International patterns of firm investment in technology: an interpretation based in how market size limits innovation[1]

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Abstract

The empirical evidence presented in this study suggests that there is high variability in the technological investment behavior of firms. It was found that within Colombia and the U.K., and within any size and any industry, a major part of the population of business units are not engaged in technological investment, a smaller group invests with medium level of intensity, and a very small number of business units dominate technology investments. The pattern appears to be robust and is only subject to measurement problems related to the qualitative aspects of innovation and industry aggregation. This pattern is explained in part by the large number of small and medium sized business units in any industry in any country that do not invest in technology. Unfortunately, it is not possible to explore why these firms do not invest in technology. However, the usual arguments related to the inability of small and medium sized firms to reach the threshold size that enables them to take full advantage of process innovations subject to technological opportunity and appropiability conditions and financial constraints it is a plausible explanation. Additionally, small and medium firms face important growth constraints. Moreover, it is shown in this study that firms are substantially smaller in Colombia than in the U.K.. It is argued that these differences arise as a consequence of the smaller market size of Colombia compared to the U.K. one. As national market size increases, higher division of labor and specialization arise in the economy, and for a given product firms are larger and have access to more densely and articulated networks of suppliers. In terms of technological opportunity literature, firms in a larger national market face higher technological opportunity to exploit advances of science and advances in technology in other industries than firms in smaller national markets. Although it is possible to overcome these limitations through access to international markets, evidence is put forward that suggests it is extremely difficult. Finally, history, institutional environment, and geography, for example, may reinforce markets size effects making even more or less difficult for firms to use international trade to overcome domestic market size limitations.

Keywords:

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[1] This article is based in my MSc dissertation at SPRU, “International comparisons of firm non-investment in technology: an analysis and interpretation. The influence of my two supervisors, Ed. Steinmueller and Nick von-Tunzelmann is evident, however any mistakes are my responsibility.

1. Introduction

The motivation for this study is an empirical one. During my short but intense experience working with an innovation survey in Colombia investigating the determinants of innovation, I developed the feeling that hypotheses about size and industry differences explaining why some firms generate innovations more frequently and/or innovations that are more important, although intuitively powerful, did not fit well the data we had. Many large Colombian firms do innovate, but many do not. And when a small firm is engaged in R&D investments, in many cases it invests more than large firms do, proportionate to its size. Additionally, within an industry we also found large variability. A dairy products company was involved in intensive co-operation with science related organizations and holds patents, while another one also producing dairy products has not been involved in R&D or embodied technology activities for the last ten years. One may think that an explanation is that there are few international level innovative firms in Colombia. When one looks at data in industrialized economies, however, there is evidence that this problem is not simply the consequence of Colombia being a middle-income economy. In the U.K. more than one quarter of the business units in Chemicals, office and computing machinery or electrical machinery industries did not invest in R&D between 1994 and 1996. Moreover, almost a fifth of them did not invest in any technological activity (R&D, embodied technology, disembodied technology, design and engineering or training), although all of these firms are identified as producing high tech goods.

Part of the explanation for the observation of a large population of innovation non-performance is the difficulty of finding innovation indicators that are a complete description of any single quality of the innovation process or meaningful for the whole set of characteristics of innovation. R&D is not the only input to innovation and it is not enough to measure the level of investment in inputs to innovation. It is also necessary to consider the outcome, the value, the direction and many other characteristics to have a good understanding of the innovative process. Case studies are a good empirical tool to measure characteristics in a more complete way and to understand in a better way the interrelated characteristics of innovation. However, the impression one has after reading case studies produced in the business studies literature is that most of them are about the same firms: IBM, General Electric, Sony, Matshushita, Bayern, BASF, Glaxo Wellcome, Honda, for example. Thus, the diversity of behavior, specifically of technology investment behavior, that exists within any industry is not frequently illustrated through case studies. Additionally, none of these firms is similar to any of the firms observed in Colombia.

The purpose of this paper is to identify at least some of the different technology investment behaviors that exist and particularly to identify the type of technology investment behaviors that do exist in high-income countries and do *not* exist in middle or low-income countries. This is only possible because of the opportunity to use two large quantitative data sets of firms of from Colombia and the U.K., both based on the Oslo type innovation survey. The next part of this article presents the data and the necessary qualifications for its measuring precision and representative ness. In the next part, the data is analyzed and the empirical findings are summarized. The third part identifies the questions raised by the empirical finding and then focus on providing a theoretical explanation to why a group of firms with a common technology investment behavior exist in the U.K. and not in Colombia. Finally, some concluding comments on issues of measurement, empirical evidence and policy implications are put forward.

2. Methodology

Some methodological comments are necessary before starting the analysis. First, as explained above, the purpose of this study is to test whether high variability within categories suggested by theories of the determinants of technological change exists or not, as a general pattern and if so, how it may be described and explained. Thus, the appropriate method of investigation and the one used is induction: establishing an empirical fact and then suggesting how and/or why it happens. In order to guarantee the robustness of the empirical findings, several statistical tools including graphical analysis, descriptive statistics, non-parametric and parametric tests, were employed and the results of these investigations are reported. The aim of all these tests is to draw robust conclusions about the different patterns of technology investments behavior, subject only to measurement limitations.

Second, the measurement limitations faced by this study come from the indicators of technological activity used and the lack of use of other complementary indicators. In this study technological innovation is measured by the cost of inputs used to generate it. The cost of inputs is measured by the investment a firm executes in research and development (R&D), embodied technology (ET), and disembodied technology (DT). Additionally, data is available on design and engineering, training, and the sum of these five investments, total innovation investment. However, this is not comparable in several ways that will be identified below.

Indicators

In this study, R&D investment is the firm's expenditure in projects whose main objective is to create new knowledge for the firm at any of its different levels (basic, applied and development). It involves activities like pilot plants, prototypes, process development, and industrial design. Embodied technology (ET) investment is the expenditure in machinery and equipment technologically novel for the firm. Disembodied technology (DT) investment is related to activities such as patent disclosure, industrial secrets, licensing, "know how" agreements, strategic alliances, trade marks, and diffusion of knowledge through seminars and industrial fairs. Each one of these investments is divided by the firm sales, to standardize by firm size, and the resulting ratios are called innovation intensities (R&DI, ETI and DTI, respectively). So, for example, a firm's embodied technology intensity (ETI) is the firm's investment in ET divided by its sales, and will be presented throughout this study as a percentage of sales.

The data used in this study comes mainly from two different countries, Colombia and the U.K. Data from Italy and the U.S. is also sometimes employed for comparisons. The data for Colombia comes from the Colombian Innovation and Technological Development at Manufacturing Business Unit Level Survey (DNP, 1996) (CCIS from now on) which is an adapted version of the Oslo Manual survey used in OECD countries (OECD, 1997). The sample was designed to cover all industries at a three-digit ISIC level and business units of all sizes -above 20 employees-. It included 239 business units selected by the government that produce more than 30% of the gross industrial product or that had been funded by government R&D programs. Additionally, 961 business units were chosen randomly within the remainder almost 4,300 business units with more than 20 employees in Colombia's manufacturing industry. The survey was carried out in 1996 by interview. The response rate was 886 of the 1,200 business[2] and they generate almost 40% of total industrial output. After excluding the surveys with incomplete information and extreme innovation intensity values[3], 444 business units are available. 103 of them are government selected business units and 341 randomly selected.

[2] These 886 business units are composed of 233 of the 239 government selected business units and 652 randomly selected business units.
[3] Sixteen business units with extreme innovation intensities were found. Five of these correspond to unusual values such as very high intensity created by a large and unexpected fall in sales. The other eleven business units correspond to values normal to the business units but not to Colombia's economy.

These 444 business units employed between 20 and 3,247 people and sold between 16,800 and more than a billion of US 1996 dollars, with mean sales of 15.8 millions of US 1996 dollars. The business unit size classes are defined by number of employees as follows: between 20 and 49 employees (small), between 50 and 199 employees (medium), and more than 200 employees (large). The mean number of business units per size range is 144 and the lowest is 103. Small business units are represented by 10% of their total population in Colombia's industry, medium ones by almost 9% and large ones by 13%. This implies that here is some large business unit sample bias in the reported aggregates, but it is not large and will probably not affect the inferences made in this study.

The industries are defined using the SIC classification rather than the ISIC one. This is to allow full comparability of Colombian data with Italian, U.K. and U.S.'s data. Moreover, it was necessary to aggregate several SIC categories into one because they were not defined at the three ISIC level in Colombia. These industries are office machinery and computing (SIC 30), electrical machinery and television (SIC 31), radio, television and communication (SIC 32) that where merged into a category called electrical machinery (SIC 30*). In addition, motor vehicles (SIC 34) and other transport (SIC 35) were merged into a category called transportation equipment (SIC 34*).

The mean number of observations per two digit level SIC industries is 24 and there are two industries with less than 15 business units. These two industries are coke and petroleum, and medical and optical instruments and will be excluded from some of the statistical analysis because the low number of observations has implications in the use of some statistical tests. It is important to note that this does not mean that these industries have low levels of representation within the sample, since they both represent more than 30% of the of the population of each industry (see Annex 1). Additionally, all industries but food and beverages, textiles, and clothing, are represented by almost 10% or more of their business units. The under-representation of these three industries is not creating an important bias in the sample because of two reasons. First, it is not creating a business unit size bias. Second, there are other technologically traditional industries included in the sample (like wood and paper) that are represented by more than 10% of their population. In summary, the sample used in this study is representative of Colombian manufacturing sector with respect to business unit size and two digit level SIC industries (see Annex 1).

The sample characteristics of the data from the U.K., Italy, and the U.S. will not be described here due to limitations of space (please see references Torbett (forthcoming), Evangelista (1996 and 1999) and Cohen and Klepper (1992)). It is important, however, to identify the main differences with the Colombian sample. The data from the U.K. comes from Torbett (forthcoming) (RT from now on). Using European Community Innovation Surveys (CIS) based up on the Oslo Manual framework (OECD, 1997), RT presents data for R&D, ET, DT, design and engineering, training, and total innovation intensity. The main differences between the Colombian data and the U.K. data are (i) a slightly larger bias towards large business units and (ii) a lower representation per industry than the Colombian data (see Annex 1). Since the probability of being engaged in R&D activities has been associated with business unit size (see Cohen and Levin (1989) and Freeman and Soete (1997) surveys), it is likely that the level of non-innovation performing business units is lower than it is in reality. Additionally, one should be cautious about the inferences from this sample due to its low representation of the underlying population.

The data from Italy comes from the tables provided in Evangelista (1996 and 1999) (E from now on). Using also CIS survey, E presents data for R&D, ET, DT, design and engineering, training, and total innovation. The main differences between the Colombian survey and the one used by E are: (i) the unit of analysis is the firm, not the business unit, and (ii) the sampling design only included auto declared innovative firms. This implies, again, that some of the information is not directly comparable because the author does not always present information for the whole Italian manufacturing sector.

The data for the U.S. comes from the tables and graphs presented by Cohen and Klepper (1992) (CK from now on). CK present only R&D statistics and their source is the only one within this study that was not framed within the Oslo Manual. There are two important issues to note from this data: (i) there is an important bias toward business units owned by large firms mostly from Fortune's top 1,000, and (ii) the frequency of business units with R&D intensities higher than 7.5% or with lower than four business units is not disclosed. Particularly important for this study is the underestimation of the number or percentage of non R&D performers that comes with the large firm bias. The second issue simply implies that information is not always directly comparable.

Quantitative limitations of indicators

Measuring technological innovation by input indicators is limited by the incapacity of these measures to provide good information about some of the quantitative and qualitative characteristics of the innovation resulting from these inputs. The quantitative measuring difficulties of using R&D investment or intensity as a proxy of technological activity are well known and have been described elsewhere (see Cohen and Levin (1989) and Patel and Pavitt (1995)). The main quantitative shortcomings identified are: reporting error because definitions used by firms for financial reporting do not merge well with R&D definitions; R&D is not the only input for innovation; R&D is not always explicitly institutionalized in small companies and therefore it may be underestimated; and R&D is normally classified according to a firm's most important production activity while its results may be used in any of the production activities.

