is a very important finding for policymakers since it shows that appropriate policies to promote innovation activities, such as providing people with good educations (technical and professional), is the best way to keep creating job opportunities in the future.

It was found that since Costa Rican manufacturing firms are on average experiencing productivity growth jobs related to old products are decreasing. This result implies that policies are required to improve the capabilities of workers engaged in the production of old products, so that they can become involved either in process innovation activities or in the production of new goods, thus avoiding losing their jobs in the near future. Activities such as retraining must be a priority in this situation.

Taking into account firm size when analyzing innovation impact on labor is useful for different reasons. First, the analysis led us to conclude that product innovation generates employment in the case of all firms regardless of size. Second, SMEs are not on average experiencing productivity growth, which implies that they are not suffering constantly decreasing employment for given levels of old products output. Therefore, it seems that policies like retraining workers should be focused more on large firms.

These results also point out that skilled labor is demanded when a firm is involved in product innovations, while unskilled labor is demanded by companies that are involved in both process and product innovations, meaning that process innovations are not necessarily related to skilled labor demand. Some differences were found between the results for SMEs and larger ones regarding the impact of product innovation on employment growth taking into account the quality of labor. When analyzing innovation strategies, it seems that those innovations made inside firms are those that generate employment opportunities in Costa Rican manufacturing firms. Therefore, policies that promote innovation efforts by these firms will promote at the same time a positive environment for new employment opportunities in the near future. No differences were found when we controlled for firm size.

In summary, several policy recommendations arise from overall analysis. First, improving possibilities for product innovation by manufacturing firms in Costa Rica seems likely to generate new employment opportunities, especially for skilled workers. Thus, authorities must focus their efforts on supporting the upgrading of the Costa Rican labor force's skills. In addition, facilitating firms' involvement in process innovations may be beneficial, since it can also generate labor opportunities. Training will be very important in achieving this last objective.

In short, the findings suggest that successfully strengthening the Costa Rican innovation system may contribute to improve employment generation in this country. Moving Costa Rica towards an innovation-driven economy seems to be a good way to increase labor opportunities for both skilled and unskilled workers in the manufacturing sector, if Costa Rican authorities can deal efficiently with the challenges described in this paper (see Table 4).

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Appendix A

List of Interviewees

Academics		
Paola Gamboa	Coordinator	PROINNOVA University of Costa Rica
Ignacio Trejos	Academic Director	CENFOTEC;
	Professor	ITCR CENFOTEC; Costa Rican Technological Institute (ITCR)
Policymakers		
Alejandro Cruz	Minister	Ministry of Science and Technology (MICIT)
Gabriela Llobet	Director	Costa Rican Investment Promotion Agency (CINDE)
Businesses (case studies)		
Manuel Grinspan	General Manager	Etipress
Jose Valverde	Director Human Resources	COOPESA
María Luisa González	Director Human Resources	Costa Rica Hewlett Packard
Asdrúbal Vásquez	Director of Institutional Relations	Sardimar

Appendix B

Case studies

Interviews were carried out with representatives of four innovative Costa Rican firms. Selection of the firms was based on the results of conversations with members of the research team and with other experts in the area of innovation in the country. The companies vary widely in size and the sectors in which they operate, from a label manufacturing company with 80 employees, to a cooperative specializing in aircraft maintenance services with 750 employees, to a fish processing and canning company with 1700 employees, to a multinational high-technology company with 6,500 employees primarily dedicated to providing services to corporate clients.

Etipres *(primary innovations: new products and services)*

Etipres is a label design and printing company founded in 1985 with 5 employees, which has enjoyed consistent commercial success and growth, and now has 80 employees and more than US$5 million in annual sales (approximately 25 percent of which is generated by sales outside Costa Rica). These markets are extremely competitive, with other local and international labeling companies being well aware of the products that Etipres offers, and constantly attempting to match and improve upon these products. The management of the company consequently places very strong emphasis on the constant creation of new products and services to differentiate itself from its competition, and to avoid having its products become commodities whose commercial success will depend primarily on their prices. The general manager of Etipres stated in an interview that successful innovation has been directly responsible for the growth of the company, both in terms of income and of employment. Recent innovations include the use of new materials (special papers and plastics) for labels, the creation of its own graphic arts division to assist clients with the design of their labels, and the design and manufacture of specialized machinery (including the design of some specialized integrated circuits for these machines) in order to make its production processes more efficient. It has created special software for the management of the company's business processes, and is considering the commercialization of this software to other label manufacturers. It also makes extensive use of the Internet for investigation of markets, and is now using Google's AdWords services to ensure advantageous placement of the company's Web site in the results of Internet searches by potential clients.

