E C O N O M I C S  B U L L E T I N

# Optimal intellectual property rights protection: the case of Colombia

Francesco Bogliacino
*Universidad EAFIT, Departamento de Economía and RISE Group*

Alberto José Naranjo Ramos
*Universidad EAFIT, Departamento de Economía and RISE Group*

## *Abstract*

We investigate the optimality of the actual degree of Intellectual Property Rights protection using a methodology derived from Patent Race Literature. We applied the methodology to Colombia, using the available two Innovation Surveys. Our result are consistent with an already optimal existing protection and we raise doubts over the gains from a stricter regulation.

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# 1 Introduction

The importance of Intellectual Property Rights (from now on IPRs) has been widely recognized. The modern Endogenous Growth Theory (from now on, EGT; see Aghion and Howitt (1998)) stresses the role played by monopoly rents in order to foster innovation, relying on a famous argument by Schumpeter (1934): in presence of knowledge, which tends to be easily appropriated -these theorists argue- and is thus exposed to inefficient free riding, the only way to provide incentives is to guarantee a legal enforced monopoly right. However there are standard economic arguments against the latter, which have to be addressed. Since EGT models are a generalization of the patent race model (Dasgupta and Stiglitz (1980)) in a General Equilibrium framework, we can rely on the large amount of Industrial Organization literature over the optimal degree of protection. A recent work, Denicolò (2007) provides an optimal and testable rule, and we willbase the present paper on his approach.

Up to the 1990s the empirical work on innovation issues was constrained by data availability. Fortunately, in the last two decades a mayor effort has been made to collect specific database over innovation effort, finally freeing the empirical work, for many years limited to the use of very poor proxies of overall innovative activity. The European experience of the Community Innovation Surveys (CIS) allowed scholars to manage data sources both comparable through countries and through time.

Although a similar interest spread out in developing and middle income countries, there is still a large gap to fill. In South America[1], for example, some countries have carried out Innovation Surveys, but with mixed results: some of them are comparable to their European counterparts, some of them not at all. In general, there is lack of common methodology, so we have to take a country base approach, missing the opportunity of comparison.

In this paper, we look at Colombia, one of the countries that realized surveys in the last decade. From the economic point of view, it is showing a good performance in the last years, benefiting from regional integration and rising commodity prices, but still the productivity gap with the United States and other more advanced economies has to be covered. For this reason the issue of how to foster innovation (and by means of it, growth) is relevant under a policy perspective. To our knowledge, this is the first work that systematically exploits this data source, the only previous analysis carried on over this data is Langeback and Vásquez (2007), with a focus over the determinants of innovation.

We claim that there is another important policy reason to explore the size, structure and dynamics of the IPRs system in middle income countries, such as Colombia. In fact, as recently suggested (Economist, 2008), in the new round of WTO talks, IPSs have been an open wound that play a role in the recent stalling and the potentially future failure:

> Many developing countries believe that the earlier round was lopsided, doing

[1] As an example of recent attention to the topic in this area, see Martínes Piva (2008).

> little to constrain the farm policies of the rich world even as it placed heavy obligations on the poor in areas such as intellectual property (IP). In the Doha round, they wanted to get their own back, by asking more of the rich world than they offered in return. (Economist, 2008 pag. 71)

Knowing if the current situation is suboptimal or not can help carifying whether and how the issue should be addressed: since the Free Trade Agenda is likely to end up into the hands of bilateral agreements, a guide to avoid messing up all the subject will favour an ordered reprise of global talks.

Moreover, while in the 1990s a more or less global consensus raised on the equation "stronger IPRs are equal to better growth performance", with some countries, like the US heavily strenghtening their regime, the present debate is full of open questions (Greenhalgh and Rogers, 2007; Hall, 2007; Shapiro, 2007 over the US case; Farrel and Shapiro, 2008)

The paper proceeds as follows: in Section 2 we present data, in Section 3 we comment the colombian patenting activity, in Section 4 we present the methodology and the results, finally Section 5 concludes.