These limitations are also valid for the other measures of innovation investment and intensity. Nevertheless, the sum of the different innovation investment and intensity is likely to be an improved measure of innovation activity because it is possible to account for other inputs than R&D to innovation. The sum of these inputs is not a complete measure, since investments in organizational change and development of information processing technologies are not counted. Moreover, it is possible that the sum of innovation activity may also reduce the bias against non-institutionalized innovation investments that can be present in some small firms because they may be counted in one of the innovation intensities.

Unfortunately, for reasons explained below, it is not possible to use design and engineering, training, and total innovation investment indicators for comparison between countries or innovation activities, and DT for comparison between countries. However, since R&D and ET represent more than 65% of the average total innovation investment and intensity in all three countries where this information is available, and DT is sometimes included in the analysis, at least we know that what is excluded is less than what is included in the analysis.

Qualitative limitations of the indicators

Measuring innovation by its inputs implies qualitative limitations to the inferences drawn from the analysis. When using innovation intensity to measure innovation it is necessary to assume that all firms achieve similar innovations per unit of money invested in order to compare innovations between firms. There is evidence that this is not the case (Freeman and Soete, 1997). Some authors suggest that this so because the opportunities and incentives firms face shape the direction of the technological innovation efforts and, consequently, the innovations that result from these efforts. Opportunities and incentives are related to the possibility a firm has to use scientific and/or technological knowledge to enhance its products or processes in order to respond to or create market demand. These opportunities and incentives vary as the sources of ideas for innovation, the importance of cumulative and tacit characteristics of knowledge, the appropriability of the benefits from innovation, and the characteristics of the users vary, mainly, from country to country, from small to large firms, and from industry to industry. The specific set of opportunities and incentives faced by the firm, guide it in executing innovation activities with the intention of generating innovations that lead to cost-cutting or revenue-enhancing competitive strategies for the firm. In addition, the specific form an innovation will take is difficult to predict due to the uncertainty inherent to the creative effort directed to generation of new products and processes.

In particular, when comparing between Colombia and the U.K., Italy or the U.S. one may expect important differences in the opportunities and incentives for innovation. Take for example, the publishing industry. This is one of the most competitive industries in Colombia. Its animated books for children are exported to several Latin American countries, Spain and even non-spanish speaking countries. Important drivers to innovation in this industry are the opportunities for intermediation and disintermediation between the publishers and consumers offered by Internet. It is dubious that companies in Colombia can take full advantage of these opportunities. While in the U.S. and the U.K. issues related to efficiency of telephone infrastructure and the regulation of the companies providing the related services are very important, in Colombia the important ones are related to income level to afford books and the coverage of the telephone infrastructure, not its efficiency. Additionally, products like the electronic book offer important opportunities and impose difficulties for Colombia's children's book publishing companies, since their competencies are related to animation of images in paper and not in electronic formats. Thus, links with other industries where these competencies may be available, like, for example, the film industry, become crucial for development of the new product. Unfortunately, Colombian publishing company's networks might not reach the film industry because it is infant in Colombia. In few words, the opportunities and incentives posed by Internet are very different between countries, consequently, the innovations expected in Colombia's firms would be less frequently related to Internet and multimedia trade compared to those from firms in the U.K. and the U.S..

The consequence of the above differences in opportunities, incentives and directions of technological change and its uncertain nature is that innovations vary in several ways. First, they vary by degree of novelty. Thus, they can be disrupting, major or minor (also referred as incremental). For example, the steam engine during the industrial revolution was a disrupting innovation (Freeman and Soete, 1997); the introduction by Ford of the first large scale transfer machine was a major innovation; and the simple relocation in a work shop of the different machines that make a process is a minor innovation.

Second, an innovation can be related to the creation of a new product, the creation of a new process, or the creation of a new way to organize and co-ordinate the division of labor within a firm. The German firm BASF, for example, integrated the three innovations together as they were one of the first firms to have an R&D department, they discovered the alizaryn dyestuff and an economical process to generate the synthesis of indigo dyestuff (Freeman and Soete, 1997).

Third, innovations can also vary in value for the developer and the society. Thus, aerospace industry innovations are strongly influenced by the government's defense expenditure, in part because of the level of resources required to achieve them and their political importance. On the other hand, the car industry innovations are characterized for being less expensive and frequently privately funded. These differences in value imply that there are differences in the innovations that a medium income and a high-income country can achieve. Additionally, while one may think of very few social costs related to the innovation of the wheel, it is uncertain what level of costs are involved in the genetic modification of foods.

Finally, and extremely important for international comparisons like the ones done in this study, innovations for a business unit can simply be part of the diffusion process of a major innovation developed by a different business unit. For example, the introduction of a numerical control machine into the process of a Colombian firm producing elevators was cited by its owner as a very important process innovation that caused, additionally, other process, organizational, and even cultural transformations within the firm. Nevertheless, it is an innovation that presumably took place several decades ago in companies producing elevators in Japan, the U.S. and Germany and it can also be seen simply as the latest part of the diffusion of a major innovation like numerical control machines.

Confidence of indicators

In addition to the above measuring limitations, the importance of cultural differences in shaping and influencing perceptions of a question may hamper the comparability of the answers within the same survey or between different surveys in time or between countries. The most common example is the question that tries to identify whether the organization has made any innovations or not. For example, Archibugi et al (1994) suggest a small firm bias exists because innovations have to be "major" ones in large firms to be called innovations, while small firms may want to emphasize a "minor" innovation, even if, in general, they are not innovative at all. The analysis of the costs of inputs analyzed in this study there provides another example. In the case of design and engineering investment and intensity, Colombian business units declared to perform this innovation activity more frequently than the U.K. ones, at all intensity levels. Additionally, the typical Colombian innovative firm, measured by the mean investment of business units engaged in at least one of the innovation activities defined above, spends more than 23% of its total innovation investment in design and engineering while in the U.K. it only invests 4%. Moreover, data presented by Evangelista (1996 and 1999) for eight different European countries shows that the share of design and engineering in total innovation investment, including marketing but excluding training, is higher in Colombia than in all these European countries, except for Germany[4]. Italy's share, for example, is only 15%, and the majority of these investments are allocated in specialized suppliers industries. This high values of design and engineering frequency and share within total innovation investment is an unexpected result since Colombia is not internationally known for having a highly developed specialized supplier industries.

The origin of this anti-intuitive pattern may be related to two different things. First, it can be the result of people in charge of answering the questions in each country understanding different things from similar questions.[5] Second, the origin of the pattern can be the consequence of the U.K.'s geographical position and economical importance for suppliers of machinery and equipment compared with that of Colombia. It has been reported in other Latin American countries that firms have to make important design and engineering efforts to compensate the fact that machinery and equipment suppliers do not provide modification and repair services to these countries (Katz, 1986). If this is the case, then design and engineering frequency and share may be higher in Colombia than in the U.K.. How much higher can they be? How much difference is sensible to expect? Which of

[4] Note that what is high is the share of design and engineering within total innovation, not the absolute value of design and engineering, which is higher in the U.K. and should also be higher in Germany.

[5] In Colombia the question is "has the business unit engaged in innovation activities of design?" and in the U.K. is did your enterprise engage in the following technological activities? where the options are industrial design, other production preparations for technologically new or improved products. Although the two questions are not exactly the same, the examples used to illustrate what are design activities are similar in both questionnaires. These examples are drawings or plans associated with the installation of new machinery and equipment, industrial engineering, start up of production process. Furthermore, both also make explicit that design of prototypes should be included as part of R&D, not as design. Additionally, the U.K.'s survey also includes changes in quality control procedures, methods and standards and associated software required to produce technologically new or improved products.

the two things is occurring? These are important questions but they are out of the scope of this dissertation.

The case of DT investment and intensity is different. There are some cases where one can also be suspicious about the values of DT frequency and share in Colombia because they are very close to those in the U.K. or even slightly higher. Nevertheless, they have the very low frequency and share within innovation inputs that has been reported in other countries.

In summary, one should be careful not to compare design and engineering between countries or innovation investments or intensities. Additionally, one should also limit comparison of DT between countries, because their values may be misleading. The implication of this is that one should also be careful in comparing total innovation investment and intensity between countries and innovation activities. In order to guarantee the rigor of the analysis, only R&D, ET and DT will be used, as it was explained above, and comparison of DT indicators between countries will not be carried out.

Environment effect and aggregation issues

Finally, one should also take into account differences in macroeconomic performance in the different countries as the data comes from cross sections and has some industry aggregation implications. The two sets of data most frequently compared in this study come from Colombia and the U.K., for the 1990-5 and 1994-6 periods respectively. In both countries the growth of the industrial sector in these years reflected the good macroeconomic conditions. In Colombia it was one of the periods of higher manufacturing growth after the 1967-74 period, and in the U.K. it was a period of recovery from an important recession at the early 1990s. Thus, both samples seem to be fairly similar in terms of macroeconomic conditions, allowing comparisons between them.

Additionally, industry aggregation limitations may also hamper inferences from this study. The industry definition adopted, the two digit level SIC classification, implies that diverse industries, defined as groups of closely competing products, are merged within the same group. There are two important issues about diversity within an industry group. First, the more intuitive argument suggests that merging several different clusters of closely competing products within the same group, or SIC industry in this case, may obscure some patterns and create other artificial ones about the technological characteristics of this industry. Second, there are examples that suggest that, at least in some groups of closely competing products, there will always exist diversity because competing products may be produced by firms following different technological trajectories (Sutton, 1998). The problem arises because customer diversity and technological diversity makes extremely difficult to draw clear lines between products, thus grouping by product may imply consumer and technological diversity.

What is striking is that technology based industry classifications are normally more aggregated than SIC classifications. The OECD R&D intensity classification has three groups, the Pavitt's taxonomy has five groups (including information intensive) (Pavitt, 1984), and the Jaffe's one has twenty-one groups (Jaffe, 1986). All of these three classifications link naturally and clearly technological groups into very aggregated industries when compared with the more than 400 industries identified by the four digit SIC code for which economic data exists. Additionally, my own short experience has shown me that results are clearer at high levels of aggregation (few groups) than at lower ones (many groups). The important implication of aggregation problems for the purposes of this study, is that it is difficult to guarantee that no spurious variability in technological activity arises simply from the aggregation of different industries into two digit level SIC industries or that the variability between firms producing well-defined competing product clusters is not obscured by aggregation.

In summary, the measures of technological innovation used in this study, innovation investment and intensity, allow to measure the effort devoted to technological development by a business unit. Although this measure is incomplete, since design and engineering, disembodied technology, technological training, organizational change, and information and communication technological efforts are not included, it is definitively an improved measure over R&D alone. In particular, one should be careful in suggesting strong generalizations across business unit size classes due to possible quantitative measurement bias against small ones and about the level of variability due to the possibility of aggregation problems. Finally, from these innovation intensities it is not possible to infer the qualitative characteristics of the innovations generated by this investment efforts and little can be said about the opportunities, incentives, directions and types of innovation.

3. Innovation investment and intensity distributions

In this part of the study the innovation intensities are examined by using country, size classes and industry as discriminatory variables. First, following CK, each innovation intensity frequency distribution diagram was plotted -the frequency curve- for the aggregate sample, the three classes of business unit size, and the seventeen two-digit level SIC industries. This allows us to see the shape of the different innovation intensity distributions and identify their salient characteristics. Since both scales have been set equal for all graphs, comparison between them is subject only to the measurement limitations stated above. Additionally, it is important to note that these frequency curves do not present the whole range of observations. This is because of scaling effects that allow visualizing better the first and most densely populated part of the innovation intensity frequency distributions. Thus, the range of the frequency distribution of innovation intensity cannot be fully analyzed by using the graphs. In any case, the annex contains tables presenting the whole range taken by each innovation intensity frequency distribution. Following the graphical analysis, the percentage of non-performers, range and skewness of the innovation intensity frequency distributions are analyzed. Next, some non-parametric statistical analysis are carried out to test whether there is a common underlying theoretical distribution that describes the innovation intensity frequency distributions or not and to identify the difference between the frequency distributions of Colombia and the U.K.. Finally, it is analyzed whether the patterns observed at size class and industry levels change when combing these two categories.

Graphical description

Country

The shape of the aggregate R&DI, ETI and DTI frequency plots is similar between Colombia and the U.K., as Figures 1, 2 and 3 show. The two most salient characteristics of the shape of the innovation intensity frequency plots in both countries are the high level of non-performing business units -innovation intensity equal to zero- and the more or less monotonically decreasing percentage of business units per innovation intensity, as innovation intensity increases. These two characteristics may be called the mode and skewness of innovation intensity frequency distributions.

