Assessing Computer Education in Costa Rica:

Results of a Supply and Demand Study of ICT Human Resources

Francisco J. Mata
Programa de Investigación y Extensión en Tecnología de Información y Comunicación
Posgrado en Gestión de la Tecnología de Información y Comunicación
Escuela de Informática
Universidad Nacional de Costa Rica
Heredia, Costa Rica
fmata@una.ac.cr

Rosaura Matarrita
Cámara de Tecnología de Información y Comunicación
San José, Costa Rica
rmatarri@yahoo.com

and

Claudio Pinto
Cámara de Tecnología de Información y Comunicación
San José, Costa Rica
claudio.pinto@fairplaylabs.com

Abstract

In the last decade, Costa Rica has established a reputation for being a global provider of information and communication technology (ICT) products and services. Several important multinational companies have begun outsourcing operations in the country. In addition, a growing number of local firms have been created to provide ICT products and services worldwide. As a consequence, the country is experiencing a shortage of ICT qualified workers.

To understand the ICT human resource situation and improve the country's capacity in computer education, a supply and demand study was conducted from 2007 to 2009. This paper presents the results of this study and its implications for the educational system. In addition, policy recommendations for computer education are proposed in order to support the country´s competiveness in the global ICT market and advances related to these recommendations are discussed.

Keywords: ICT human resources, computer education programs, Costa Rica

1. Introduction

Costa Rica has become a global provider of information and communication technology (ICT) products and services. Several important multinational companies, including Hewlett Packard, IBM, Intel, Procter and Gamble and Western

Union, decided to start operations in the country. In addition, a growing number of local firms have been created in order to provide ICT products and services globally. As a result of this situation, the country has experienced a shortage of ICT qualified workers during the first decade of the new millennium, particularly in careers related to computer sciences and informatics [1,2,3].

Several factors constrain the capacity of the country to keep up with the growing demand of qualified computer trained personnel: the country´s small population, the reduced coverage of upper secondary and tertiary education, the limited capacity of the private universities to graduate computer professionals, and the weak technical and para-academic educational programs in the country [4,5].

To understand the ICT human resource situation and improve the country´s computer education, a demand and supply study was conducted from 2007 to 2009 by the Costa Rican Association of ICT Companies (CAMTIC) in conjunction with the Program in Information Technology and Development of the Universidad Nacional de Costa Rica (UNA). This study was funded by the International Development Research Centre (IDRC) of Canada through the Research Program on the Knowledge Economy in Latin American and the Caribbean of the Latin American Faculty in Social Sciences (FLACSO-Mexico).

Based on previous studies (Mata and Jofré [6], Mata *et al.* [7,8,9,10] and Araya *et al.* [11,12,13]), eight ICT occupations were considered on the demand side of the study: 1) Software Engineers,[1] 2) Application Programmers, 3) Project Managers, 4) Technical Support Specialists, 5) End-User Technical Supporters,[2] 6) Specialists in Quality Assurance, 7) Specialists in Software Testing, and 8) Specialists in Marketing and Sales of Software Services and Products. These occupations are focused on software development and technical support.

An electronic survey was conducted to 83 organizations obtained from a judgment sample of 160 organizations (52% response rate). Questionnaires were addressed to the persons in the organizations in charge of recruiting ICT staff. The sample obtained had the following structure: ICT companies (76%), private organizations not related to the ICT sector (11%), public and non-profit organizations (2%), other types of organizations (9%) and organizations that did not disclose their sector (2%). Subsidiaries of multinational corporations (MNC) constituted 19% of the final sample.

The number of total employees in the final sample of organizations ranged from 2 to 44,000 with an average of 870 employees per organization. A large standard deviation for the total number of employees was obtained (4,197), which can be explained by the fact that 46% of these organizations can be classified as small organizations (11 to 35 employees) and 26% as large (more than 100 workers). Micro organizations (1 to 10 employees) accounted for 12% of the sample and medium organizations (35 to 99 workers) to 16%.

On the supply side, computer graduates in programs related to software development and technical support were considered at the technical, para-academic,[3] and academic levels of the educational system of Costa Rica for the decennium 1997-2006.[4] Data was obtained from the National Council of Rectors (CONARE) and from the National Council for University Higher Education (CONESUP) for 23 universities, public as well as private, and from the Ministry of Public Education (MEP) for 7 community colleges and 91 technical colleges.[5]

This work presents a summary of the results of the supply and demand study conducted and discusses policy recommendations based on these results to improve computer education and support Costa Rica´s competitiveness in the global ICT market.[6] Furthermore, actions already undertaken towards those policies are also presented.

[1] This occupation was referred by Mata *et al.* [8] to as Software Engineers/System Analysts. However, for the sake of simplicity it is denoted in this work simply as Software Engineers.
[2] This occupation was referred by Araya *et al.* [13] to as End-User Technical Supporters/Computer Technicians.
[3] The para-academic level is comprised by public and private "Colegios Universitarios", which are the equivalent of the community colleges in the U.S., and public universities which offer diplomate degrees, equivalent to associate degrees.
[4] Due to the delay in reporting graduation statistics, the study had to rely on data available until 2006.
[5] Although information on degrees granted was available for this study, the same was not centralized. For this reason, that information had to be extracted from several spreadsheets containing information about the degrees granted for all the programs offered by each educational center. Furthermore, given the variety of names that these programs have, a list for them had to be compiled, requiring in some cases a review of the programs, prior to extracting and organizing the data.
[6] More information about this study can be found in Herrera *et al.* [5] and Mata *et al.* [14,15].

This paper is organized in five sections. Section 2 presents a brief description of the ICT sector in Costa Rica. The results of the supply and demand study are discussed in section 3 and policy recommendations based on the findings are presented in section 4. Section 5 contains the conclusions.