## 2 Data

The data for this paper come from the first and second innovation surveys carried on in Colombia, which refer respectively to years 1993-1995 (the first one, called *Primera Encuesta de Innovación y Desarrollo Tecnológico*) and 2003-2004 (the second one, called *Segunda Encuesta de Innovación y Desarrollo Tecnológico*), both collect data only on manufacturing firms. These are survey inspired by the European CIS, in particular, they refers to the Bogotá Manual (Manual de Bogotá (2001)), which is an adaptation for Latin America of the famous Oslo Manual (OECD (2005)).

They collect very detailed information over the expenditure on innovation inputs, other innovation information (hampering factors, sources of ideas, objectives) and over employment, data about the establishment (location, identification, number of plants, and the economic activity according to the CIIU at three digits[2]), and the regulatory environment (financing, policies, intellectual property). There are measures of the innovative output, at last with regards to the most formalized part of it, such as patents, trademarks, certifications etc.

The two surveys are barely comparable; the sample size is very different (885 firms in the first one versus 6670 in the second), the differences in the general design and the temporal gap make a merging of the two meaningless.

[2]Clasificación Industrial Internacional Uniforme de todas las Actividades Económicas . The Latin American classification is harmonized with the intsernational ISIC.

Given that many firms are not investing in R&D and since we don't want to lose that information, we construct all the variable in log scale, $y = \log(x)$, in the following way:

$$\begin{cases} y = 0 & \text{if } x = 0 \\ y = \log(x) & \text{if } x > 0 \end{cases}$$

# 3 Patenting and R&D in Colombian firms

In the Innovation Surveys we lack detailed data over the individual patent, but we gain the possibility to match the IPRs data with the firm characteristics and, even more important, with the expenditure in R&D, which makes them more valuable.

In Tables 1 and 2 we show some descriptive statistics about R&D expenditure and patents from the First and the Second Innovation Survey, respectively.

| **Variable** | **Mean** | **Std Dev** |
|---|---|---|
| Turnover | 10261.17 | 36638.88 |
| R&D 1993 | 35.17 | 277.00 |
| R&D 1994 | 31.71 | 232.52 |
| R&D 1995 | 65.58 | 1041.21 |

(a) Turnover and R&D Expenditure. Millions 1993 Colombian Pesos.

| | **Patents** | **New Products** |
|---|---|---|
| 0 | 594 | 263 |
| 1-10 | 24 | 365 |
| More Than 10 | 2 | 126 |

(b) Patents and Product Innovations (the numbers into the matrix are the number of firms).

Table 1: Descriptive Statistics. Source: Primera Encuesta de Innovación.

Starting from the first wave, we can try to classify the patenting activity by industry, using the CIIU classification[3]. We can see that 60% of the patents are concentrated in two sectors, Manufacturing of other chemicals products (34%) and Manufacturing of Plastic Products (26%). However, if we repeat the exercise for the total products introduced, we see that this concentration declines. The two sectors above are still predominant, but their shares reduce, respectively to 14% and 9%.

These stylized facts are consistent with two alternative explanations. On the one hand, the nature of the chemical industry makes it more oriented towards patenting (a robust

[3]Clasificación Industrial Internacional Uniforme de todas las Actividades Económicas (following the International Standard).

| Variable | Mean | Std Dev |
|---|---|---|
| Overall R&D 2003 | 65.03 | 1579.15 |
| Overall R&D 2004 | 11.09 | 503.11 |

(a) R&D Expenditure. Millions 2003 Colombian Peso.

| | Patents | Copyright |
|---|---|---|
| 0 | 6060 | 5190 |
| 1-10 | 139 | 989 |
| More Than 10 | - | 20 |

(b) Patents and Copyright (the numbers into the matrix are the number of firms).