The most visible difference in the shape of the innovation intensity frequency plots between Colombia and U.K. is the thickness of the frequency plot at zero level intensity and at higher than zero levels of intensity. In R&D and ET investment and intensities, Colombia's frequency plots present higher percentages of business units not performing innovation activities. Additionally, in

R&D and ET investment and intensity Colombia's frequency plots present lower percentages of business units performing *each* innovation intensity level. This thickness characteristic may be called the density of innovation intensity frequency distributions.

Furthermore, not only some innovation intensities vary in density between countries, they also do vary between innovation intensities. In both countries, R&D and ET intensities tend to be less dense than DT at zero intensity levels and denser than DT investment and intensity at positive intensity levels.

Size

Innovation intensity frequency plots by business unit size class were graphed as follows. First, R&DI, ETI and DTI were graph together for each business unit size class and each country. Design and engineering and total innovation investment were excluded from these graphs because it was noted above that they should not be compared between countries or with other innovation intensities. Nevertheless, it is important to state that their shape is similar to that of other innovation intensities and this is also true for all business unit size classes and industries.

The size class innovation intensity frequency plots reveal the same shape and the same characteristics by country and innovation activity as the innovation intensity frequency plots reported for the aggregate levels. The mode is located at zero level of intensity, high skeweness, and differences in density between countries and innovation activities (see Annex 2). Additionally, the density of all innovation investment and intensities varies between size classes. As size class increases, all innovation intensities show a decrease in the frequency of non-performers and a more or less general increase in the frequency of performers at all intensity levels. Finally, taking into account the important large firm business units bias in the sample used by CK, one may compare what they present as an aggregate level R&D intensity frequency plot with Colombia's and the U.K.'s plots for large business units. The comparison suggests that in all three countries the frequency distribution of R&D follows the same shape.

Figure 1
R&DI intensity frequency plot for Colombia and the U.K.

Sources: CCIS (DNP, 1995) and RT (forthcoming)

Figure 2
ETI intensity frequency plot for Colombia and the U.K.

Sources: CCIS (DNP, 1995) and RT (forthcoming)

Figure 3
DTI intensity frequency plot for Colombia and the U.K.

Sources: CCIS (DNP, 1995) and RT (forthcoming)

Industry

The industry level innovation intensity frequency plots are presented in a similar way to the size class graphs (see Annex 2). These innovation intensity frequency plots reveal the same shape and the same characteristics by country and innovation activity as the ones reported for the aggregate and size ones: mode at zero and high skewness. However, the more or less monotonically decreasing frequency of innovation intensity as innovation activity increases observed at aggregate and size class levels is a little less clear within industries. This implies that the differences in density between innovation intensities or between countries are more difficult to identify. Despite these difficulties, it is clear that all innovation intensities are asymmetrical (positively skewed) and at least two different groups of industries may be identified.

1) *Industries where ET intensity presents higher density than R&D and DT intensity at positive innovation activity*. These industries are food and beverages, textiles, clothing, leather, wood, paper, publishing, rubber and plastics, non-metallic mineral products, basic metals and fabricated metal products. In food and beverages, textiles, clothing, leather, paper, and rubber and plastics industries, this pattern is observed in both countries. Note that at positive levels R&D intensity presents a clearly higher density than DT intensity in the UK while in Colombia R&D and DT intensity have similar frequency. In wood, publishing, non-metallic minerals, basic metals, and metal products industries, R&D and DT have similar frequencies in both countries. Finally, in all these industries, R&D intensity presents a higher density in the UK than in Colombia, and, although less clear, it is also possible to suggest the same relation for ET intensity.

2) *Industries where R&D intensity presents higher density than ET and DT intensity at positive innovation activity*. These industries are chemicals, machinery and equipment, electrical machinery and transportation equipment. In these industries, for positive innovation activity levels, in the UK the density is higher in R&D intensity, medium in ET intensity, and then lower in DT intensity. In Colombia, in chemical and machinery and equipment industries the density of ET intensity is higher or similar to R&D intensity, and DT intensity presents a lower density. And in electrical machinery and transportation equipment industries the density of ET intensity is higher or similar to DT intensity, while R&D intensity presents a lower density. Finally, in all these industries, R&D intensity presents a higher density in the UK than in Colombia, and, although less clear, it is also possible to suggest the same relation for ET intensity. DT intensity presents a very similar density in both countries.

These two different groups of industries illustrate the difference between technology producers and users (see Patel and Pavitt, 1995). The first one, where traditional and bulk materials processing industries are grouped, is characterized by a more frequent use of market transactions to obtain technology (ET) relative to the use of internal resources and capabilities to develop technology (R&D). Thus, this may be called the technology user group. The second group, where chemicals, mechanical and electrical industries are grouped, is characterized by a more frequent use of internal resources and capabilities to develop technology (R&D) relative to the use of market transactions to obtain technology (ET). Thus, this may be called the technology producer group. This is a pattern observed in both countries, although in Colombia it is perceived a general lower frequency of use of R&D than in the UK. Thus, in Colombia within the group of technology user industries R&D frequency is even lower than ET, and within the group of technology producers a similar frequency of use of R&D and ET is observed -rather than a more frequent use of R&D-.

Additional evidence may be drawn from CK that has R&D intensity frequency plots for several industries. Since plots presented by CK do not have Y-axis scale and the sample used implies a large firm business unit bias, the comparison is difficult, but some similar patterns may be identified and highlighted. First, the location of the mode is zero or very close to zero. In six industries it is zero, in seven it is less than 0.5% of R&D intensity, and in two more it is between 0.5% and 1%. Second, all industry R&D intensities are highly skewed.

Summary of innovation intensity frequency distribution graphical analysis:

- All innovation intensities, that is R&DI, ETI and DTI in Colombia and U.K. have mode 0 and are highly positively skewed, independently of the two-digit level SIC industry or the size class.
- It is frequently observed that the density of innovation intensity changes by:
  Country: it is frequently observed that (i) innovation intensity modes are more populated in Colombia than in U.K. and that (ii) every positive innovation activity level is less populated in Colombia than in U.K..
  Size: it is frequently observed that (i) the percentage of non-performing business units is higher for every innovation intensity plot in small business units size classes than in large ones and that (ii) for every positive intensity, innovation intensity plots are less populated in small business units size classes than in large ones.
  Industry: it is frequently observed that (i) technology user industries more frequently use ET than R&D and (ii) technology producer industries more frequently use R&D than ET, although in the case of Colombia industries use them both with similar frequency.
- Innovation intensity may be described by its (i) mode, (ii) range, (iii) skewness –asymmetry- and (iv) density.

In order to explore how the mode, range, skewness and density of the innovation intensity frequency distributions change and what is related to these changes, additional statistical analysis was performed. The following analysis using these statistical tests verifies the conclusions of the graphical analysis above and adds depth and clarity where the graphical analysis was unclear. The results of the statistical tests for the aggregate sample are presented in Table 1.

Table 1
Summary statistical tests

Country	Statistic test			R&D	ET	R&DI	ETI
U.K.	Mode: non-performers (% of business units)						
	Range (* US dollars, ** % of sales)						
	Skewness						
	Density: K-S one sample tests	Normal	K-S test				
			Asymp. Sig.				
		Uniform	K-S test				
			Asymp. Sig.				
		Exponential	K-S test				
			Asymp. Sig.				
Colombia	Mode: non-performers (% of business units)			78.6	64.3		
	Range (* US dollars, ** % of sales)			48,385*	53,338*	9.6**	37.7**
	Skewness			4.3	4.0	5.4	4.1
	Density: K-S one sample tests	Normal	K-S test	9.3	8.6	8.0	6.7
			Asymp. Sig.	0.0	0.0	0.0	0.0
		Uniform	K-S test	19.2	18.1	16.3	14.8
			Asymp. Sig.	0.0	0.0	0.0	0.0
		Exponential	K-S test	39.2	27.1	34.7	22.2
			Asymp. Sig.	0.0	0.0	0.0	0.0

Sources: CCIS (DNP, 1995) and RT (forthcoming)

Non-performers

Analysis of the percentage of non-performing business units per country, size class and industry confirms what was pointed out in the graphical analysis (see Table 1 and Annex 3). First, all industries and all size classes in both countries have innovation investment and intensities with mode zero. Second, it was also confirmed that as size class increases so does the percentage of business units engaged in innovation activities, independently of the country and the innovation activity. Third, the percentage of non-performing R&D and ET business units is higher in technology user industries and lower in technology producer ones, although the relation is not strict across industries. Additionally, and interestingly, in the U.K. some technology user industries present a higher population of non ET performers than the population of non R&D performers.

Range

The analysis of the range of the different innovation intensities per country, size class and industry suggests the following findings (see Table 1 and Annex 4). First, the range of R&D and ET investment and intensity are usually higher in the U.K. than in Colombia. Second, analysis by business unit size classes suggest that small business unit size class has lower R&D and ET investment range than medium and large size classes in Colombia and the U.K., while small business unit size class has higher R&D intensity range than medium or large size classes in Colombia and the U.K.. Third, analysis by industry suggests that in the U.K. high ranges of R&D investment are observed in technology producer industries and food and beverages industries, while low ranges are located in technology user industries. And high ranges of ET investment are observed in food and beverages, publishing, chemicals, electrical machinery and transportation industries, while low one are observed in clothing and leather. Additionally, R&D and ET intensities show a clear producer-user of technology pattern, but in both activities, R&D and ET intensity, technology producer industries exhibit high ranges. Exceptions are food and beverages that has a high R&D and ET intensity ranges, and rubber and plastic that exhibits a high ET range. In Colombia, R&D and ET investment and intensity range shows no clear pattern, and all that can be said is that high R&D and ET ranges are clustered in chemical industry. Finally, it is necessary to highlight the difference in the level of the range of technology investment between the U.K. and Colombia: while in U.K. the range of R&D and ET investment goes up to more that 200 millions of US dollars, in Colombia it is close to only 20% of it.

Skewness

The analysis of the skewness of innovation investments and intensities per country, size classes and industries confirms what was observed in the graphical analysis. All innovation intensities are positively skewed in both countries (see Table 1 and Annex 5). Additionally, R&D intensity in U.S. presented by CK varies from 0.9 in measuring, analyzing and controlling instruments to 9.2 in food and kindred industries. Thus, the asymmetry of the innovation investment and intensity frequency distributions is a robust finding.

Shape of frequency distribution

The Kolmogorov-Smirnov one sample test was used to identify the possibility of all frequency distributions coming from a single theoretical probability distribution. If this is true, the implications in terms of approach for analysis and policy implications are important[6]. However, the results give little support to these research approaches. The Kolmogorov-Smirnov test suggests that

[6] For an example of this literature see Iriji and Simon (1977) and Katz (1999).

neither normal, uniform or exponential distributions can generate any of the investment and intensity frequency distributions (see Table 1 and Annex 6).

Differences between Colombia and U.K. frequency distributions

In order to identify differences between Colombia and the U.K. in the density of R&D and ET investment and intensity frequency distributions, the Kolmogorov-Smirnov two independent samples test was used. Note that only differences between countries in R&D and ET were tested since DT should not be compared between countries, as explained above. The Kolmogorov-Smirnov test is a general one. Thus, it permits to identify any difference between the two distributions but it is not capable of indicating whether a difference is originated by differences in central location, asymmetry, or dispersion between the two distributions.

In order to overcome this difficulty, the Kolmogorov-Smirnov test was carried out partitioning the R&D and ET investment and intensity distributions. The partitioning allows the researcher to control differences in non-performers and range characteristics permitting to identify the origin of the difference between the two countries. In order to control for differences in non-performers between countries, the test was carried out including and excluding non-performers. Additionally, with the purpose of controlling for differences in range, the test was carried out including and excluding the observations with investment of more than 50,000 US dollars and of more than 1% intensity.

Unfortunately, it is not always possible to partition the frequency distribution. When the presence of performers is lower than five observations the test was not conducted partitioned. Since this is the case in Colombia and not in the U.K., it is clear that when the test could not be carried out partitioned the major source of difference between the two countries arises from business units that do perform R&D or ET. The results are reported in Annex 7.