2. Costa Rica's ICT Sector

An indigenous ICT cluster began to develop in Costa Rica in the 1980s [6], mainly in the Central Valley. Later, Intel decided in 1997 to build an assembly and testing plant in Costa Rica. Even though local ICT companies precede the installation of Intel´s plant, the decision of this company to invest in the country represented a milestone for creating a national ICT cluster. This decision induced other MNCs to establish operations in the country. Following Intel, Procter and Gamble decided to open a global business services center in 2000, Western Union established a customer interaction center in 2000, and Hewlett Packard decided to install a business process outsourcing center in 2003 [4]. Recently, IBM announced the opening of a new ICT service center in Costa Rica with an expected investment of US$300 million for the next 10 years and the generation of 1,000 new jobs from 2011 to 2014 [16].

According to statistics from the Ministry of Science and Technology [17], ICT imports in Costa Rica amounted US$2,340 million in 2007, which represents a reduction from the US$2,508 million reported in 2006. However, ICT exports were US$2,878 million in 2007, an increase from the US$2,345 level registered in 2006. Furthermore, employment in the ICT sector has been estimated at 49,901 jobs in 2007 (2.47% of the economically active population) and 45,066 employees in 2006 (2.32% of the economically active population), reflecting an increase of 10.72% of the employment in this sector.

Related to the structure of the ICT sector in Costa Rica, Mata and Mata Marin [4] indicate that the same can be divided into two subsectors. The first subsector, and most important in employment and production, is that composed of subsidiaries of MNCs established in the country. In 2006, this subsector was composed of approximately 95 large and medium companies, mainly related to the industries of electronic components (production of microprocessors, design and production of electronic circuits, etc.) and IT-enabled services (global business services, customer interaction services or contact centers, back-office operation services, business process outsourcing, etc.). These companies generated US$2,200 million in total sales and employed 24,000 workers, resulting in approximately US$92,000 of sales per employee. In contrast, the second subsector is composed of domestic companies, amounting to around 600 in 2006, mainly micro, small and medium enterprises. These local companies focus on IT direct services (database services, network services, customized software development, consulting, and other related services) and development of horizontal and vertical software solutions, being the majority of them software companies which offer outsourcing services. Companies in this second group produced US$300 million in sales and generated 9,400 jobs, with an average of US$32,000 of sales per employee. Consequently, there is an asymmetrical profile between these two ICT subsectors, and as a result of this, MNCs are able to pay higher wages to ICT employees.

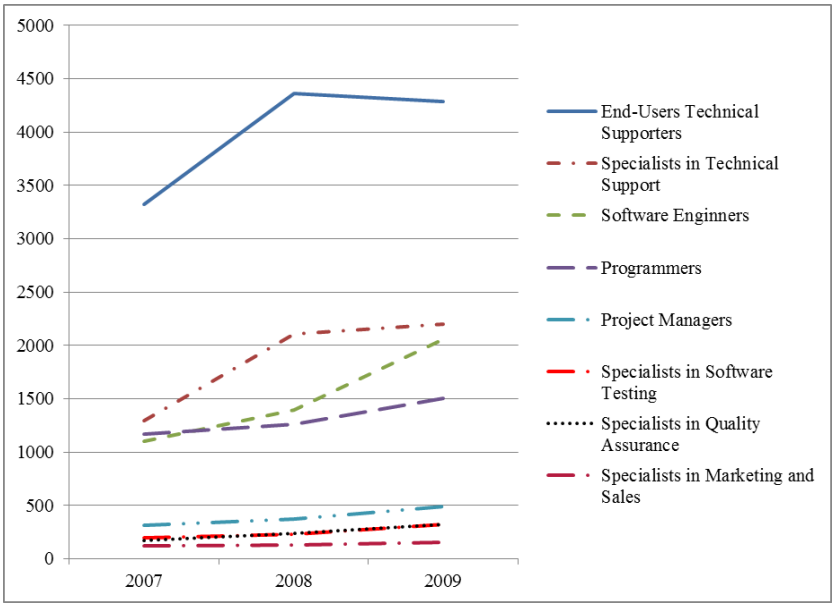
3. Results of the Demand and Supply Study

3.1 Demand for ICT Workers Classified by Occupations

In the year 2007, most of the ICT employees in the organizations surveyed were End-User Technical Supporters (43%), followed by Specialists in Technical Support (17%), Programmers (15%), Software Engineers (14%), Project Managers (4%), Specialists in Software Testing (3%), Specialists in Quality Assurance (2%) and Specialists in Marketing and Sales of Software Services and Products (2%).

Figure 1 presents data on the demand for ICT workers, classified by the occupations studied, from the organizations surveyed. Data for 2007 corresponds to actual figures, while data for 2008 and 2009 are estimations. The growth for the occupations for the period 2007-2009 can be classified as *high* for the Specialists in Quality Assurance (92%), Software Engineers (86%), and Specialists in Technical Support (70%), *medium* for the Specialists in Software Testing (62%) and Project Managers (56%) and l*ow* for the Specialists in Marketing and Sales (30%), End-User Technical Supporters (29%) and Programmers (29%). From all the eight occupations, the only ones that show a reduction in

growth from 2008 to 2009 are the End-User Technical Supporters (31% versus -2%) and Specialists in Technical Support (63% versus 4%).



Note: The values for the Specialists in Software Testing and for the Specialists in Quality Assurance for the three years are very similar and their demand lines overlap
Items in demand survey: "Total actual number of employees in your organization at the end of 2007 considering each occupation," "total estimated number of employees in your organization at the end of 2008 considering each occupation," and "total estimated number of employees in your organization at the end of 2009 considering each occupation"

Figure 1: Actual (2007) and estimated (2008 and 2009) number of total employees by occupation

End-User Technical Supporters and Specialists in Technical Support account for more than 50% of the employees in the eight occupations for the years 2007, 2008 and 2009. Furthermore, as Table 1 presents, the average number of employees in the organizations surveyed for this study is greater than the average observed in a previous study carried out in 2000 by Mata and Jofré [6], particularly in the case of the previous two occupations.[7] These facts indicate a notable change in the ICT occupational profile in Costa Rica: from software development, in 2000, to technical support, in 2007.