Etipres has not encountered problems in obtaining an adequate supply of engineers, ICT technicians, and other types of graduates of universities and technical colleges, and in fact no more than 20 percent of current employees have university degrees, many of which were earned while the recipient was already employed in the company. The company places a very strong emphasis on finding and employing excellent line-level workers, and many of its most valued employees have no more than a sixth grade formal education. However, workers are provided with an extremely high level of internal training, which ranges from areas such as production activities and process improvements to a continuing series of courses in areas such as English, health and first aid, sex education, and even dancing, and also participate in periodic brainstorming sessions on ways to improve operations.

These efforts, coupled with opportunities to rise to higher levels in the company, a commitment to avoid firing workers unless circumstances are extreme, and relatively high wages, have produced a workforce that is not only highly efficient, but one that is also extremely identified with the company, well-informed about its activities, and explicitly interested in improving its commercial success. A number of new product specifications and process improvements have been based on employee suggestions.

Etipres's management has considered the use formal mechanisms for intellectual property protection (patents, etc.), but has so far limited itself to protecting its brand and image through legal registration of trademarks in Costa Rica. The cost of obtaining other types of IP protection—for its software, for instance—is considered to be higher than the benefits that this would protection would justify. The general manager said that their investigations indicated that the cost of obtaining a U.S. patent, which is the only alternative that the company has considered, would range between US$20,000 and US$50,000, and that the complete process would take several years.

COOPESA *(primary innovations: process improvement) and organization of work)*

The Cooperativa Autogestionaria de Servicios Aeroindustriales (COOPESA) provides maintenance and fueling for large jet aircraft owned by international operators from facilities located on the grounds of the Juan Santamaría Airport in Alajuela. Although it was originally founded with the participation of the national government, which was part owner of the company, it is now completely owned by associates—the approximately 80 percent of the 750 current employees who have been hired for a full-time position and have chosen to pay association fees.

Almost all COOPESA mechanics have graduated from the COOPESA training school, which has an average annual enrollment of approximately 30 students, of whom somewhat more than 20 usually graduate and are hired by COOPESA. Most of these students have been previously educated in vocational schools rather than universities, and all pay their own tuition for training which usually takes three years.

The airline industry has been strongly affected by events such as the 9/11 terrorist attacks and the 2008–2009 global recession; during industry downturns, COOPESA has had to terminate employees (usually nonassociates), while observing all legal requirements for prior notification and termination payments, which it does not regard as burdensome or unjustified. When more labor is required, COOPESA gives preference to rehiring those who have previously worked satisfactorily for the company. Management has also seriously considered the hiring of skilled foreign workers in circumstances of unusually high demand for labor, but the necessity of proving that no qualified Costa Rican workers are available for the positions to be filled, and waiting several months for visas to be approved, have proven to be serious impediments to a strategy which is intended to provide a rapid response to labor shortages.

The fact that the airline industry is highly regulated, and subject to a great number of requirements for training and official certification of the organizations and individuals that work in the industry, means that COOPESA must invest heavily and continuously in training to enable its maintenance specialists to pass periodic examinations conducted by regulating agencies in the United States, the European Union, and various countries in Latin America and the Caribbean. In addition, a newer generation of airplanes is coming into service that differ from previous ones in depending far more on computerized diagnostic maintenance techniques than on manual mechanical inspection; this has required extensive employee retraining and a higher level of employee familiarity with the English language.

COOPESA has no domestic competition, but faces an extremely high level of international competition from maintenance organizations in Brazil, Chile, El Salvador, and Panama, since the international airlines and leasing or financial corporations, their only clients, are free to choose the country in which they temporarily remove their jets from service for maintenance and repairs. The most important factor that fleet owners tend to consider when choosing between otherwise equally acceptable maintenance providers is the efficiency and speed with which routine maintenance is carried out, and unanticipated problems detected and repaired, so that airplanes may be returned to service on or before established deadlines.

In these circumstances, COOPESA has made very strong efforts to innovate in terms of the processes that they use to repair and maintain aircraft. Among other things, it has created a planning department which focuses on constant process improvement (as well as studying the profitability of maintaining different types of aircraft, and the training and tools that each model requires), and has worked with major Costa Rican universities to improve their training techniques and the design of repair processes. Employees also make increasing use of the Internet to keep themselves up to date on international best practices in repair and maintenance techniques, and to have real-time access to the latest versions of manuals and other information placed online by aircraft manufacturers and airlines.