At aggregate level the difference between the two countries seems to arise from business units located at all parts of the frequency distributions. The R&D investment and intensity frequency distributions are different between Colombia and U.K. for almost all size classes. The only case where the Kolmogorov-Smirnov test did not reject the null hypothesis -the two samples are similar- is ET investment within large business units. The differences between countries at industry level are more frequent for R&D investments and intensities than for ET investments and intensities. In the case of R&D investment, in thirteen industries the Kolmogorov-Smirnov test suggested important differences between countries, while this is also true in twelve industries for R&D intensity. These twelve industries include the whole technology producer industries and some other industries, like food and beverages, clothing, rubber and plastic, other non-metallic mineral industries, and fabricated metal products. In the case of R&D investment it was possible to trace the origin of the difference between Colombia and the U.K.'s distribution in some of these twelve industries to the range.

In the case of ET investments and intensity, the Kolmogorov-Smirnov test suggests differences in six and four industries, respectively. Additionally, when it was possible to trace the difference, it was related to range in the case of ET investment and to non-performers in the case of ET intensity.

Thus, it is possible to conclude that differences between Colombia and the U.K. arise more frequently in R&D than in ET investment and intensity. The sources of those differences, when it is possible to identify them, are related to the range in the case of investment in R&D or ET and to the non-performers in the case of intensity in R&D and ET.

The following is a general summary of the description of innovation investment and intensities made above.

- In Colombia and the U.K. the innovation investment and intensity frequency distributions have the same shape: most business units do not engage in technological innovation activities; some do technological innovation activities, with medium investment and/or intensity; and very few invest disproportionately more than the rest of the business units within the category. This shape may be described by mode at zero investment or intensity, and positive skewness. It holds at aggregate levels, within any size class, and within any industry.
- The frequency of non-performers is higher in Colombia than in the U.K.. It is also higher in small business units than in large ones, and in technology user industries than in technology producer industries.
- The frequency of non R&D performers is not always lower than the frequency of non ET performers in technology user industries in the U.K.. Thus, even in some technology user industries generally use internal development rather than the market to acquire technology. In technology producer industries population of non-performers is higher for ET activities than for R&D activities. In Colombia frequency of non-performers of ET is always lower than that of R&D, but in technology producer industries the difference tends to be smaller.
- The range of innovation intensities is higher in the U.K. than in Colombia.
- In the U.K., low ranges of R&D and ET investment are observed in small business units and in many technology user industries, while high ranges are located in medium and large business units and most of the technology producer industries. Additionally, R&D and ET high intensities are exhibited by technology producer industries. In Colombia, no clear relation appears between R&D and ET intensity range, and size class or industries. All that can be said is that high R&D and ET ranges are clustered in chemical industry.
- The ET intensity range is higher than R&D and DT intensities range in almost all industries in both countries, except in some few technology producer industries in U.K. where R&D intensity is higher.
- There is no evidence that the frequency distribution of any innovation investment or intensity comes from a theoretical distribution.
- Differences between Colombia and the U.K. arise more frequently in R&D than in ET investment and intensity. The sources of those differences, when are possible to identify, are related to the range in the case of investment in R&D or ET and to the non-performers in the case of intensity in R&D and ET.

In general, the empirical evidence presented here is similar to that of other empirical literature on the patterns of technological activity including Patel and Pavitt (1995), Cohen and Levin (1989) and Cohen (1995). Nevertheless, there are several new observations in this analysis. First, the level of business units not engaged in technological activities is much larger than one might assume. Even in clearly high tech industries like office machinery and computing, in the U.K. the population of business units not investing in technology, not even in technological training, is as large as 13%. Moreover, the results of the comparison between Colombia and the U.K. suggest the importance of the non-performer business units in both economies. Additionally, the result that associates differences in the range of investment in R&D and ET with the differences between Colombia and the U.K., suggests that it is the extremely large business units that concentrate most of the investment in R&D and ET in the U.K. that are rare in Colombia. This allows us to infer that the main difference between the performers of both countries arises at least in part from the business unit size effect.

The empirical evidence presented above noted that a variety of investment behaviors are observed within categories that are suggested by the theory of the determinants of innovation used to group innovative firms. Additionally, it may be argued that it is not each category alone that should be used to group the innovative firms, but the combination of these categories. Thus, it is necessary to explore the hypothesis that by combining size and industry characteristics makes it possible to form more homogeneous groups of firms, this is firms that behave alike in terms of innovation investment. Unfortunately, there are not enough technological activity performers within some industries in Colombia's sample to do a detailed analysis by combining the different categories. Nevertheless, it is possible to explore if the presence of non-performers within any industry is associated to the size of the business units producing in that industry.

In order to explore this issue, the share of small, medium and large business units that are non-performers in each industry and the share of non-performers within the whole population of small, medium and large business units per industry were calculated. The results show that the majority of non-R&D and ET performers within any industry are small both Colombia and the U.K. (see Table 2). Moreover, more than 40% of small and medium sized business units within any industry do not perform R&D *or* ET (see Table 3). Additionally, the share of large business units within non-performers is close to 50% in some industries, including food and beverages, leather, paper, and chemical industries in the U.K., while in Colombia it is only observed in clothing industries. Finally, the percentage of large business units that do not perform R&D is lower than 40% in most industries in the U.K., while in Colombia it is higher than 40% for most industries. In the case of ET, a similar but less marked pattern exists.

The analysis of this data suggests the following pattern: large business units in Colombia represent a lower share of non-performers than in the U.K., but the majority of them do not perform R&D or ET while most of them in the U.K. do perform R&D or ET. This paradoxical pattern may be explained by the low absolute number of large business units in Colombia, compared to the U.K.. This explains why large business units are not an important share of all non-performers in an industry although most of them do not perform R&D or ET investments.

To sum up, size does seem to play a role in determining whether a business unit is engaged or not in innovation investment: it is extremely unlikely to find small and medium sized business units engaged in R&D or ET investment. Additionally, one should also be careful to suggest that large business units have high likelihood of engaging in R&D and ET investments because in both countries a substantial population of large business units in every industry is not engaged, although this population is higher in Colombia than in the U.K.

This finding is not new and it supports what has become a consensus about the role of size, as suggested by Cohen (1995) and Freeman and Soete (1997) in their reviews of empirical literature mostly from OECD countries:

- The probability of a business unit performing R&D increases with size
- The R&D expenditure increases with business unit or firms size within business units or firms engaged in R&D activities
- The R&D intensity is not clearly related to business unit or firm size within business units engaged in R&D activities.

Table 2
Share of small, medium and large business units within non-performers per industry

SIC	R&D non-performers %						ET non-performers %					
	U.K.			Colombia			U.K.			Colombia		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15				51.6	25.8	22.6				60.9	26.1	13.0
17				30.4	43.5	26.1				38.9	44.4	16.7
18				35.3	17.6	47.1				45.5	27.3	27.3
19				43.5	39.1	17.4				50.0	35.0	15.0
20				52.4	42.9	4.8				58.8	35.3	5.9
21				57.1	42.9	0.0				70.0	30.0	0.0
22				53.3	26.7	20.0				75.0	25.0	0.0
23				0.0	66.7	33.3				0.0	66.7	33.3
24				52.9	29.4	17.6				47.4	42.1	10.5
25				35.7	50.0	14.3				40.9	50.0	9.1
26				53.6	28.6	17.9				43.5	39.1	17.4
27				73.7	21.1	5.3				68.4	21.1	10.5
28				34.8	39.1	26.1				50.0	33.3	16.7
29				54.2	37.5	8.3				54.5	40.9	4.5
30				35.3	47.1	17.6				25.0	56.3	18.8
33				57.1	42.9	0.0				66.7	33.3	0.0
34				20.0	53.3	26.7				22.2	55.6	22.2

Source: DNP (1996) and Torbett (forthcoming)

Table 3
Share of non-performers within whole population of small, medium and large business units per industry

SIC	R&D non-performers %						ET non-performers %					
	U.K.			Colombia			U.K.			Colombia		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15				94.1	72.7	58.3				82.4	54.5	25.0
17				100.0	100.0	85.7				100.0	80.0	42.9
18				100.0	75.0	100.0				83.3	75.0	37.5
19				100.0	100.0	100.0				100.0	77.8	75.0
20				100.0	100.0	50.0				90.9	66.7	50.0
21				100.0	85.7	0.0				87.5	42.9	0.0
22				88.9	80.0	100.0				66.7	40.0	0.0
23				0.0	100.0	33.3				0.0	100.0	33.3
24				75.0	50.0	30.0				75.0	80.0	20.0
25				83.3	77.8	57.1				75.0	61.1	28.6
26				100.0	53.3	45.5				66.7	60.0	36.4
27				100.0	57.1	16.7				92.9	57.1	33.3
28				80.0	90.0	85.7				90.0	60.0	42.9
29				92.9	60.0	33.3				85.7	60.0	16.7
30				85.7	66.7	50.0				57.1	75.0	50.0
33				100.0	75.0	0.0				100.0	50.0	0.0
34				75.0	100.0	80.0				50.0	62.5	40.0

Source: DNP (1996) and Torbett (forthcoming)

The importance of the first and third relations in terms of explanatory power is reported to be low, however. This finding suggests much less confidence in policies aimed at large firms based upon the premise that such firms are likely to be more innovative.

It is necessary to guarantee that the same pattern is observed in Colombia, since most of this evidence comes from high-income OECD countries. This is why some more rigorous statistical tests were executed. A logit model to determine the influence of business unit size and industry effects over the probability of engaging in R&D and ET was estimated. Additionally, OLS models to determine the effect of size and industry effects over investment and intensity of R&D and ET were also estimated. The results suggest that exactly the same pattern is observed in Colombia for business unit size (see Table 4) and that it is also observed for ET investment and business unit size (see Table 5). Business unit size positively affects the probability of engaging in R&D or ET, and the investment of R&D and ET, not the intensity. However, the fit of the logit model suggests that business unit explains more why business units are not engaged in R&D than why they are engaged. The model predicted 95% of the non-performers and only 5% of performers. It is important to note that this result may not be robust since it can be affected by the lower performance of the logit model when the dependent variable is not approximately balanced[7] and the presence of heteroscedasticity (Greene, 1997). The high influence and fit of business unit size variability over R&D investment variability –within firms engaged in R&D- and the low statistical significance and influence of business unit size on R&D intensity of R&D is in agreement with Cohen (1995) and Freeman and Soete (1997).

Finally, it is important to note that industry differences do not seem to play and important role in explaining business unit investment or intensity in R&D and ET. This result is somewhat different to that observed in the U.S.. The evidence reported by Cohen, et al (1987) suggests that industry differences measured or fixed, are important in explaining R&D intensity. Although they do not report explicitly evidence on the importance of industry differences on the probability of engaging R&D it is possible that it is also important. However, they also report that fixed effects at two-digit level SIC industries were not significant while fixed effects at three-digit level SIC industries were significant. Cohen, et al (1987) argue that this is so because of aggregation problems implied by the two-digit level SIC industries. If this was true in Colombia, then it is possible that industry effects may be important in explaining R&D intensity when fixed at lower aggregation levels or appropriately measured.

[7] The dependent variable is not balanced when the proportion of R&D performers and non-performers are varies significantly from 50% within the sample. Remember the percentage of performers is low, especially in R&D where non-performers are close to 80% of the sample.

Table 4
Logit and OLS of R&D investment and intensity and business unit size and fixed industry effects

Model	Logit R&D			OLS R&D investment			OLS R&D intensity		
Sample	Complete sample=403			Only performers=91			Only performers=91		
	B	T	Sig.	B	T*	Sig.	B	T*	Sig.
Constant	-1.36	-10.51	0.00	-832.10	-4.76	0.00	1.21	6.64	0.00
Sales	0.00	2.49	0.01	0.04	7.65	0.00	0.00	0.66	0.51
R Log Likelihood	-215.27			-904.85			-172.44		
Log Likelihood	-209.32			-808.42			-172.16		
X2	11.90	0.00		192.88			0.55		
Non performers fit	310	99.4%							
Performers fit	5	5.5%							
Total fit	315	78.2%							
R2 Adj.				0.88			-0.01		
F (1,89)				652.13	0.00		0.54	0.47	
BP het. Test				169.17			0.27		

Including industry fixed effects

R Log Likelihood	-215.27			-904.85			-172.44	
Log Likelihood sales	-209.32			-808.42			-172.16	
Log Likelihood sales & industry	-187.86			-795.77			-165.63	
X2	54.82	0.00		25.28			13.06	
X2 industry dummies	42.92	0.00		25.28			13.06	
Non performers fit	308	98.7%						
Performers fit	8	8.8%						
Total fit	316	78.4%						
R2 Adj				0.89			-0.05	
F (16,74)				46.22	0.00		0.75	0.74
B-P Het. Test				118.92	0.00		54.50	0.00

* T statistic computed with robust estimation of standard error.