Table 1: Average number of employees by occupations (2007 and 2000)

Occupations*	**Average number of employees**	
	2007#	**2000&**
Software Engineers	13.4	5.4
Application Programmers	15.1	4.0
Project Managers	3.9	2.5
Technical Support Specialists	17.3	0.6

[7] It is important to highlight that the two studies rely on different samples.

Table 1 cont.

End-User Technical Supporters	45.5	1.2
Specialists in Quality Assurance	2.4	0.6
Specialists in Marketing and Sales of Software Services and Products	1.6	1.3

* Only occupations common to both studies are considered
[#] 2007 data from electronic survey
[&] 2000 data from Mata and Jofré [6]

3.2 Tightness of the Labor Market

As Table 2 shows, the organizations surveyed indicated that they were not able to hire 2,299 employees for the eight occupations in 2007. This situation reveals a tight labor market in Costa Rica for the occupations considered, as there are more positions available than employees to fill them.

Table 2: Deficit of employees in 2007

Occupation	Deficit of employees 2007
Software Engineers	226
Application Programmers	223
Project Managers	63
Technical Support Specialists	555
End-User Technical Supporters	1,057
Specialists in Quality Assurance	66
Specialists in Software Testing	84
Specialists in Marketing and Sales of Software Services and Products	25
All occupations	**2,299**

Item in demand survey: "Number of employees in each occupation that your organization could not hire during 2007"

In addition to the previously presented evidence, the organizations participating in this study expressed a generalized opinion that availability of employees was low for these occupations and that their salaries would likely increase over the next three years (2007-2009)[8] (see Tables 3 and 4).

[8] Evidence of such situation had been already reported in the newspapers [18].

Table 3: Perceived availability for occupations (2007-2009)

Occupation	Availability index*	Standard deviation	Do not know or do not answer
Specialists in Quality Assurance	1.27	0.45	19.28%
Specialists in Software Testing	1.36	0.60	20.48%
Project Managers	1.38	0.57	12.05%
Software Engineers	1.48	0.62	7.23%
Specialists in Marketing and Sales of Software Services and Products	1.63	0.71	25.30%
Technical Support Specialists	1.65	0.70	10.84%
Application Programmers	1.77	0.69	9.64%
End-User Technical Supporters	2.15	0.68	20.48%

* Availability index computed as the average of the values of a Likert scale (1=low, 2=medium, 3=high)
Item in demand survey: "In your opinion, is the availability of employees for each occupation in the Costa Rican labor market low, medium or high?"

Table 4: Perceived situation of salaries for occupations (2007-2009)

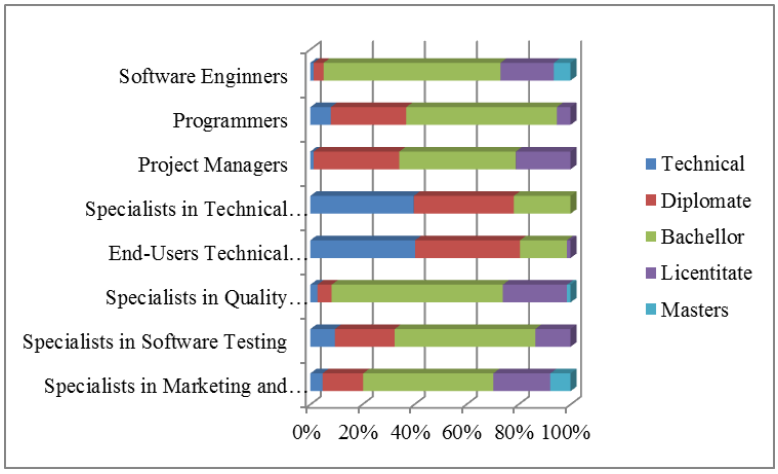
Occupation	Salary index*	Standard deviation	Do not know or do not answer
Application Programmers	2.92	0.43	6.02%
Software Engineers	2.85	0.42	3.61%
Project Managers	2.84	0.36	7.23%
Specialists in Quality Assurance	2.83	0.38	14.46%
Specialists in Software Testing	2.72	0.43	15.66%
Technical Support Specialists	2.61	0.54	3.61%
End-User Technical Supporters	2.53	0.53	12.05%
Specialists in Marketing and Sales of Software Services and Products	2.31	0.49	24.10%

* Salary index computed as the average of the values of a Likert scale (1=decrease, 2=constant, 3=increase)
Item in demand survey: "Do you consider that the salaries for each occupation will decrease, remain constant, or increase for the period 2007-2009?"

3.3 Academic Requirements for the Occupations

The ideal degree for most occupations is a bachelor's degree, according to the organizations surveyed (see Figure 2). Exceptions are the case of the Project Managers – for which a licentiate degree[9] is mostly mentioned –, and Specialists in Technical Support and End-User Technical Supporters – which require more often a diplomate[10] or a technical degree.

[9] This degree is above the bachelor degree yet below the master.
[10] As previously indicated, this degree can be considered equivalent to an associate degree in the U.S.



Item in demand survey: "Select the educational level deemed necessary for each occupation in your organization"

Figure 2: Ideal degree for the occupations

The importance of the diplomate and technical degrees for the above-mentioned occupations represent a major difference between this study and the one previously carried out by Mata and Jofré [6], which found that the bachelor degree was ideal for all the occupations considered.