Although COOPESA has focused in the past on the optimization of processes and reorganization of worker teams to more efficiently carry out the services that it has traditionally offered, it has recently begun to prepare itself to offer a new range of services, moving beyond its previous focus on "heavy maintenance" (related to the principal mechanical and electronic components of aircraft) to services related to the maintenance and repair of seats, carpeting, and other elements primarily located in the passenger cabins of the airplanes that it services. These new services will be offered beginning in the year 2012.

Sardimar *(primary innovations: new products)*

Sardimar is the largest fish processing and canning company in Costa Rica, with a full-time workforce that varies between 1700 and 2000 full-time employees. It also adds several hundred temporary employees in the period previous to the Easter holidays, when the demand for fish is especially high, and management estimates that as many as 4,000 to 5,000 other persons in the country are involved in activities that are in some way associated with the company's production and distribution chains.

The principal product that Sardimar produces is processed tuna. Approximately 84 percent of the tuna consumed in the country is produced locally, and Sardimar provides almost all of that locally processed and canned tuna with 50 percent of its production, marketed either by Sardimar under its own brands or by other large companies such as Walmart under their brands. The other 50 perecnt of Sardimar's production is marketed internationally under Sardimar brands.

Sardimar works constantly to develop new products. It played an important role in the introduction of canned tuna mixed with vegetables in Costa Rica, for instance, which allowed the company to not only extend the market for their products, but also to use less tuna in each can sold. While the company originally used manual labor to mix tuna and vegetables, it was found that this resulted in unacceptable variations in the proportions of ingredients in each can, and the process was automated, with a consequent loss of approximately 120 positions in the packing process. The employees whose activities were automated were moved to different positions within the company.

Other innovations have clearly created new jobs. The results of a recent study by researchers from the University of Costa Rica showed that the sludge remaining in the approximately 100 tons of waste water produced daily in the cleaning of fish was suitable for conversion into a high-grade fertilizer, and other researchers are currently completing a specification of the optimal mix of ingredients. As a result of these efforts, a new division of the company dedicated to fertilizer production will be created and new employees will be hired to work there. The company plans to patent the methods used to process the sludge, and will also need to develop a new brand and marketing strategies to commercialize the final product.

In another case of job creation through innovation, Sardimar's decision to participate in the development of gourmet products led to a contract with an Italian company to produce special slices of the belly meat of yellow fin tuna, which are packed in olive oil sent from Italy, together with other ingredients such as jalapeño peppers. Marketed as Tonnino Tuna Filets, the products have been a great commercial success, leading to an expansion of production and a need for more workers to carry out specialized selection and processing of yellow fin tuna.

Some types of innovation carried out by Sardimar are more the result of necessity than of choice. The company is facing the prospect of declining catches of tuna from the Pacific coastal waters of Costa Rica as a result of heavy global exploitation of migratory fish, for instance, and is increasingly purchasing containers of frozen fish from suppliers in the Western Pacific, whose quality is somewhat lower than that of the fish taken in Costa Rican waters. As a result, Sardimar is finding it necessary to develop new brands and marketing strategies for separate products made with this lower-quality tuna to avoid customer perceptions that the quality of existing brands and products is declining.

Hewlett Packard *(primary innovations: new services, products)*

Hewlett Packard (HP) is one of the largest ICT companies in the world, with more than 300,000 employees in 170 countries around the world and global 2010 revenues of almost US$115 billion. In 2003, the HP opened an office in Costa Rica with 123 employees, and by the end of 2010 it had more than 6,500 employees in the country, making it the second-largest single employer in Costa Rica.

Costa Rica, together with Bulgaria, China, India, Malaysia, and the Philippines, has been designated as an HP Global Delivery Hub, a key element in the HP "Best Shore" global services delivery model which provides clients throughout the world with outsourced IT infrastructure, as well as call center, business process, and other services. HP also created its first Latin American R&D center in Costa Rica, which currently employs 70 engineers dedicated to the development of new technology; HP's other R&D centers are located in the Canada, India, Singapore, Taiwan, and the United States.

Measures are in place in all divisions of HP operations for monitoring and improvement of processes, market research is constant, and customer satisfaction surveys are carried out frequently. Employees are periodically provided with on-the-job training in areas ranging from interaction with call center clients to highly technical topics related to the development and implementation of ICT products and services.

In common with many other multinational corporations (MNCs), HP was attracted to Costa Rica by the availability of a relatively large number of well-educated workers, as well as the country's reputation for political stability and various government incentives intended to attract Foreign Direct Investment (FDI). The steady influx of MNCs, coupled with the small absolute size of the population, has depleted the availability of the technical college and university graduates, which HP requires for almost all of its positions, and competition between employers has caused salary expectations to rise.