Table 5
Logit and OLS of ET investment and intensity and business unit size and fixed industry effects

Model	Logit ET			OLS ET investment			OLS ET intensity		
Sample	Complete sample=403			Only performers=152			Only performers=152		
	B	T	Sig.	B	T*	Sig.	B	T*	Sig.
Constant	-0.76	-6.41	0.00	254.20	1.14	0.26	5.10	10.48	0.00
Sales	0.00	3.90	0.00	0.04	4.43	0.00	0.00	-0.83	0.41
R Log Likelihood	-267.05			1511.43			-484.46		
Log Likelihood	-252.18			1423.77			-484.40		
Log Likelihood	29.76	0.00		175.31			0.11		
Non performers fit	241	96.0%							
Performers fit	32	21.1%							
Total fit	273	67.7							
R2 Adj.				0.68			-0.01		
F (1,150)				325.31			0.11	0.74	
B-P Het. Test				531.58			0.23		
Including fixed industry effects									
R Likelihood	-267.05			1511.43			-484.46		
Log Likelihood sales	-252.18			1423.77			-484.40		
Log Likelihood sales & industry	-245.95			1413.40			-477.35		
X2 sale & industry	42.21	0.00		196.06			14.22		
X2 industry	12.45	0.28		20.76			14.11		
Non performers fit	230	91.6%							
Performers fit	41	27.0%							
Total fit	271	67.2%							
R2 Adj.				0.69			-0.02		
F (16,135)				22.21			0.83	0.65	
BP het. Test				489.81			109.95		

* T statistic computed with robust estimation of standard error.

Summarizing, the general results of this exploration of R&D, ET and DT investment and intensity frequency distributions suggest strong evidence that a general pattern to describe them exists, although it does not come from a theoretical distribution. This pattern reveals at least three different groups of technology investment behavior and may be described as follows most business units do not engage in technological innovation activities; some do technological innovation activities, with medium investment and/or intensity; and very few invest disproportionately more than the rest of the business units within the category. In statistical terms, it is described by mode at zero investment or intensity level and high positive skewness. The mode is characterized by non-performers of technology investment and their population increases as business unit size class decreases and in technology user industries compared to technology producer industries. The high positive skewness is characterized by those firms concentrating most of technology investment within the category and their concentration of investment increases as business unit size class increases and in technology producer industries compared to technology user industries in U.K.. In Colombia, business units concentrating those levels of technology investment are rare and have been identified as the main difference between Colombia and U.K. Finally, combining size class and industry categories allows to group better investment behavior. Small and medium business units in any industry in Colombia and U.K. are not likely to invest in technology. However, high variability of behavior is still observed within large business units. Some large business units do not invest in technology. Moreover, in Colombia most of large business units do not invest in technology. Other large business units invest moderately. And finally, a few of them concentrate a major part of the investment in technology. This last group is larger in U.K. than in Colombia.

4. Why are large firms concentrating high levels of investment in technology rare in Colombia?

Several questions arise form these results. Why firms do not invest in technology, especially small and medium ones? If there is any advantage related to large size, why firms are not larger? Why large business units concentrating high level of R&D and ET investments are rare in Colombia? What explains the variability of technology investment within larger firms? Why do many of them not invest in technology? The first and the second questions have been explored by market structure and innovation literature[8] and industrial dynamics literature[9], respectively. The fourth and the fifth have been explored by the strategy[10], entrepreneurship[11], and technological opportunity literature[12].

This study is going to focus on explaining the third question. The results above have shown that it is possible to classify small and medium sized business units into an homogenous group: it is unlikely that any of them will invest in technology. Additionally, the tests identifying the source of the difference between Colombia and the U.K. in investment and intensity of R&D and ET suggested that the main difference between both countries is the investment executed by extremely large business units that only exist in U.K.. Thus, it is sensible to ask: why large Colombian business units concentrating high levels of investment in technology are rare? Or, put in a different way, why are Colombian business units smaller than those in the U.K.?

Before proceeding with the interpretation, it is important to illustrate the magnitude of the difference of business unit size between Colombia and the U.K.. The median and mean business unit size within every industry is by far higher in the U.K. than in Colombia, except for clothing industries (see table 6). For example, in foods and beverages industries, the median sales of a business unit in the U.K. was above 276.000 million US dollars, while in Colombia it is only 7% of this value. Within the seventeen industries studied, in five industries the mean size in the U.K. was ten times larger or more (food and beverages, coke and petroleum, machinery and equipment, electrical machinery, and transportation), and in fifteen it was three times larger or more. These differences in size are confirmed when measured by the median: most of the ratios suggest that firms are at least five time larger in U.K. than in Colombia, with the exception of electrical machinery where firms are four times larger in U.K. than in Colombia, and clothing where firms have almost similar size. Thus, it is clear that with the exception of firms in clothing industries, business units are larger in U.K. than in Colombia and the magnitude of the size difference varies by industry but in most industries a U.K. business unit is between five and ten times larger a Colombian one.

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[8] See Cohen (1995) for a review of this literature.
[9] See Jovanovic (1982), Baldwin (1995), and Sutton (1997) for important contributions on this literature.
[10] See Sutton (1991).
[11] See Casson (1990).
[12] See Nelson (1993), Mowery, et al (1999) and Klevorick, et al (1991).

Table 6
Mean and median business unit sales comparison ratio

SIC	Mean business unit sales Colombia/ Mean business unit sales U.K.	Median business unit sales Colombia/ Median business unit sales U.K.	Mean sales of no-exporter business unit sales Colombia/ Mean sales of exporter business unit Colombia	Median sales of no-exporter business unit sales Colombia/ Median sales of exporter business unit Colombia
	%	%	%	%
15	6.9	3.1	6.6	0.9
17	20.4	15.9	8.7	12.5
18	33.3	90.4	17.2	20.3
19	15.8	18.1	36.5	80.0
20	11.1	19.4	17.5	26.3
21	35.5	13.3	13.7	22.4
22	12.5	14.5	18.6	10.1
23	4.6	1.1	2.1	4.7
24	11.0	13.7	17.4	20.3
25	20.1	17.2	29.4	46.3
26	10.9	6.8	35.6	8.0
27	27.5	6.9	18.4	10.2
28	20.6	13.1	10.9	25.6
29	6.4	14.7	53.6	30.8
30	8.0	26.2	24.6	50.0
33	11.4	17.6	19.6	117.5
34	5.8	10.0	4.9	16.9

Source: DNP (1996) and Torbett (forthcoming)

It is important to note that the fact that business units in the U.K. are normally larger than the ones in Colombia is not the consequence of dualism, since only business units with more than 20 employees are included in the sample. It is not the extremely small, informal and unregulated firms that may explain that Colombian firms are smaller. It is simply because they operate at a lower scale while producing products that could potentially compete with those produced by the U.K. firms in many cases. Thus, it is clear that business units in Colombia are substantially smaller than the U.K. ones.

What determines the size of the firm? Theories of the firm based on transactions costs (Coase (1937) and Williamson (1979)), although illuminating in terms of the nature of the firm and the direction of integration, are not very precise in terms of suggesting how much bigger or smaller is a firm depending on transaction costs. Theories of the firm based on the principal-agent approach intend to explain the incentive scheme and the organizational form of the firm, but not the size of the firm (Alchian and Demsetz, 1972).

On the other hand, the very narrow and unsatisfactory description of what a firm is adopted by the production function approach, gives much more information about the size of the firm than the other two more recently developed approaches. In the production function approach, size is determined as the result of a profit maximization process that depends on demand (market size) and scale economies, given input prices. The higher the market size and scale economies, the higher the firm size tends to be (Panzar, 1989).

Let me concentrate first on the issues concerning market size. Is Colombia's market so small compared to that in the U.K.? The answer is yes. Simple and broad measures of market size are population, GNP, and GNP per capita. In 1996 the U.K. had 59 million inhabitants, the GNP was 1,152 billions of US dollars, and the GNP per capita was 19,200 US dollars. On the other hand, Colombia had 37 million inhabitants, the GNP was close to 7% of that in U.K., and GNP per capita was 11% of GNP per capita in U.K.[13] (World Bank, 1998). Additionally, the number of firms in the manufacturing sector with more than 20 employees in the U.K. was close to 45,000 while in Colombia was a tenth of that number. It is intriguing that the value of sales for Colombia's business units (between 6% and 20%), Colombia's market size (11%) or Colombia's total number of manufacturing business units (11%) is close to 10%. This is not to suggest that a clear rule exists but just to note that the order of magnitude of the difference between Colombia's economic variables and the U.K.'s ones is similar independently of the variable.

However it is possible to use international trade to gain access to larger markets. Can international markets offer Colombian business units the opportunity to grow larger? Can international markets offer Colombian business units the opportunity to use international level production inputs? Can international competitors in domestic markets lower the opportunities for survival of small national business units? In principle, positive answers may be offered to both questions, but the issues require some detailed discussion.

First, can exports offer the opportunities required by Colombian business units to grow larger and invest more frequently and heavily in R&D and ET activities? Several theoretical arguments have been developed by economists showing that firms that export can grow larger than firms that rely on domestic markets, particularly in small and low and medium income level countries (see Tybout, 2000). Additionally, evidence from Colombia's case is in agreement with these propositions: in all industries studied, except in machinery and equipment industries, the mean business unit sales of business units that do not export is less than a third of the mean of those that do export. In machinery and equipment industries the mean sales of non-exporter businesses is close to 50% of the mean sales of exporter business units. When measured by the median, the ratio suggests a similar pattern although it casts doubt on whether this pattern is also observed in leather and medical and optical instruments industries. Thus, there is some evidence suggesting that business units that export are larger than those that do not export.

Nevertheless, some other observations suggest doubts on the extent of validity and generality of the evidence reported above and the theoretical arguments they support. In order to understand this it is necessary first to recall Adam Smith's (1776) argument on the relation between market size, division of labor, sources of productivity growth and firm size. In Smith's view, the exclusively human propensity to trade, based on reason and speech, allows humans to trade, and by trading they engage in unintended co-operation through the division of labor. Since it is trade the factor that opens the possibility for a person to specialize as a brewer, a baker or a butcher, it is the level of trade, the size of the market, what determines the extent of the division of labor. Additionally, when analyzing the division of labor within a given production process, like the famous example of the pin factory, Smith identified three sources of productivity growth, consequence of the extent of the division of labor and market size. First, by focusing only in one task the worker can develop improved skills –learning economies-; second, the reduction of time lost between one task to another within a production process –similar to coordination economies-; and third, the invention of machines. Finally, as Rosemberg (1994) suggests, Charles Babbage identified a fourth source of productivity growth: a virtue of the division of labor is to unbundle labor. When division of labor does not exist, the manufacturer has to purchase the labor to do all the required tasks implicit in an integral process, and thus has to pay for the skills required for the most difficult task for all tasks. When division of labor breaks the production process into several distinct tasks, the manufacturer can purchase the exact labor it needs for each task.

[13] In 1996, the U.K. registered the fifth highest GNP in the world, while Colombia was ranked thirty seventh. Additionally, in the same year, the U.K.'s GNP per capita was ranked seventeenth and the Colombian fifty fourth.

The ideas presented above point out two key issues for our discussion. Firstly, the relation between the division of labor internal to a production process and productivity growth, and the size of the firm. The number and the qualification of the employees demanded by a firm are closely related to the extent of internal division of labor reached in a given production process. At the same time the number and qualification of employees demanded by a firm and the productivity gains achieved by them -following Smith's conceptualization- in addition to other inputs, determine the level of output and the size of a firm. Additionally, since the division of labor between productive processes is determined by national market size, thus the extent to which it is possible to carry up the division of labor within a production process is also dependent on national market size. Note that this is a more inter-linked view of the production function approach to determine firm size, where technology is endogenous to demand, up to a level where it is simply impossible to divide more the process. A dynamic interpretation of Smith´s argument made by Stigler (1951) on the relation between market size, the division of labor and firm size suggests that in industries that grow one may expect vertical disintegration while in industries that decline one may expect integration. This is because, as market size grows, increasing division of labor within the process creates more specialized processes that may be independent from each other (new business units or firms (or groups of them) that will position upstream along the productive chain), and larger and more specialized firms along the chain.