3.4 Performance of Workers Classified by Occupations

According to the organizations surveyed, Software Engineers, Programmers and Project Managers are perceived to have a performance above "good", whereas the other occupations just have a performance above the "regular" level (see Table 5). This situation could be explained by the fact that profiles for the first occupations have been traditionally considered in educational programs in Costa Rica, particularly at the university level.

Table 5: Perceived performance for the occupations

Occupation	Performance index*	Standard deviation	Do not know or do not answer
Software Engineers	4.38	0.54	4.82%
Application Programmers	4.14	0.71	15.66%
Project Managers	4.06	0.82	13.25%
Technical Support Specialists	3.97	0.86	16.87%
End-User Technical Supporters	3.82	0.78	31.33%
Specialists in Quality Assurance	3.80	0.75	44.58%
Specialists in Software Testing	3.72	0.67	48.19%
Specialists in Marketing and Sales of Software Services and Products	3.49	0.99	45.78%

* Performance index computed as the average of the values of a Likert scale (1=very bad, 2=bad, 3=regular, 4=good, 5=very good)
Item in demand survey: "Using a five-point scale, where 1 is very bad and 5 is very good, indicate your opinion about the performance of the employees in your organization considering each occupation"

3.5 Educational Quality

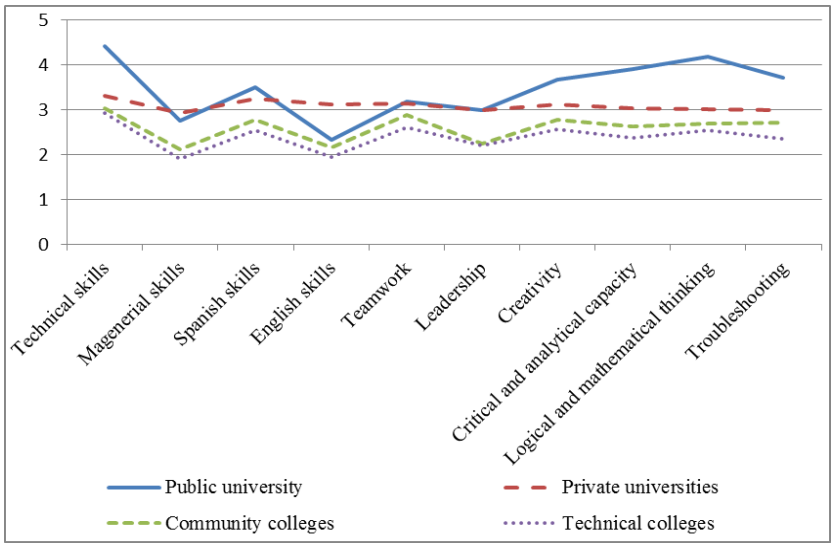
Educational quality was first evaluated by grouping educational centers into public universities, private universities, community colleges, and technical colleges. According to these groups, the organizations surveyed perceived the quality of the public universities above the "good" level, whereas the quality of the private universities was deemed just above the "regular" mark. On the other hand, the quality of the community colleges, which exclusively offer diplomate degrees, and of the technical colleges, which only grant technical degrees, were perceived below "regular" (see Table 6).

Table 6: Perceived quality by type of educational center

Type of educational center	Quality index*	Standard deviation	Do not know or do not answer
Public universities	4.21	0.79	2.41%
Private universities	3.23	0.77	6.02%
Community colleges	2.94	0.79	22.89%
Technical colleges	2.86	0.88	20.48%

* Quality index computed as the average of the values of a Likert scale (1=very bad, 2=bad, 3=regular, 4=good, 5=very good)
Item in demand: "Using a five-point scale, where 1 is very bad and 5 is very good, indicate your opinion about the quality of graduates from each educational center"

In terms of knowledge, abilities and skills, public universities show higher values in all categories considered than private universities (above the "regular" level), except in English skills and managerial knowledge, abilities and skills (values both below "regular"), as depicted in Figure 3. These values are perceptions of the respondents, as in the previous case. In particular, public universities excel in technical competences and logic and mathematical thinking (values above the "good" level). Furthermore, public universities have better perceptions of quality than community and technical colleges for all the types of knowledge, abilities and skills considered.



* Quality index computed as the average of the values of a Likert scale (1=very bad, 2=bad, 3=regular, 4=good, 5=very good)
Item in demand survey: "Using a five-point scale, where 1 is very bad and 5 is very good, indicate your opinion about the quality of graduates by educational center considering the different categories of knowledge, abilities and skills"

Figure 3: Perceived quality by type of educational centers considering categories of knowledge, abilities and skills

Private universities appear just above the "regular" level for all categories of knowledge, abilities and skills considered, yet they have values higher than community colleges, which in turn have values higher than technical colleges. These two last types of educational centers have marks below "regular".

When evaluating educational quality of centers individually, two public universities obtained marks above "good". A group composed by the other two public universities, two private universities and a private para-academic institution were deemed moderately above "regular" Meanwhile, the remaining six private universities received values below "regular".[11]

These quality perceptions were related to the selection and recruitment processes of the organizations surveyed. The higher the evaluation of quality of an individual center, the more its graduates were taken into account during these processes. Therefore, in spite of the scarcity of human resources, the organizations surveyed are selective in their selection and recruitment processes and these processes seem to be influenced by the perceived quality of the educational centers.

3.6 Supply of Degrees

The ratio of private universities offering programs in computer sciences or informatics to public universities was almost 5 to 1 (19 versus 4) in 2007. However, between 1997 and 2006 public universities supplied 42% of total bachelor degrees, 19% of licentiate degrees and 69% of master degrees. In the case of licentiate degrees from the public universities, there is evidence that it is being substituted by licentiate degrees from private universities o by master degrees, from both public and private universities. In the case of diplomate degrees, public universities granted 47% of such degrees during 2004-2005, period for which there was information available for para-academic institutions. Therefore, in addition to have better quality perceptions about their programs, public universities grant more academic degrees than private universities, and a similar number of diplomate degrees to community colleges.