Among other things, increasing salaries mean that providing lower-value and relatively standardized services, such as call center outsourcing, is becoming less attractive to HP, and emphasis is being placed on providing more innovative and valuable services, such as customized business process outsourcing in their place; this move is also attractive because there is less employee turnover involved in the provision of more sophisticated services. The more technical nature of higher-value services as compared to call center services implies that as this transition is carried out, the level of technical education and training of workers will rise, resulting in higher-quality employment opportunities.

HP is constantly searching for new ways to find and help create the types of human resources needed to maintain and expand its global services delivery operations in Costa Rica. It has coordinated with the Ministry of Education (MEP) to provide technology for rural schools (more than US$800,000 worth of equipment in 2009), and has made a number of efforts to inform institutions in the educational system of the types of skills that modern high-technology companies require. In the case of universities, it not only advises their administrations about desirable skills, but also invites professors to visit its facilities and learn more about the company's activities, and sends representatives to give presentations to students about how to improve their chances for future employment in the high-tech sector. It has also worked with the Costa Rican Investment Promotion Agency (CINDE) to modernize training in technical colleges, and actively participates in major job fairs throughout the country to publicize the advantages of working for the company.

The engineers working in the research and development component of HP operations in Costa Rica are focused primarily on the development of embedded software for HP's ProCurve network hardware. They constantly seek to improve their products, and measure that improvement in a variety of ways, including reductions in the number of errors detected in the code that they generate and increases in levels of customer satisfaction with their products. They work closely with clients to determine needs for new features that can be incorporated into their existing products, and to detect the possibility of creating profitable new products. Products are reviewed periodically to determine if there is any necessity to protect new intellectual property with U.S. patents, which has been found to be necessary on several occasions; obtaining these patents has taken between two and four years.

Appendix C

Variable Definitions (in alphabetical order)

Buy innovation strategies (Buy): Dummy variable which takes the value 1 if the enterprises acquired technology through licensing, external R&D, hardware, software, consultancies, and machinery or equipment, and 0 otherwise.

Employment growth* (l)*: Rate of change of the firm's employment for the whole period.

***Foreign owned 10% or more*:** Dummy variable which takes the value 1 if the enterprise has more than 10 percent of foreign capital and 0 otherwise.

Increased range of goods: Variable that takes the value 0 if the firm reports that the effect of innovation has been irrelevant for the broadening of the range of goods and services, 1 if it has had a low impact, 2 if it has had a medium impact, and 3 if it has had a high impact.

Increased in productive capacity: Variable that takes the value 0 if the firm reports that the effect of innovation has been irrelevant for increasing the productive capacity, 1 if the impact of innovation is low, 2 if it has had a medium impact, and 3 if it has had a high impact.

Industry dummies: System of industry dummies at a 2-digits level of the International Standard Classification.

***Located in the capital*:** Dummy variable that takes the value 1 if the firm is located in the capital city of Costa Rica, and 0 otherwise.

Make innovation strategies (Make): Dummy variable that takes the value 1 if the enterprises reports having carry out R&D and/or other innovative activities (in-house training, in-house engineering and industrial design, in-house management) and report a non-negative budget for these activities, and 0 otherwise.

***Prices indices at detailed industry levels*:** Obtained for manufacturing at a 2-digit level of the International Standard Classification from Central Bank of Costa Rica.

***Process innovator only* (d):** Dummy variable that takes the value 1 if the enterprise reports doing *only* process innovations (where the "only" refers to firms that do not do product innovation), either to the firm, country or world, during the considered period, and 0 otherwise.

***Product innovator only* (d2):** Dummy variable that takes the value 1 if the enterprise reports having only introduced new products (either to the firm, country, world), and 0 otherwise.

***Product or process innovator* (TPP):** Dummy variable that takes the value 1 if the enterprise reports having introduced new products (either to the firm, country, world) or significantly improved processes (either to the firm, country, world) during the considered period, and 0 otherwise.

Real sales growth of old goods **(g1-π):** Sales growth due to old products minus the increase of prices at detailed industry level.

Sales growth due to new products **(g2):** Computed as the product of the fraction of turnover due to new or significantly improved products and one plus the rate of change of the firm's turnover for the whole period.

Sales growth due to old products **(g1):** Sales growth minus sales growth due to new products.

Skilled employment growth (l^s): Rate of change of the firm's skilled employment for the whole period, where skilled labor refers to technicians and professionals.

Unskilled employment growth (l^{us}): Rate of change of the firm's unskilled employment for the whole period, where unskilled employees are those with basic or inferior education level.