The second key issue is that the sources of productivity growth point to the importance of the network available in a country. This network is observed, for example, in the level of qualification and specialization of the labor supply, and in the availability of machinery producers that produce specifically designed machines and offer the maintenance and reparation services. Thus, the lower the market size, the lower the division of labor between production processes, the lower the network available for a given firm, and the lower the sources of productivity growth.

It should be noted the similarity of the arguments presented above with the national innovation systems literature. This literature emphasizes on the linkages between user and producer firms, private and public agents, and the importance of country income level, size, resource endowments, and institutional stability and defense public spending (Lundavall (1992) and Nelson (1993)). In addition, it should be also noted the similarity of the arguments described above with the literature on technological opportunity. In short, technological opportunity determines the productivity of investment in the creation of new technology. It is influenced by the access to the sources where this new technology might come from. These sources of technological opportunity for a firm have been identified as advancements in science, in technology in other industries, and feedback from own technology (Klevorick, et al, 1991). Thus, the relation between the network developed by the division of labor and the first two sources of technological opportunity is evident.

Smith's argument and the following developments here reported provide the framework to understand the extent to which the export-led firm growth argument is valid. Following the this framework, since Colombia´s market is substantially smaller than that in U.K., one would expect Colombia´s firms to be fewer, smaller, less specialized, and with less access to a dense network of suppliers and sources of productivity growth than firms at U.K.. Thus, to take advantage of the international markets and grow through exports, Colombian firms must overcome the limits of this environment increasing specialization and building their own network of suppliers of human capital, machinery, inputs, productivity growth, … , because they are not available in Colombia. Probably this network of suppliers is neither available in the U.K. because it is much more specialized there. Remember the huge differences in market size and its implications on the level of specialization. But even if the network was available at U.K., it is difficult to think how could Colombian firms use U.K.'s network and be more competitive than U.K. firms in order to export. This argument clearly oversimplifies the problem because international trade does not only takes place between Colombia and the U.K.: East Asia, Brazil, Chile, and Mexico, for example, may provide opportunities to build network and markets for exports. However the following observations suggest that some truth may lie on this oversimplified argument:

- A leading software company that has been growing in Colombia even though the harsh economic recession suffered in the last three years decided to go into exports. When visiting the possible clients in other countries, they reported the following experience: doubts about their capacity to offer a software solution to a particular problem were raised because they were not specialized only in producing software solutions to that kind of problem.

- Benjamin Franklin observed (reported in Stigler, 1951),

  "manufacturers, where they are in perfection, are carried by multiplicity of hands, each of which is expert only in his own part, no one of them a master of a whole; and if by any means spirited away to a foreign country, he is lost without his fellows. Then it is a matter of extreme difficulty to persuade a complete set of workmen, skilled in all parts of manufactory, to leave their country together and settle in a foreign land. ... . If by royal munificence, and an expense that the profits of the trade alone would not bear, a complete set of good and skilful hands are collected and carried over, they find so much of the system imperfect, ... , and the knot of hands so easily broken by death, dissatisfaction, and desertion, that they and their employers are discouraged altogether, and the project vanishes into smoke" (Stigler, 1951, pp. 140-1).

- A supplier of perforated tubes faced the need of a special machine to do some of the tasks of the production process. They could access the machine for 450,000 US dollars in the international markets, however it would imply strong limitations on flexibility to start and stop production. They decided that it was possible to build internally, with the help of a university engineering team, a machine that could comply with the requirements of the tasks needed, tailored to their specific needs, and that could start and stop production frequently. They built the machine for 75,000 US dollars. It was not a comparable machine, but it fulfilled the needs of a company that providing almost a third of domestic market demand was only producing 100 tons per year, compared with one in Brazil producing 3,000 tons per year. Similar examples have been frequently observed in studies about why firms do not import machinery in Latin America. The lack of machinery adapted to local conditions and of repair and maintenance services supplied by international providers limits Latin American firms to use imported machinery and equipment. Nevertheless, it is frequently the case a firm has no alternative but to import the machine because there are no national providers. In these cases there is evidence that it is difficult for national firms to use efficiently the new machinery. Additionally, frequently the import of a machine implies large financial efforts. Since smaller national markets may also generate smaller capital markets, the firms have to organize in order to overcome credit rationing. Obviously, the other face of these investments sometimes is the possibility to exploit market power though installed excess capacity. The organization of firms to prevent credit rationing and the possibility to exploit market power can explain the organization of economic groups where financial service providers are a required part of the group, like Santo Domingo, Ardilla Lulle and Sindicato Antioqueno in Colombia. Thus, integration does not come to exploit any type of economy but to guarantee access to capital in the face of low division of labor.

The first observation is a perfect example of the difficulties that firms have to go from a given pattern of division of labor to a more specialized one. It is illustrative of the difficulties of inserting into an environment where the supplier network is organized in a more specialized manner than in than in Colombia and thus it is dubious that a Colombian firm can effectively supply useful goods and services to another firm that country. The second and the third examples illustrate the difficulties of increasing specialization of production in a domestic setting, where access to human capital resources of various kinds, to machinery and to financial capital is restricted. In the three examples, it is evident the importance of national market size and its consequences on the division of labor and the possibility to use international trade, whether they be international demand or international inputs.

Additionally to the importance of differences in national market size, there is evidence that historical accidents may determine the location of industry and generate more or less ample regional markets and thus, higher or lower possibilities to exploit the advantages of the division of labor. In the case of Colombia, there is evidence that because of historical accidents and social and economic reinforcing mechanisms, the industry has located in the central part of the country and far away from the coasts and frontier borders, and has been orientated towards the internal market. Since manufacturing industry is mostly located in the center, Colombian business units have to incur in high transportation costs to use the international markets (Yemail, 2000). Therefore, Colombia's central region market limits the division of labor and firm size not only because of its size but also because of transportation costs. Moreover, the low quantity and quality of the infrastructure and the mountainous geography observed in Colombia intensify this effect. Further, Tybout (2000) suggests that geographical fragmentation in lower income countries may imply the existence small independent markets that maintain aggregate large populations of small firms that are limited by local demand. A final element that may limit the division of labor is the uncertainty about property rights, policies, and demand. It has been shown the importance of a stable and legitimate system of property rights to support the development of capitalism, and of stable macroeconomic environment to support investment in general and to intensify efficient resource allocation between industries (see Tybout (2000) for references). In the specific case of Colombia, these are important elements limiting the confidence on the working of the market, thus limiting the division of labor.

It is important, at this point of the discussion, to note that history, geography, poor infrastructure, uncertainty about property rights, and macroeconomic stability do not only imply limits to firm size but also protection for small regional market based firms that very likely do not engage in technology investment activities. Thus, answering the question asked above, "can international competitors in domestic markets lower the opportunities for survival of small national business units?" there is strong evidence suggesting that international trade has limitations. How strong these limitations are? It is difficult to assess this question and it is out of the scope of this article, however it can be said that, although the effects of Colombia's trade liberalization during the 1990's have translated into a de-industrialization of the country (although not all the de-industrialization may be a consequence of the trade liberalization) that has strongly affected small businesses, still some small firms survive based on domestic market specificity's.

In summary, although there is evidence that business units that export are larger than the ones that do not export in Colombia, we have identified and discussed some elements that may prevent firms to export and grow, thus maintaining low levels of engagement in technology investment activities. These elements are related to the systemic characteristics of the firm that may export and its network of suppliers. The firm has to increase its level of specialization in order to produce goods or services that fit into a more developed division of labor in other countries. Additionally, the firm has to "push" its network of suppliers into a deeper pattern of specialization that allows itself to increase specialization to export. The essence of these two types of difficulties the firm has to overcome to export lies in the difference in the "level" of division of labor in each nation, that is the consequence of domestic market size, following Smith's argument. Thus, the main determinant of firm size is national market size. However, it is difficult but possible for a firm to overcome the limitations imposed by national market size and start facing international markets, exporting and growing into large.

Having discussed the role of market size as determinant of firm size, we now turn to the role of scale economies. The question here is whether the possible gains in size provided by the existance of scale economies to a Colombian business unit are affected by the fact of working at lower production scales compared to U.K. business units. By definition, the answer is yes: the level of scale economies a business unit can exploit depends on the scale of production it runs. For example, it is frequently said that although automobile industry provides high level of scale economies, automobile providers in Colombia do not exploit them. Part of the explanation lies in the limitation imposed by national market size, as discussed above, and that implies low demand when compared to production possibilities for a business unit. Additionally, the level of automation is also lower than in business units in other countries. Thus, the effective economies of scale Colombian plants could exploit, even if they work at full capacity, are lower than those faced by business units in other countries with higher levels of automation and R&D intensity. Again, it could be asked whether it is possible to overcome the domestic market size limitations by articulating to international trade. Again, the answer is: possibly, but with great difficulties. The difficulties faced by business units and described above are also valid at this level. It is difficult for Colombian business units to export because they cannot offer competitive prices or new models. Competitive prices depend partly in exploitation of scale economies, economies not achieved by Colombian business units. New models originate in other countries like the U.S., Japan, Italy, France, Germany or Korea. But, also Brazil offers R&D capability to adapt Volkswagen models to tropical conditions, a capability not installed, if available, in Colombia. It is also difficult for Colombian business units to overcome the supplier network limitations, even if actually most parts of the car (including motor, transmission, gears, bulbs, doors, chassis, …) are imported and the main local manufacturing activity is assembling. Thus, the link between technology, in this case a particular characteristic of a technology, as scale economies are, and market size is evident again, as in Smith and Stigler's arguments. At last, one may add another piece of evidence: clothing industry. Clothing industry is not characterized by being extremely competitive in U.K. while it is a traditional export of Colombia. In this industry, where the presence of scale economies is not important, it is where the lower differences in business unit size are observed (see table 6).

Finally, the above discussion over the origin of international differences in business unit size and its important implications over the likelihood of observing investment in technology activities has pointed the importance of future research topics. Firstly, the relation between market size, technological opportunity -as a conceptualization useful for studying technological diffusion as well as technological innovation processes- and international trade. It is possible that through this research a more comprehensive explanation will allow to understand better the what are the difficulties of leap-frogging, what are the conditions required by a country to evolve into technological and industrial development, why industry effects are not important in explaining R&D and ET investment patterns in Colombia, why is it so difficult to promote population growth of small technology based firms in a context where few technology intensive large firms exist, capital markets are not deep enough to offer diversified financial services, and only few technological strategies may be explored. Secondly, and in order to approach successfully the study of this relation there is need to build a formal analytical tool that addresses the issue of market size, division of labor, specialization, industry integration and dis-integration and sources of productivity growth and technological change. Both of these future research topics are related to the emphasis required to be developed by economic theory on a systemic view of the processes of economic growth and technological development. It need not be national, it may be technological, or regional, and more probably a mix of the three.

5. Conclusions

Finally, some general conclusions are put forward in relation to three different topics. First, advancements and future research topics on the measurement of innovation are addressed. Second, empirical results and its theoretical implications are summarized. At last, some policy implications are discussed.

Innovation measurement

This study has used a more complete description of the rate of innovation per business unit than many other previous studies. These indicators have been made available by Oslo Manual type surveys. Additionally, since these surveys have been launched in many countries and more importantly in non-OECD countries where data limitations are more important, they provide a potential for international comparisons never available before. The results in this study suggest that it is possible to make fairly safe comparisons between Colombia and the U.K. using R&D and embodied technology investments. Additionally, it may also be robust to do comparisons between a partial calculation of total investment in innovation by adding up R&D and embodied technology investments, since they represent more than 65% of total investment in several countries. Thus, the information generated by Oslo manual type surveys although limited by a very basic description of the qualitative characteristics of innovation and the cultural differences in the understanding of certain concepts of innovation, is proving to have immense potential to address questions about international differences in technological development.