Table 7 presents forecasts for the supply of degrees for the years 2007, 2008 and 2009 using the data obtained from 1997 to 2006. In the case of bachelor, licentiate and master degrees, linear regression models were used for such forecasts. Due to limitations with the data for diplomate[12] and technical degrees,[13] averages were used as forecasts.

Table 7: Forecast and real supply of degrees for 2007, 2008 and 2009

Degree	Year									MAPE[&]
	2007			2008			2009			
	Forecast[*]	Actual	APE[*]	Forecast	Actual	APE[*]	Forecast	Actual	APE[*]	
Master	153	187	18.18%	170	207	17.87%	187	196	4.59%	13.55%
Licentiate	345	309	11.65%	367	274	33.94%	389	347	12.10%	19.23%
Bachelor	1,179	1,125	4.80%	1,263	1,111	13.68%	1,347	978	37.73%	18.74%
Diplomate	358	N/A		358	N/A		358	N/A		
Technical	576	N/A		576	N/A		576	N/A		
All degrees	**2,611**	**N/A**		**2,734**	**N/A**		**2,857**	**N/A**		

*Absolute percentage error=abs(actual-forecast)/actual
[&]Mean absolute percentage error

As this table shows, the educational system in Costa Rica was expected to supply a total of 2,611 graduates in ICT related careers in 2007, 2,734 in 2008, and 2,857 in 2009. Given the fact that the 83 organizations surveyed indicated

[11] Due to the large number of educational centers in the country, only those granting more diplomas or which are better known were evaluated individually in terms of quality.
[12] Data for diplomate degrees were obtained for public universities from 1997 to 2006, yet only for 2004 and 2005 for community colleges, which contribute significantly to the total number of graduates with this degree.
[13] Data for technical degrees were obtained only for 2004, 2005 and 2006.

that there was a deficit of 2,299 employees in 2007 (see Table 2), the educational system should at least double the supply of graduates that year to cover this deficit.[14]

Actual values[15] and forecast errors are presented in the same table for master, licentiate and bachelor degrees. [16] These data show that the best forecast (13.55% mean absolute percentage error) was obtained for the master degree and the worst (19.23% mean absolute percentage error) for the licentiate degree. Furthermore, the forecast values for the master degree series are consistently below the actual values for 2007, 2008 and 2009. In contrast, the forecast values for the licentiate and bachelor series are above the real values for those years. Therefore, supply is falling below expectations for academic degrees, except the master´s.

As mentioned in section 3.3, the bachelor degree is the most important for the ICT occupations considered. Figure 4 shows the actual and estimated supply for this degree by public and private universities. As depicted in this figure, public universities present a greater linear annual growth for bachelor degrees for the period from 1997 to 2006 (44 per year) than private universities (40 per year). On the other hand, private universities show a large variability in the number of bachelor degrees across time compared to public universities, and individual data for the majority of private universities indicate a reduction in the number of bachelor degrees granted. Considering the reduced number of public universities in the country and the high demand for the bachelor degree, the pressure on such degree is then passed to the public universities.

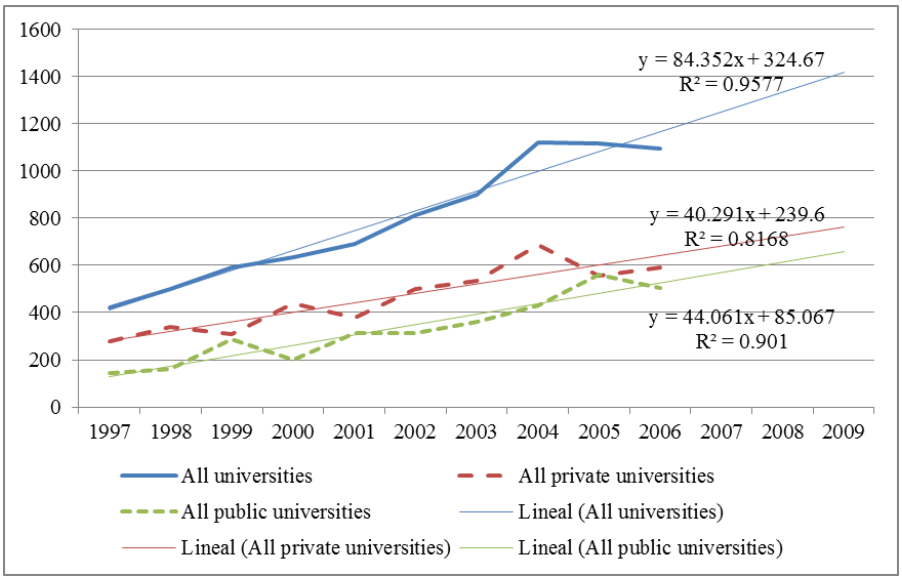


Figure 4: Supply of bachellor degrees, including linear trends

3.7 Demand versus Supply

The demand for ICT workers classified by occupations, stated by each organization surveyed, was converted into demand for academic degrees using the academic requirements for each occupation, indicated by the same organization (see section 3.3). Although this procedure provides an easy way to compare demand with supply, it assumes that any degree from an educational center can be used to fill any occupation, which might not be valid in all cases.