Table 2: Descriptive Statistics. Source: Segunda Encuesta de Innovación

finding of all the literature over innovation), so we can just assume that due to a market size effect, the rest of manufacturing firms are less worried about imitation and so less oriented to fill patents for new products. On the other hand, it can be interpret as a structural change pattern: the figures of product introduction will be reflected also in terms of patents, as time goes by. To motivate this interpretation, we should stress that the first half of the 1990s coincides with the second big wave of tariffs reduction. The remarkable aspect of this openness strategy was

> that did not just reduce the average level of tariffs and NTBs, they more importantly changed the structure of protection. (Attanasio et al., 2007: p. 7)[4]

Although we cannot state conclusively in favour of one of the two, we claim that the second one is important: in the same paper Attanasio et al. (2007) show that the effect of new competition coming from tariff reduction was a mayor factor pushing the firms to innovate; thus, it is plausible that they were also looking for means to defend their new effort, including the legal ones. As we will see, the size in terms of total patents observable in the second wave is consistent with this thesis.

Some other interesting insights are present in the reported interviews: 6% of firms say that they introduced a product new for the national and international market, 30% introduced a product new for the national, but not for the international one, while the 40% simply imitated, by adopting a product already existing into the national market.

In terms of process innovation, 27% introduced the new process because it was associate with the new product, 10% generated the new process through R&D (such that it was new also for the market). Significantly, these firms account for no more than one third of the firms that actively made R&D. Finally, 66% made simple adoption choice, and 68%

[4]NTB stands for Non Trade Barriers.

carried on incremental process innovation. These last percentages clarify that the mayor part of process innovation is either through adoption of outside developed technology or, for a smaller part, through non-formalized research, exploiting the tacit knowledge of the internal sources.

Finally, we can characterize directly the R&D investment through the objective declared by the firm. We can distinguish between applied research and development (basic research is negligible). With regard to the former, in percentage of the total firms carrying R&D (basic, applied research, and development) 31% declared an aim of introducing a new product, 31% of improving the existing one, while the percentages for new or improved products are respectively 21 and 28%. If we compute a correlation matrix, in order to characterize the individual strategies, we can see that process improvement and process innovation are highly correlated between them (0.56), are robustly correlated with improving existing products (31 and 42% respectively), while the product innovation shows a negative relation with improving existing product (-0.05) or process (-0.22) and a low correlation with process innovation (17%).

In terms of development, 72% of firms declared the aim of product innovation and the same percentage declared product improvement (however the correlation is only 0.16). The percentages for process decrease respectively to 49 and 65%. The correlation is high between process introduction and improvement (0.46). Product and process innovation have a correlation coefficient of 0.23, product improvement has a correlation of 0.27 with new process and 0.24 with improved process.

Jumping to the second survey, we have to remind that the general scheme has changed completely. In particular, we gain in terms of information over expenditure, financing, and representaticity, but we lose something in terms of innovation output. The main shortcoming concerns the lack of variables measuring new process and new product introductions.

In terms of sectoral description of patents, we can find that still the chemicals are playing the role of the giant, although with a 40% share. The 20% decrease is completely concentrated in the manufacturing of plastic. If we consider the overall IPRs, including copyright, industrial design, brand, which are disciplined under the same chapter (TRIPS, Trade Related Intellectual property Rights), the sum of all chemicals industries (including the basic chemicals which has a relevant position) get a 26% share, while the textile industries are now reaching a 15%, thanks to industrial design and brands. At a glance, it is apparent that the propensity to get legal protection is higher when we include all various forms: the ratio between firms with other IPRs (total minus patents) and the firms with patents is 6.25.

In terms of declared objectives, the survey suffers for a low rate of response, however among those carrying R&D, 30% are oriented towards new products, which are more likely to be protected through some forms of IPRs.

Finally, we can see how large is the subset of R&D performing firms, which is looking

for some sort of certification. We remind that certification is usually more likely for process innovation. The 3% of this set of firms has certified products and the 23% has certified new process.

# 4 Methodology and Results

Intellectual property rights (IPRs) is perhaps one of the most studied issue around innovation. All Endogenous Growth Theory in the Aghion and Howitt setup is built on the statement that since growth is dependent on the production of knowledge, and since the latter is a quasi-public good, legally enforced monopoly rights are necessary to stimulate economic performance.