Future research topics within this area should be focused on understanding why design and engineering investment levels vary so much between countries. It is important to understand why this happens since design and engineering has been identified to be an extremely important source of innovation in high and fast growing middle-income countries. Additionally, when it is understood why these differences arise, it will be possible to compare design and engineering with other sources of innovation like disembodied technology. Moreover, further understanding of the cultural differences in the answers between countries, will permit to exploit many of the qualitative data not used in this study and available from Oslo type surveys. Especially important are the description of innovations and its related appropiability mechanisms, and the internal description of the firm, in order to control for qualitative differences between innovations and further understand technological opportunity created from feedback of technology. All these efforts should be performed within the convergence in question formats and sample design to allow full comparability between countries.

Empirical results

The empirical evidence presented in this study suggests that there is high variability in the technological investment behavior of firms. It was found that within Colombia and the U.K., and within any size and any industry, a major part of the population of business units are not engaged in technological investment, a smaller group invests with medium level of intensity, and a very small number of business units dominate technology investments. The pattern appears to be robust and is only subject to measurement problems related to the qualitative aspects of innovation and industry aggregation. This pattern is explained in part by the large number of small and medium sized business units in any industry in any country that do not invest in technology.

Unfortunately, it is not possible to explore with this data set why these firms do not invest in technology. However, the usual arguments related to the inability of small and medium sized firms to reach the threshold size that enables them to take full advantage of process innovations subject to technological opportunity and appropiability conditions and financial constraints it is a plausible explanation. Additionally, small and medium firms face important growth constraints. Moreover, it is shown in this study that firms are substantially smaller in Colombia than in the U.K.. It is argued that these differences arise as a consequence of the smaller market size of Colombia compared to the U.K. one. As market size increases, higher division of labor and specialization arise in the economy, and for a given product firms are larger and have access to more densely and articulated networks of suppliers. In terms of technological opportunity literature, they face higher technological opportunity to exploit advances of science and advances in technology in other industries. Market size limitations are important precisely because of their systemic nature. It is difficult for firms to increase specialization levels without also being supported by a network of suppliers that have also increased specialization. And it is difficult to start exporting without increasing specialization levels. Thus, although it is possible to use international trade to open more ample markets and overcome domestic market size limitations, it is a difficult and internally coordinated process to do it. At last, the role of history, institutional environment, and geography, for example, may reinforce the effect of domestic market size.

Finally, it was found that the importance of industry effects is large in the U.K.. However, although the importance of user-producer industry effects is clear, there are some user industries in which business units invest more frequently in internal development of technology through R&D rather than acquisition through the market mechanism, by way of ET. In Colombia, if any industry effects exists, they are obscured by aggregation problems. Nevertheless, it is more probable that the issue is related to the interaction of market size, specialization, development of competencies, technological opportunity and international trade, a theme that surely deserves future research. A related but different topic for future research is the need to go from interpretation to the identification of the actual mechanisms that promote the use of the networks available to firms, since different firms use in different ways and with different efficiency levels these networks. Research on developing formal analysis tools of these issues is important. Additionally, the empirical evidence suggests another set of important questions like why is there so much variance in the intensity of the ones engaged in technology investment.

Policy implications

The policy implications are important. Trade policy has implications on the level and pattern of specialization of an economy and thus on the size of the firm and its technology investment. The effects of trade policy are related to the country size, the effect over the linkages within productive chains, and incentives to concentration of economic power. Many strategic issues are key, like the important differences that economic integration and trade liberalization may have in terms of specialization and technological activity, like who is the optimal partner for economic integration, and so on. Employment policies orientated toward the promotion of small enterprises have important effects since small and medium sized firms have low probabilities of survival and investing in technology. Finally, the above results are ceteris paribus macroeconomic stability and low uncertainty. As it has been emphasized in many investment studies, macroeconomic stability is a necessary condition for investment growth, although not a sufficient condition as pointed above. Additionally, high institutional uncertainty due to violence is also an important factor affecting investment behavior by creating a bias towards short-term investments and even lower investment levels. The degree of importance of these two factors in Colombia cannot be explored within this context, and much less to argue that they explain the high level of non-performer firms, but note that this does not mean that the author do not believes they are central in explaining investment behavior in Colombia.

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Annex 1 General description of sample

Business unit population, surveyed and sample by size classes

		Colombia						U.K.					
		Population	CCIS	Sample	CCIS/Pop	Sample/Pop	Sample/CCIS	Population	CIS	Sample	CCIS/Pop	Sample/Pop	Sample/CCIS
20-50 employees	1	1,707	268	171	15.7	10.0	63.8						
50-200 employees	2	1,825	338	160	18.5	8.8	47.3						
More than 200 employees	3	776	225	103	29.0	13.3	45.8						
Total		4,308	831	434	19.3	10.1	52.2						

Note: the difference between the total business units and the total by size ranges is due to business units that did not report number of employees

Business unit population, surveyed and sample by industry

	Colombia							U.K.					
	SIC code	Population	CCIS	Sample	CCIS/Pop	Sample/Pop	Sample/CCIS	Population	CIS	Sample	CCIS/Pop	Sample/Pop	Sample/CCIS
Food and beverages	15	857	89	41	10.4	4.8	46.1						
Tobacco	16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
Textiles	17	342	45	24	13.2	7.0	53.3						
Clothing	18	530	37	18	7.0	3.4	48.6						
Leather	19	210	40	26	19.0	12.4	65.0						
Wood	20	233	41	23	17.6	9.9	56.1						
Paper	21	100	36	16	36.0	16.0	44.4						
Publishing	22	220	40	18	18.2	8.2	45.0						
coke and petroleum	23	28	10	6	35.7	21.4	60.0						
Chemicals	24	336	92	32	27.4	9.5	34.8						
Rubber and plastic	25	287	77	37	26.8	12.9	48.1						
other non metallic mineral products	26	267	76	42	28.5	15.7	55.3						
basic metals	27	88	40	28	45.5	31.8	70.0						
Fabricated metal products	28	326	60	28	18.4	8.6	46.7						
Machinery and equipment	29	234	64	37	27.4	15.8	57.8						
Electrical machinery	30*	144	48	25	33.3	17.4	52.1						
office machinery and computers	30	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
Electrical machinery	31	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
radio, television and communication	32	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
Medical/optical instruments	33	54	20	9	37.0	16.7	45.0						
Transport	34*	172	40	17	23.3	9.9	42.5						
Motor vehicles	34	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
Other transport	35	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.						
Other	50	102	30	18	29.4	17.6	60.0						
Total		4,530	885	445	19.5	9.8	50.3						

Annex 2. R&D, ET and DT intensity frequency distribution plots

Figure 1.
R&D, ET and DT intensity frequency plot by small business unit size class for Colombia and U.K.

Sources: CCIS (DNP, 1995) and RT (forthcoming)

Annex 3.Percentage of non-performing business units

	UK			Colombia		
	R&D	ET	DT	R&D	ET	DT
Small				91.9	81.4	88.2
Medium				76.3	64.1	76.9
Large				58.6	33.3	60.6
15				78.0	58.5	78.0
17				95.8	75.0	91.7
18				94.4	61.1	83.3
19				100.0	88.0	80.0
20				95.7	78.3	95.7
21				87.5	62.5	75.0
22				88.9	50.0	88.9
23				50.0	50.0	50.0
24				53.1	59.4	75.0
25				75.7	59.5	73.0
26				69.0	57.1	69.0
27				71.4	71.4	75.0
28				85.7	67.9	89.3
29				70.3	64.9	67.6
30				68.0	64.0	72.0
33				77.8	66.7	88.9
34				88.2	52.9	76.5
Total				78.6	64.3	77.9

Annex 4. Range of innovation intensities

	UK			Colombia			UK			Colombia		
	R&D	ET	DT	R&D	ET	DT	R&D I	ETI	DTI	R&D I	ETI	DTI
Small				169.8	505.3	2,266.5				9.6	10.6	5.3
Medium				170.5	3,368.3	13,259.8				5.2	23.6	5.0
Large				48,385.1	53,338.9	4,780,912.5				5.3	37.7	5.2
15				490.1	8,982.2	50,820.7				1.4	18.8	1.6
17				57.0	852.2	1,010.2				0.1	14.2	0.0
18				13.5	1,661.9	6,737.3				1.1	6.2	4.0
19				0.0	157.1	47,817.9				0.0	4.7	5.0
20				390.8	84.3	5,389.8				0.6	7.6	0.1
21				1,692.7	4,491.4	12,342.7				1.6	10.4	4.6
22				84.3	1,685.2	2,223.3				1.1	23.6	1.3
23				48,385.1	53,338.9	4,780,912.5				6.0	4.6	4.2
24				931.6	14,599.1	47,723.5				5.3	37.7	2.7
25				315.9	8,979.0	224,068.8				9.6	15.0	4.5
26				896.5	12,352.7	392,792.3				5.2	15.1	5.3
27				565.7	16,845.8	315,201.8				3.0	28.0	3.1
28				73.3	2,808.8	4,530.3				4.3	10.0	0.4
29				243.0	5,611.8	13,481.3				3.2	9.9	2.6
30				226.0	562.2	20,380.3				3.0	5.0	5.0
33				169.3	3,059.6	3,386.3				2.6	5.2	0.5
34				170.2	4,498.1	18,026.4				0.9	10.5	3.0
Total				48,385.1	53,338.9	4,780,912.5				9.6	37.7	5.3

Annex 5. Skewness of innovation intensities

	UK			Colombia			UK			Colombia		
	R&D	ET	DT	R&D	ET	DT	R&DI	ETI	DTI	R&DI	ETI	DTI
Small				3.9	3.4	5.2				6.5	3.4	6.1
Medium				4.0	3.7	8.4				3.2	2.7	4.1
Large				4.2	4.8	7.1				4.4	3.1	3.5
15				3.7	4.3	6.2				4.7	2.5	3.9
17				1.7	0.9	4.2				4.9	3.3	3.8
18				3.1	1.4	.				4.2	2.0	4.0
19				1.4	2.2	3.7				.	2.8	2.7
20				4.7	3.5	3.9				4.8	2.4	4.8
21				3.1	1.5	2.9				3.1	2.6	3.9
22				3.1	3.5	1.7				4.0	3.3	3.6
23				2.4	3.0	3.7				1.2	2.0	2.3
24				4.3	5.5	6.0				2.6	3.6	4.5
25				2.5	3.1	4.7				5.3	1.8	5.1
26				3.6	1.4	6.0				3.1	1.7	3.2
27				2.1	4.2	4.4				3.6	3.1	3.3
28				5.2	2.7	2.2				5.0	1.7	4.3
29				3.7	4.6	6.1				2.3	2.0	3.0
30				2.5	3.1	7.9				3.2	1.9	3.2
33				2.0	2.5	4.5				2.9	1.9	3.0
34				5.8	4.3	7.4				2.9	3.1	2.9
Total				4.3	4.0	8.8				5.4	4.1	4.5

Annex 6. Kolmogorov-Smirnov One sample test

Normal distribution

		R&D	ET	R&DI	ETI
Aggregate	Kolmogorov-Smirnov	9.83	8.89	8.31	6.94
	Asymp.	0.00	0.00	0.00	0.00
Small	Kolmogorov-Smirnov	20.21	18.90	17.32	15.52
	Asymp.	0.00	0.00	0.00	0.00
Medium	Kolmogorov-Smirnov	40.89	28.04	36.64	22.96
	Asymp.	0.00	0.00	0.00	0.00
Large	Kolmogorov-Smirnov	6.19	5.46	6.31	5.73
	Asymp.	0.00	0.00	0.00	0.00
15	Kolmogorov-Smirnov	11.74	11.44	11.70	10.32
	Asymp.	0.00	0.00	0.00	0.00
17	Kolmogorov-Smirnov	42.04	25.84	41.80	24.52
	Asymp.	0.00	0.00	0.00	0.00
18	Kolmogorov-Smirnov	5.01	5.05	5.16	4.24
	Asymp.	0.00	0.00	0.00	0.00
19	Kolmogorov-Smirnov	9.68	10.81	9.75	8.54
	Asymp.	0.00	0.00	0.00	0.00
20	Kolmogorov-Smirnov	20.26	15.84	20.10	13.84
	Asymp.	0.00	0.00	0.00	0.00
21	Kolmogorov-Smirnov	4.58	3.62	3.46	2.83
	Asymp.	0.00	0.00	0.00	0.00
22	Kolmogorov-Smirnov	9.56	7.87	7.54	6.80
	Asymp.	0.00	0.00	0.00	0.00
23	Kolmogorov-Smirnov	13.01	6.97	9.97	5.13
	Asymp.	0.00	0.00	0.00	0.00
24	Kolmogorov-Smirnov	2.59	2.66	2.60	2.09
	Asymp.	0.00	0.00	0.00	0.00
25	Kolmogorov-Smirnov	5.29	4.99	5.09	4.38
	Asymp.	0.00	0.00	0.00	0.00
26	Kolmogorov-Smirnov	11.48	7.56	11.14	6.52
	Asymp.	0.00	0.00	0.00	0.00
27	Kolmogorov-Smirnov	2.64	2.08	2.64	2.01
	Asymp.	0.00	0.00	0.00	0.00
28	Kolmogorov-Smirnov	4.70	3.67	4.70	3.81
	Asymp.	0.00	0.00	0.00	0.00
29	Kolmogorov-Smirnov		7.84		
	Asymp.		0.00		
30	Kolmogorov-Smirnov	2.28	1.48	2.28	1.40
	Asymp.	0.00	0.03	0.00	0.04
33	Kolmogorov-Smirnov	4.01	3.08	4.01	2.59
	Asymp.	0.00	0.00	0.00	0.00
34	Kolmogorov-Smirnov		4.52		
	Asymp.		0.00		