By doing this conversion for the years 2008 and 2009, taking into consideration the estimations for the occupational demand obtained from the survey (see section 3.1) and the forecasts for the supply of degrees (see previous section), it is

[14] This conclusion is based on the assumptions that all graduates for that year were hired and that other organizations not participating in the survey had also problems recruiting ICT employees.
[15] Actual data for 2007, 2008 and 2009 were obtained from CONARE and CONESUP in 2011, after the supply estimations were made.
[16] Actual data for diplomate and technical degrees were not available for 2007, 2008 and 2009.

possible to obtain the expected utilization for a given degree ─defined as the proportion of the demand for the degree to its supply. As shown in Figure 5, the utilization for 2008 is higher to 65% for the majority of degrees, with the exception of the master, whose utilization is just 19%. In particular, the utilization of the diplomate degree for that year was expected to exceed 200%.[17] The large utilization of most of the degrees provides further evidence of the tightness in the labor market (see section 3.2), especially since the values for utilization only consider the demand of the 83 organizations that participated in the survey; however, it does take into account all the supply of degrees in the country.

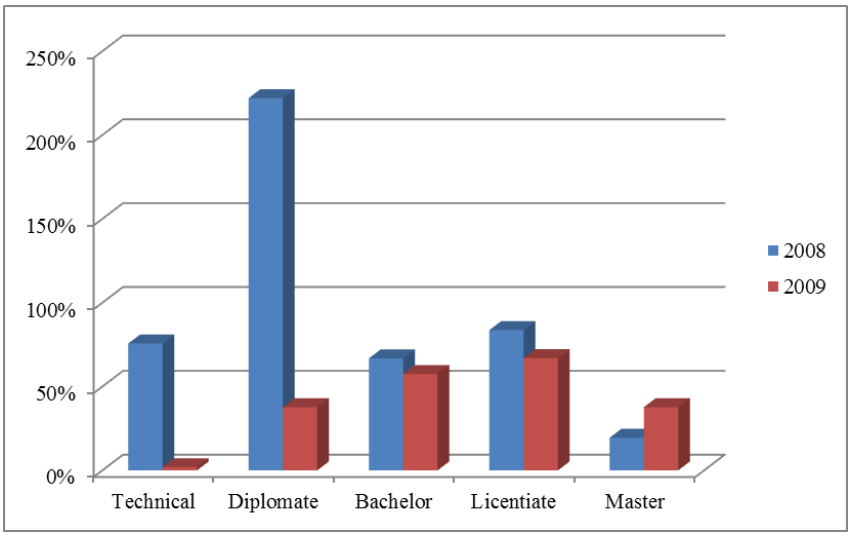


Figure 5: Expected utilization of degrees

Although the expected degree utilization was anticipated to decrease for the year 2009, as depicted in Figure 5, it remained above 50% for the bachelor and licentiate degrees and above 30% for the master, only degree whose utilization increased from 2008 to 2009. In the case of technical degrees, the expected utilization dramatically dropped to 2%, and it decreased to 38% in the case of the diplomate. The drop observed for technical and diplomate degrees could be explained by the reduction in the growth rate from the year 2008 to 2009 in the demand for Specialists in Technical Support and End-User Technical Supporters, for which these degrees are particularly relevant (see section 3.3).

Figure 6 presents a graphical comparison of the demand of ICT human resources in 2007 and the supply of degrees in software development and technical support careers in 2006. It is interesting to note that while the base of the pyramid for the 2007 demand is located between the bachelor and diplomate degrees, the base of the supply pyramid for 2006 is located exclusively at the bachelor degree. This shows a mismatch between supply and demand in relation to the diplomate degree, which seems consistent with the high utilization for this degree in the year 2008, previously mentioned. Given the scarcity of diplomate degrees in the labor market, it seems logical to presume that organizations tend to hire more persons than needed with a bachelor degree in order to fill positions requiring diplomate degrees. This situation puts additional pressure on universities to graduate more bachelors, given the fact that they are the only educational centers authorized to grant such degrees.

[17] This very large utilization is consistent with the deficit of Specialists in Technical Support and End-User Technical Supporters in the organizations surveyed (see section 3.2), for which the diplomate degree is important.

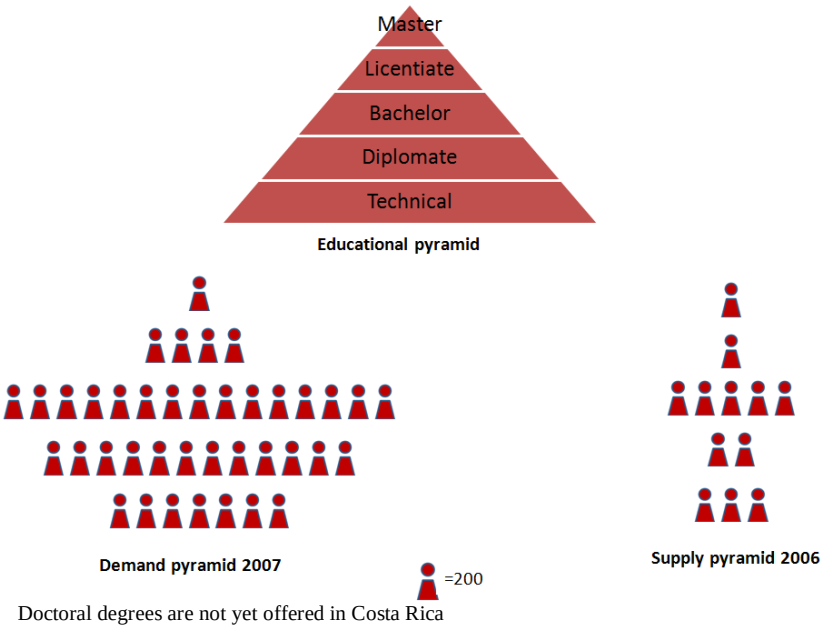


Figure 6: Demand and supply pyramids

Metaphorically speaking, graduates with technical and diplomate degrees can be denoted as the "digital infantry" of the ICT industry. This expression does not only coincide with the less time required to graduate them but also with the larger expected number of them, in comparison to the other degrees. The fact that neither the technical nor the diplomate degree constitutes the base of the supply pyramid, might affect the opinion that the bachelor degree is the ideal for most of the occupations studied (see section 3.3).