These rights are the compensation to innovators for the resources invested. Whether this compensation is optimal or not, i.e. if patents over-compensate, under-compensate or optimally compensate innovators, depends on the trade-off between the static inefficiency of the monopoly and the dynamic efficiency of larger stimuli to innovate.

However there are alternative objections to keep in mind. Some scholars (Boldrin and Levine, 2002) suggest that property rights are important but they have to be deemed as *rights over objects including ideas* and not as rights to control the use of ideas - downstream licensing -, the latter being highly inefficient.

At the same time, some scholars stress the existence of "composition effects": Aghion, Harris, Howitt and Vickers (2001) state that although lower protection reduce individual incentives to innovate, it changes steady state distribution of lead size: more firm would be able to imitate and in more sectors we will end up in a neck-to-neck situation where the incentives to innovate are larger.

Finally, we have to keep in mind all the evolutionary objections (Dosi, Marengo and Pasquali (2006)). IPRs are just one of the appropriability conditions, together with lead times, secrecy, learning, and cost of duplication; the mix among those being determined ultimately by the technological paradigm. Above a certain threshold *a tragedy of the anti-common* may prevail through rent seeking activity (see the discussed case of the *sleeping patents*).

We think that many of the objections to the standard trade off approach are actually related to the patents approval process (which in some countries, like the US is probably too much loose). Moreover Denicolò (2007) provides a very general setup, capturing many of the standard issues raised, and formalizes a very simple and empirically testable rule, derived by a social welfare maximization problem in a patent race framework. The rule states that the ratio of appropriated profits over total potential profits from innovation have to be equal to the elasticity of the expenditure into the knowledge production function, i.e. the elasticity of the number of patents to the R&D. Formally:

$$\frac{\pi_a}{\pi_p} = \eta \tag{4.1}$$

where $\eta$ is the elasticity of the knowledge Production Function, $\pi_a$ is the profit appropriated through IPRs regime, and $\pi_b$ is the maximum potential profit of a perfect infinite monopoly. $\frac{\pi_a}{\pi_p}$ is called the profit ratio: he shows that it can be expressed as the product between two factors:

- $z$, which is the normalized length, $1 - \exp(-rT)$, i.e. the present discounted value of a constant annuity over the patent lifetime over a perpetual annuity, where $r$ is a discount rate and $T$ the statutory length of a patent;
- $\beta \in (0,\ 1)$, which is the share of the profits appropriated at each period, excluding the spillovers and the imitation that are not prosecuted due to fallacy of the judicial system or other factors.

On the one hand, the normalized lenght, $z$, can be computed since $T$ is the statutory patent life in the country from the date of filing and $r$ a long run, risk-free real interest rate, subtracted the economy's rate of growth to account for the growth in profits, deadweight losses, etc., and added the instantaneous probability of exogenous technological breakthroughs. In addition, the share that effectively is appropriated by the inventor, $\beta$, has been studied by the literature. Mansfield et al. (1981) suggest that the process of inventing around a patent alone pushes $\beta$ below 0.6 (see Denicolò, 2007) and Lichtenberg and Philipson (2002) findings, focusing on pharmaceuticals, would imply that $\beta$ is unlikely to exceed 0.5.

On the other hand, $\eta$ can be estimated from a regression in which the number of patents are regressed over the amount spent on R&D:

$$\text{patents} = f(\log(R\&D_t), \log(R\&D_{t-1}), ....., \log(R\&D_{t-n}), \text{controls})$$

where $\eta$ is the sum of the parameters in the R&D variables.

Hence we proceed by estimating $\eta$ for Colombia from the innovation surveys, than we calculate $z$ and we determine the optimal $\beta$ under the rule. By confronting the latter with the estimated values in the literature, we can conclude in favour of a present IPRs regime either consistent or not with an optimal degree of protection.