Uniform distribution

		R&D	ET	R&DI	ETI
Aggregate	Kolmogorov-Smirnov		2.59		
	Asymp.		0.00		
Small	Kolmogorov-Smirnov		4.40		
	Asymp.		0.00		
Medium	Kolmogorov-Smirnov		13.18		
	Asymp.		0.00		
Large	Kolmogorov-Smirnov	2.59	2.12	2.59	2.18
	Asymp.	0.00	0.00	0.00	0.00
15	Kolmogorov-Smirnov	4.59	3.75	4.59	3.86
	Asymp.	0.00	0.00	0.00	0.00
17	Kolmogorov-Smirnov		8.64		
	Asymp.		0.00		
18	Kolmogorov-Smirnov	1.93	1.81	2.03	1.26
	Asymp.	0.00	0.00	0.08	0.00
19	Kolmogorov-Smirnov	3.50	3.50	3.50	2.61
	Asymp.	0.00	0.00	0.00	0.00
20	Kolmogorov-Smirnov	10.41	5.44	10.26	4.60
	Asymp.	0.00	0.00	0.00	0.00
21	Kolmogorov-Smirnov	2.19	1.63	2.12	1.32
	Asymp.	0.01	0.00	0.06	0.00
22	Kolmogorov-Smirnov	3.95	3.38	3.77	2.89
	Asymp.	0.00	0.00	0.00	0.00
23	Kolmogorov-Smirnov	11.98	4.12	11.64	3.57
	Asymp.	0.00	0.00	0.00	0.00
24	Kolmogorov-Smirnov	1.20	1.20	0.92	0.79
	Asymp.	0.11	0.37	0.57	0.00
25	Kolmogorov-Smirnov	2.04	2.04	1.51	1.45
	Asymp.	0.00	0.00	0.02	0.03
26	Kolmogorov-Smirnov	2.88	2.88	2.17	2.05
	Asymp.	0.00	0.00	0.00	0.00
27	Kolmogorov-Smirnov	2.02	2.28	1.96	2.05
	Asymp.	0.00	0.00	0.00	0.00
28	Kolmogorov-Smirnov	4.27	4.98	3.96	4.53
	Asymp.	0.00	0.00	0.00	0.00
29	Kolmogorov-Smirnov	5.31	6.73	5.44	6.54
	Asymp.	0.00	0.00	0.00	0.00
30	Kolmogorov-Smirnov	2.66	2.37	2.41	1.92
	Asymp.	0.00	0.00	0.00	0.00
33	Kolmogorov-Smirnov	5.09	4.88	5.09	3.62
	Asymp.	0.00	0.00	0.00	0.00
34	Kolmogorov-Smirnov	10.44	7.11	10.22	6.06
	Asymp.	0.00	0.00	0.00	0.00

Exponential distribution

		R&D	ET	R&DI	ETI
Aggregate	Kolmogorov-Smirnov	2.48	2.96	2.37	1.96
	Asymp.	0.00	0.00	0.00	0.00
Small	Kolmogorov-Smirnov	5.23	5.69	4.54	3.82
	Asymp.	0.00	0.00	0.00	0.00
Medium	Kolmogorov-Smirnov	8.89	8.11	8.41	6.02
	Asymp.	0.00	0.00	0.00	0.00
Large	Kolmogorov-Smirnov	2.02	2.47	1.90	2.09
	Asymp.	0.00	0.00	0.00	0.00
15	Kolmogorov-Smirnov	3.88	4.55	4.05	3.94
	Asymp.	0.00	0.00	0.00	0.00
17	Kolmogorov-Smirnov	7.55	8.50	7.68	7.62
	Asymp.	0.00	0.00	0.00	0.00
18	Kolmogorov-Smirnov	2.52	2.15	2.42	2.04
	Asymp.	0.00	0.00	0.00	0.00
19	Kolmogorov-Smirnov	4.54	4.23	4.54	3.59
	Asymp.	0.00	0.00	0.00	0.00
20	Kolmogorov-Smirnov	12.30	7.36	12.78	6.78
	Asymp.	0.00	0.00	0.00	0.00
21	Kolmogorov-Smirnov	2.21	2.51	2.32	2.19
	Asymp.	0.00	0.00	0.00	0.00
22	Kolmogorov-Smirnov	4.91	5.21	4.34	4.02
	Asymp.	0.00	0.00	0.00	0.00
23	Kolmogorov-Smirnov	8.98	8.29	8.12	6.98
	Asymp.	0.00	0.00	0.00	0.00
24	Kolmogorov-Smirnov	2.05	2.07	1.89	1.69
	Asymp.	0.00	0.00	0.00	0.01
25	Kolmogorov-Smirnov	4.15	4.00	3.80	3.29
	Asymp.	0.00	0.00	0.00	0.00
26	Kolmogorov-Smirnov	7.17	6.52	6.81	5.84
	Asymp.	0.00	0.00	0.00	0.00
27	Kolmogorov-Smirnov	1.30	1.33	1.27	1.15
	Asymp.	0.07	0.06	0.08	0.14
28	Kolmogorov-Smirnov	2.33	2.45	2.33	2.07
	Asymp.	0.00	0.00	0.00	0.00
29	Kolmogorov-Smirnov	5.28	4.30	5.40	3.79
	Asymp.	0.00	0.00	0.00	0.00
30	Kolmogorov-Smirnov	2.05	1.85	2.13	1.30
	Asymp.	0.00	0.00	0.00	0.07
33	Kolmogorov-Smirnov	3.77	3.52	3.64	2.80
	Asymp.	0.00	0.00	0.00	0.00
34	Kolmogorov-Smirnov	11.24	4.79	11.01	3.75
	Asymp.	0.00	0.00	0.00	0.00

Annex 7. Two independent sample Kolmogorov-Smirnov test

	Description	KS<1		0<KS<1		KS>0		TOTAL	
		Chi-square	Significance	Chi-square	Significance	Chi-square	Significance	Chi-square	Significance
RD	Aggregate	1.400	0.025	3.500	0.000	2.200	0.000	7.400	0.000
	Small	1.200	0.086	1.200	0.084	2.200	0.000	3.700	0.000
	Medium	1.300	0.420	2.900	0.000	1.200	0.079	4.200	0.000
	Large	0.600	0.816	3.100	0.000	0.200	1.000	4.300	0.000
	15	0.400	0.999	1.300	0.066	1.200	0.165	2.800	0.000
	17							2.200	0.000
	18							0.600	0.869
	19							1.500	0.023
	20							0.900	0.277
	21							1.800	0.003
	22							0.600	0.801
	23							0.600	0.883
	24	1.000	0.215	2.000	0.001	0.600	0.882	2.200	0.000
	25	1.000	0.236	1.100	0.173	1.200	0.099	2.300	0.000
	26	0.700	0.699	1.600	0.009	0.300	1.000	1.800	0.003
	27	0.500	0.967	1.200	0.086	0.150	1.000	1.200	0.088
	28							1.700	0.006
	29	1.000	0.267	2.100	0.000	0.500	0.899	2.800	0.000
	30							2.700	0.000
	33							1.600	0.012
	34							2.100	0.000
ET	Aggregate	1.200	0.092	2.200	0.000	0.600	0.769	4.100	0.000
	Small	1.400	0.038	2.500	0.000	0.700	0.696	2.600	0.000
	Medium	0.800	0.540	2.100	0.000	0.200	1.000	2.400	0.000
	Large	0.900	0.330	1.100	0.209	0.400	1.000	1.100	0.207
	15	0.800	0.510	1.100	0.204	0.300	1.000	1.800	0.003
	17							1.600	0.011
	18							0.400	0.999
	19							0.610	0.842
	20							1.100	0.160
	21							1.200	0.199
	22	0.900	0.700	1.100	0.160	0.300	1.000	0.900	0.380
	23							0.300	1.000
	24	0.500	0.950	1.000	0.270	0.500	0.950	1.000	0.292
	25	0.400	0.990	0.800	0.550	0.200	0.990	1.400	0.045
	26	1.100	0.170	1.500	0.018	0.600	0.840	1.100	0.130
	27							1.500	0.020
	28	0.800	0.440	0.800	0.440	0.300	1.000	1.490	0.024
	29	0.700	0.770	1.300	0.062	0.300	1.000	1.100	0.164
	30	1.200	0.120	1.300	0.043	0.500	0.950	1.800	0.002
	33			0.500	0.950	0.610	0.850	0.700	0.750
	34	0.600	0.902	1.300	0.058	0.700	0.780	1.000	0.281

	Description	KS<1		0<KS<1		KS>0		TOTAL	
		Chi-square	Significance	Chi-square	Significance	Chi-square	Significance	Chi-square	Significance
RDI	Aggregate	4.600	0.000	1.700	0.004	1.900	0.001	7.050	0.000
	Small	1.400	0.031	0.700	0.757	0.800	0.577	3.700	
	Medium	2.800	0.000	1.400	0.045	0.800	0.601	3.700	
	Large	2.200	0.000	1.200	0.121	2.100	0.000	3.600	
	15	2.700	0.000	1.200	0.095	1.200	0.131	2.700	
	17							2.200	
	18							0.600	0.869
	19							1.500	0.023
	20							1.000	0.277
	21							1.800	0.003
	22							0.500	0.935
	23							0.600	0.883
	24	1.300	0.127	1.700	0.004	1.700	0.007	2.300	
	25	2.300	0.000	0.900	0.295	0.600	0.831	2.300	
	26	1.400	0.039	0.900	0.338	0.800	0.501	1.500	0.014
	27	0.800	0.518	0.800	0.454	0.800	0.531	1.100	0.222
	28							1.600	0.015
	29	2.200	0.000	0.400	0.995	1.600	0.014	2.200	
	30	1.010	0.252	1.100	0.145	1.600	0.010	2.400	
	33							1.700	0.006
	34							1.900	0.001
ETI	Aggregate	3.400	0.000	0.900	0.360	2.300	0.000	3.500	0.000
	Small	0.900	0.406	0.500	0.955	0.900	0.356	2.000	0.000
	Medium	1.300	0.046	0.700	0.689	1.300	0.052	1.700	0.005
	Large	1.200	0.124	1.000	0.229	2.100	0.000	1.600	0.012
	15	1.400	0.031	0.400	0.319	1.200	0.128	1.400	0.034
	17							1.600	0.008
	18							0.500	0.878
	19							0.500	0.966
	20							1.100	0.169
	21							0.900	0.424
	22	0.160	1.000			0.800	0.498	0.700	0.705
	23							0.500	0.936
	24	1.500	0.017	1.100	0.184	1.500	0.016	0.900	0.369
	25	0.980	0.290			1.200	0.119	1.100	0.193
	26	0.270	1.000	0.500	0.925	0.900	0.373	0.500	0.914
	27							1.400	0.030
	28	0.770	0.590	0.600	0.774	1.000	0.269	1.200	0.120
	29	0.800	0.596	0.600	0.877	0.800	0.610	0.500	0.936
	30	0.500	0.957	0.700	0.730	0.700	0.710	1.300	0.066
	33	0.920	1.000			0.700	0.722	0.500	0.975
	34	0.410	0.989	0.900	0.405	0.460	0.982	0.370	0.999