4. Policy Recommendations

With the aim of having more qualified human resources and taking into consideration the results of the demand and supply study, four strategic objectives and nine policies areas are proposed to improve the country's computer educational capacity and thus support the competitiveness of the Costa Rican ICT sector (see Figure 7). These objectives and policies are discussed below along with actions already taken towards them.

4.1 Strengthening of Technical and Para-academic Education

The strengthening of the technical and para-academic education is recommended with the purpose of balancing the demand with regard to the supply (see Figure 6). By doing so, the pressure on the bachelor degrees will be reduced, particularly from the public universities. In addition, this objective could help to trickle-down the benefits of ICT to more disadvantaged socioeconomic sectors, since the time and financial resources required to obtain the technical and diplomate degrees are less than for the bachelor degree and also the entry requirements for such degrees are reduced. To achieve this objective, the following policies are proposed to increase the number of diplomate graduates:

- *Clarifying the role of the most recently created public university, the Universidad Técnica Nacional,*[18] *which brought together several of the community colleges in the country granting diplomate degrees in computer education*. In this regard, it is necessary that the community colleges that are part of this new university continue to offer diplomate degrees, and do not eliminate this degree in lieu of the bachelors, as other public universities have done in the past. As of August 2011, the Universidad Técnica Nacional still offers a diplomate in Information Technology.

[18] Created in 2008.

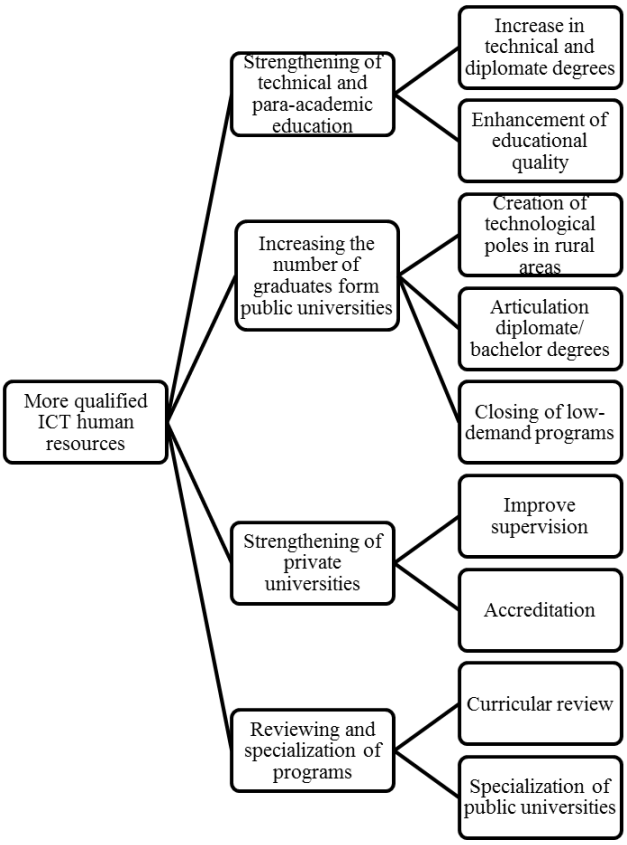


Figure 7: Objectives and policies for improving computer educational system in Costa Rica

- *Promoting the creation of more para-academic and technical computer education centers and programs in the country, particularly private ones*. The Costa Rica Specialist Program, launched in 2009 by the Costa Rican Association of ICT companies (CAMTIC) with several private universities as a pilot program to train ICT technicians, is a good example of this policy [19]. One hundred and eighteen students graduated from this program at the beginning of 2011 [20].

- *Creating diplomate degrees in public universities as lateral exits of bachelor degree programs*. The Universidad Nacional de Costa Rica presents a good example of such option. Discussions are underway between this university and the National Institute of Training (INA), organization in charge of technical education in the country, to jointly offer a diplomate program in computer programming based on the one currently offered by the Universidad Nacional.

Furthermore, to enhance the quality of the technical and para-academic education, the creation of programs for training trainers was proposed. In this vein, the Universidad Nacional de Costa Rica offered in 2009 training courses to professors of the technical colleges, particularly focusing on programming and databases.

4.2 Increasing the Number of Graduates in Public Universities

While the perception in quality in private universities is improved and taking into consideration that organizations are selective in their personnel selection and recruitment processes, the increase in the number of graduates at the beginning should come primarily from the public universities. To achieve this objective, the following policies are proposed:

- *Creating technological poles in rural areas with the aim of taking advantage of benefits in infrastructure and budget capacities of the public universities in their regional campuses*. All public universities have regional campuses which offer programs related to software development and technical support. Given the fact that the admission of new students in computer science and informatics programs in the main campuses of the public universities seems to be constrained by the available infrastructure and budget, options should be explored to increase the admission in regional campuses. The creation of technological poles in rural areas is one of such options. This would allow having computer professionals in the regions as professors, solving in part the lack of qualified lecturers in the rural areas. Furthermore, it will trickle-down the benefits of ICT to rural areas. The case of the area of San Carlos, in conjunction with the Tecnológico de Costa Rica, provides a good example of how these technological poles could be developed. In this policy, however, the use of ICT is fundamental to avoid the immigration of graduates to the capital. Therefore, ICT should be proactively used to link graduates, as well as new companies, in the rural zones to existing companies in the metropolitan areas.

- *Achieving a better articulation of the diplomate and bachelor degree programs, increasing the pipeline of bachelor students in the public universities*. To achieve this goal, it is necessary to develop diplomate programs that effectively articulate with the bachelor degree. An example of this process is provided by Mata *et al.* [21], in which first-level courses in the bachelor program are shared with the diplomate. The joint project to offer a diplomate program in computer programming by the Universidad Nacional de Costa Rica and the INA, discussed in the previous objective, is another example of how articulation mechanisms between the para-academic and academic education can be achieved. Graduates from this program might be able to continue studying the bachelor degree in this university.