We run different specifications of the baseline equation. First of all, since a lag is likely to occur between the product introduction and the recognition of the patent, we use also the number of total products introduced (in the first survey, while in the second, where we lack it, we use the total number of copyrights). We control for the amount of skilled employment, which is affecting the effectiveness of R&D, for a protection-through-secrecy strategy (we use a dummy that tells us if the objective was a new process introduction,

where secrecy is more likely), for turnover (in the first one where we have this datum, in the second we put the rate of change of value added at industry level, taken from another source, the annual manufacturing survey), and for firm size (a dummy for large one in the first survey and the share of foreign equity in the second one, since all foreign owned firms are big). Since the dependent variable is a count one, we rely on Poisson and Negative Binomial estimation, as usual for a large part of the literature.

We confined all the estimations in the Appendix A. Table 3 and 4 show the results for the First Innovation Survey, while Table 5 and 6 refer to the estimations on the data coming from the Second Survey.

As we can see summarized in the following Table 3a, the Colombian elasticity is likely to be among $0.10 - 0.30$, while main of the literature on more developed countries (reviewed in Denicolò (2007)) present a value that is more than double.

The results are fairly robust. There are not significant variations among different specifications, alternative dependent variables and various likelihood assumptions. In particular the use of alternative dependent variables with higher coverage[5] and the stability of the results show that the sample size for the patents variable (no too many firms seems to file patents) is not creating problems of reliability. Econometrically, one may also argue that the probability mass in zero is likely to affect estimates. We try also to run an hurdle model on the second wave[6], where we combine a binomial to explain the binary choice (zero vs positive), combined with a truncated poisson for the positive. Of course we have now problem of sample size when we use the patents variable, but we can perform estimation with the total copyrights variable. The elasticity is even lower, so we rely on the higher values since we want an upper bound.

We can now calculate the $z$ using the fact that patents last 20 years in Colombia and calculating a discount rate. We calculate the average over the last eight years of the real interest rate over sovereign bonds (CDT at 2 years and TES at three years[7], on annual basis, subtracting the consumer price index increase), we subtract the average GDP growth rate and we add a Poisson rate of technological breakthrough that can make the product out-of-date (we use two and five percent, which generate a structural break respectively every fifty and twenty years). Combining the two extremes of the range of $\eta$, point one and point three, with the four values of $z$ (intersecting the two values of the Poisson rate with the two values of the return on the risk free assets), we have up to eight values of the $\beta$ derived under the optimal rule. They are shown in Table 3b: they are all consistent with the estimations available in the literature.

From this we conclude that an increase in IPRs protection is probably not the main strategy to pursue for Colombia: this is fairly consistent with the existing industrial struc-

[5]In the second wave, the ratio between the firms with some forms of IPRs and only patents is 7.25, and in the first one the ratio between new products and patents reaches twenty.

[6]it is the most representative and also the most importante, given that it is closer.

[7]Source: *Banco de la República de Colombia* (Central Bank of Colombia).

ture, mainly characterized by small and medium size firms, focused on backward sectors and where the formalized innovation is likely to be less important than imitation or technological acquisitions.

| **Estimated Elasticity of the R&D** | | | | |
|---|---|---|---|---|
| First Innovation Survey (Pat.) | 0.2762 | 0.3928 | | |
| First Innovation Survey (Prod.) | 0.1163 | 0.0658 | 0.0786 | 0.08799 |
| Second Innovation Survey (Pat.) | 0.1251 | 0.1167 | 0.1077 | 0.1132 |
| Second Innovation Survey (Cop.) | 0.0801 | 0.0951 | 0.1084 | 0.0890 |

(a) Estimation of the Knowledge Production Function: Summary

| $z$ / $\eta$ | 0.1 | 0.3 |
|---|---|---|
| 0,45 | 0.22 | 0.66 |
| 0,70 | 0.14 | 0.42 |
| 0,60 | 0.16 | 0.49 |
| 0,78 | 0.12 | 0.38 |

(b) Optimal $\beta$: Summary

# 5 Conclusions

In this paper we build an empirical verification of an optimal rule for IPRs protection. We based it over a generalization of the standard patent race model. Using this rule we can calculate the optimal breath of protection under the rule and see if this is consistent with the measures available in the literature.

In our application to Colombia, we see that the actual degree of protection is consistent with optimality, thus we raise doubts over the benefit of further strictness: this is important given the role of the issue in many free trade agreement currently on the table.

Further work should be done using sector taxonomy in order to address the same issue at a more disaggregated level, and a natural extension is that towards other countries of the South American region.

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# A The Knowledge Production Function Estimation

In this Appendix, we show all the estimation of the knowledge production function performed. The estimations of the elasticity of patents to R&D expenditure in the various versions are in the following Tables 3 and 4, for the first wave of the survey, and Tables 5 and 6 for the second one.

| *Dependent Variable: Total Patents (introduced and under revision)* | | |
|---|---|---|
| | **(1) Poisson** | **(2) Neg Bin** |
| **Log(Turnover 1995)** | 0.4641 | 0.7841 |
| | [3.670]*** | [2.104]** |
| **Log(RD 1995)** | -0.3205 | 0.1115 |
| | [1.959]* | [0.525] |
| **Log(RD 1994)** | 2.0431 | 1.0478 |
| | [3.880]*** | [2.365]** |
| **Log(RD 1993)** | -1.5617 | -0.7665 |
| | [2.490]** | [1.584] |
| **Large** | 0.7011 | 0.1294 |
| | [0.870] | [0.145] |
| **Graduate RD Employees** | -0.0769 | -0.1626 |
| | [2.258]** | [3.852]*** |
| **Process Strategy** | 2.6548 | 3.8951 |
| | [2.694]*** | [7.788]*** |
| **Constant** | -6.6955 | -9.1762 |
| | [5.163]*** | [3.808]*** |
| **Observations** | 539 | 539 |
| **Log Pseudo-Likelihood** | -678.04 | -499.25 |

Robust z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Primera Encuesta de Innovación

Table 3: Estimation of a Knowledge Production Function for Colombia

| *Dependent Variable: Total Products Introduced* | | | | |
|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** |
| | **Poisson** | **Neg Bin** | **Poisson** | **Neg Bin** |
| **Log(Turnover 1995)** | 0.1024 | 0.1342 | 0.1718 | 0.2360 |
| | [1.341] | [1.145] | [2.072]** | [2.971]*** |
| **Log(RD 1995)** | 0.0436 | 0.0277 | 0.0362 | 0.0027 |
| | [0.793] | [0.329] | [0.423] | [0.028] |
| **Log(RD 1994)** | 0.1793 | 0.2109 | 0.1762 | 0.2482 |
| | [2.347]** | [2.499]** | [1.859]* | [2.423]** |
| **Log(RD 1993)** | -0.1066 | -0.1728 | -0.1338 | -0.1610 |
| | [1.374] | [2.071]** | [1.489] | [2.046]** |
| **Large** | 0.1626 | 0.1964 | 0.2212 | 0.6351 |
| | [0.565] | [0.761] | [0.571] | [1.728]* |
| **Graduate RD Employees** | 0.0211 | 0.0730 | 0.0160 | 0.0185 |
| | [1.679]* | [1.381] | [0.955] | [0.331] |
| **Process Strategy** | 0.0404 | -0.0301 | -0.0956 | -0.1498 |
| | [0.144] | [0.104] | [0.363] | [0.716] |
| **Constant** | 0.5966 | 0.3545 | -1.7258 | -2.5937 |
| | [1.222] | [0.446] | [2.437]** | [2.879]*** |
| **Industry Dummies** | | | Yes | Yes |
| **Observations** | 610 | 610 | 610 | 610 |
| **Log Pseudo-Likelihood** | -21715.51 | -6818.52 | -17886.65 | -6465.89 |

Robust z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Primera Encuesta de Innovación