- *Closing low-demand programs and re-orienting the use of the resources allocated to them to higher demand degrees*. A good example is licentiate programs in public universities, which have master programs related to the bachelor degree. This is justified by the substitution process of the licentiate degrees in public universities, previously mentioned. By closing such licentiate programs, existing resources could be channeled to bachelor programs, which have greater demand. A related example is provided by the Universidad Nacional de Costa Rica, which decided in 2011 to close its program in Educational Informatics due to its low demand, and reoriented its allocated resources to its Systems Engineering program, increasing the admission for new students from 180 in 2011 to 300 for 2012.

4.3 Strengthening of Prívate Universities

To improve the perception of quality of private universities, and thus increasing the base for selecting and recruiting ICT graduates from Costa Rican organizations, the following policies are proposed:

- *Improving the supervision of private universities, clearly defining and strengthening the role of the National Council of Private Higher-Education (CONESUP).*

- *Fostering accreditation processes by private universities as a mechanism to assure quality in the computer education programs, and in doing so, establishing quality requirements which are internationally accepted*. As of August 2011, only five universities in the country, three public and two private, have accredited computer science and informatics programs by the National System of Accreditation (SINAES).

4.4 Reviewing and Specialization of Programs

The previous policies should be accompanied by an assessment of the existing educational programs *vis-à-vis* the competences required for the different occupations and programs available in other educational centers. With this aim, the following policies are recommended:

- *Conducting a curricular review of existing programs to obtain a better match between such programs and the needs of the organizations and to update knowledge areas and strengthen abilities and skills due to new*

technological developments. As part of this process, new educational programs might be devised, particularly focusing on occupations that have demand yet are not well embraced in existing programs, for example Specialists in Software Testing (see sections 3.1 and 3.4). It is important to mention that the proposed curricular review should not be guided only by industry considerations; suggestions and recommendations from professional organizations, such as the ACM or the IEEE, and the academic community should also be considered.

- *Specializing educational programs in public universities to certain occupations.* This policy would favor a better use of public funds, as well as foster collaboration, instead of competition, among public universities. Nevertheless this policy requires first establishing coordination mechanisms within the framework of the National Council of Rectors (CONARE).[19]

5. Conclusions

The demand and supply study found that there is a notable change in the ICT occupational profile in Costa Rica, from software development in 2000 to technical support in 2007. This situation is the result of the establishment of subsidiaries of MNCs in the country, particularly those operating technical support contact centers. This situation requires analysis of the existing computer curricula in the country, since traditionally they have been focused towards software careers such as Software Engineers, Applications Programmers and Project Managers. For this reason, policies are proposed for reviewing and specializing curricula, particularly in public universities.

Furthermore, this study provides evidence of a tight market labor in Costa Rica for the ICT occupations considered. This situation is the result of a greater growth in demand than in supply for these occupations. Such condition is worsened by differences in the perception of quality for different types of educational centers in the country, which appears to influence the selection and recruitment processes of the organizations.

A tight labor market in the ICT sector is likely to continue as long as MNCs establish new ICT operations and broaden existing ones in Costa Rica, which is the result of government policies focused towards an aggressive foreign direct investment attraction strategy [4]. This assumption is supported by a recent presentation of the Costa Rican Investment Promotion Agency (CINDE), which indicates that the demand for ICT human resources is likely to grow for the MNCs established in the country [22].

To ameliorate the deficit, an increase in the number of graduates is necessary. Policies are proposed to increase the number of graduates in public universities, like creating technological poles in rural areas, articulating diplomate and bachelor programs, and closing low-demand programs. Furthermore, due to the perception of higher quality of public universities and the apparent preference by organizations of graduates from these educational centers, it is necessary to strengthen private universities and technical and para-academic education. In this regard, policies related to improving supervision and to conducting accreditation processes are proposed, in the case of the private universities, and to increasing the number of diplomate and technical degrees and to enhancing educational quality in technical and para-academic institutions are proposed, in the case of community and technical colleges.

Although there is preference in the labor market for graduates with a bachelor degree, there is also evidence that organizations are beginning to consider diplomate and technical degrees. This is a major difference with the previous demand and supply study conducted by Mata and Jofré [6]. However, the supply of diplomate and technical degrees is low and the perception of quality of community and technical colleges that offer them is also low. Therefore, policies are proposed to strengthen technical and para-academic education in the country. Such policies are expected to contribute to balance the supply pyramid, and in doing so, pressure will be released from the universities, particularly the public ones, which at the time of conducting the study seem to bear most of the burden of keeping up with the demand.

[19] This organization coordinates the activities of the public universities in Costa Rica.

Software Engineers, Applications Managers and Project Managers are perceived in this study as the occupations with better performance. This reinforces the need for conducting a curricular review in order to ensure that knowledge, abilities and skills necessary for other occupations are also embraced in the educational programs.

Even though some actions have been taken by several stakeholders in support of the proposed policies, the lack of a national coordination mechanism makes it difficult to implement a national plan to increase the number of qualified ICT human resources in Costa Rica. The participation of the government is essential in this regard. As the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) indicates in its report on human resources development for information technology [23]: "The construction of the information society … cannot be done without active governmental involvement in the creation of an information infrastructure and the reformation of the education system. In particular, human resources development (HRD) is seen throughout the world as crucial to the development of information-based economies and the achievement of global competitiveness" (p. 18).

Finally, to track differences in the demand and supply patters across time, it is necessary to conduct similar studies periodically. Nevertheless resources are needed to do so. This study was possible due to funding from the International Development Research Centre (IDRC) of Canada. The previous study [6] was undertaken with financial assistance from the Inter-American Development Bank (IADB).

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