Table 4: Estimation of a Knowledge Production Function for Colombia

| *Dependent Variable: Patents* | | | | |
|---|---|---|---|---|
| | **(1)** **Poisson** | **(2)** **Neg Bin** | **(3)** **Poisson** | **(4)** **Neg Bin** |
| **Log(Overall RD 2003)** | -0.0858 | -0.2300 | -0.1396 | -0.3099 |
| | [0.808] | [2.799]*** | [0.835] | [1.776]* |
| **Log(Overall RD 2004)** | 0.2109 | 0.3467 | 0.2473 | 0.4231 |
| | [1.793]* | [4.223]*** | [1.439] | [2.348]** |
| **Graduate RD Employees** | 0.0092 | 0.0149 | 0.0091 | 0.0162 |
| | [2.921]*** | [0.831] | [2.778]*** | [0.894] |
| **Foreign Share of Equity** | 0.0012 | -0.0028 | -0.0007 | -0.0033 |
| | [0.149] | [0.297] | [0.090] | [0.400] |
| **Process Strategy** | 1.2268 | 1.3394 | 1.2832 | 1.2413 |
| | [3.513]*** | [3.176]*** | [3.878]*** | [3.804]*** |
| **Value Added Real Growth 2003** | | | -4.0301 | -3.7647 |
| | | | -4.6719 | -2.1534 |
| **Value Added Real Growth 2003** | | | -3.7149 | -2.1536 |
| | | | [2.619]*** | [1.033] |
| **Constant** | -3.7503 | -3.7737 | -3.5019 | -3.5383 |
| | [11.545]*** | [12.839]*** | [12.607]*** | [12.416]*** |
| **Dummy for outliers** | Yes | Yes | Yes | Yes |
| **Observations** | 3253 | 3253 | 3246 | 3246 |
| **Log Pseudo-Likelihood** | -828.82 | -497.34 | -785.07 | -489.78 |

Robust z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Segunda Encuesta de Innovación

Table 5: Estimation of a Knowledge Production Function for Colombia

| *Dependent Variable: Total Copyright Registered* | | | | |
|---|---|---|---|---|
| | **(1) Poisson** | **(2) Neg Bin** | **(3) Poisson** | **(4) Neg Bin** |
| **Log(Overall RD 2003)** | 0.0196 | -0.0316 | -0.0021 | -0.0391 |
| | [0.328] | [0.589] | [0.022] | [0.564] |
| **Log(Overall RD 2004)** | 0.0997 | 0.1267 | 0.1105 | 0.1281 |
| | [1.673]* | [2.546]** | [1.070] | [1.783]* |
| **Graduate RD Employees** | 0.0090 | 0.0572 | 0.0087 | 0.0482 |
| | [2.363]** | [2.385]** | [1.645]* | [1.896]* |
| **Foreign Share of Equity** | 0.0059 | 0.0065 | 0.0049 | 0.0059 |
| | [2.363]** | [2.385]** | [1.645]* | [1.896]* |
| **Process Strategy** | 0.7036 | 0.7143 | 0.7433 | 0.7526 |
| | [5.839]*** | [6.359]*** | [6.036]*** | [5.861]*** |
| **Value Added Real Growth 2003** | | | -2.6806 | -2.7109 |
| | | | [3.762]*** | [3.114]*** |
| **Value Added Real Growth 2004** | | | -2.2389 | -1.5826 |
| | | | [3.736]*** | [2.838]*** |
| **Constant** | -1.5216 | -1.5856 | -1.3196 | -1.4037 |
| | [8.294]*** | [9.574]*** | [14.237]*** | [14.947]*** |
| **Dummy for outliers** | Yes | Yes | Yes | Yes |
| **Observations** | 3253 | 3253 | 3246 | 3246 |
| **Log Pseudo-Likelihood** | -3270.14 | -2205.69 | -3162.37 | -2179.31 |

Robust z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Segunda Encuesta de Innovación

Table 6: Estimation of a Knowledge Production Function for Colombia.