Methodology Design for Massively Structure Investment Projects in Research & Development (R&D) to Close the Productivity Gap

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ABSTRACT: Colombia needs a productive transformation. It has been proved that the operational way to do it is by investing in Research and Development (R&D) projects at the firm level. Young professionals with a focused training may be converted in the qualified human capital to do such job, working hand by hand with consulting and research groups. This methodology design is proposed as a possible solution for the productivity gap problem in the country by employing young professionals as the necessary human capital capable of transforming positively the productive system, with the support of public and private institutions.

1 INTRODUCTION

This applied research work aims to explore the endogenous nature of the low investment on Research and Development (R&D) in Colombia from a different perspective — not an economist or econometric one — but through the systems dynamics and, in particular, through operational thinking.

Rather than an econometric model, the R&D is a function of complex variables such as highly skilled human capital, physical capital, the size of enterprises, the mental map of employers, structured projects, inherent times and delays, government incentives, risk and profitability.

Part of the low productivity in countries, especially in Latin America, is due to low investment in R&D (Crespi, Fernández-Arias, & Stein, 2014). There is a huge productivity gap between Latin American countries and the United States; which ends up affecting the lives of millions of people in regard of lower sophisticated jobs and longer working hours (Pages, 2010). A productive transformation is needed and can be pursued through investment in R&D.

Therefore, the productive transformation of the Colombian business sector should be seen as a great collective effort to incorporate technical progress in sustainable long term production processes from all firms – large companies and SMEs – by structuring, funding and executing investment projects in R&D focused on closing the productivity gap at the firm level, reaching international standards and moving towards higher technological sophistication.

This paper proposes a methodology whose theoretical foundation comes from systems thinking and develops throughout the operational thinking, in order to answer the research question posed: how to close the productivity gap in the manufacturing industry and agribusiness in Colombia?

2 THEORETICAL FRAMEWORK

R&D Investment in Colombia is not just a statistic. It is not product of highly correlated variables. It is possible to make a sophisticated econometric model based on data from the Colombian Science and Technology Observatory (OCyT, 2013) and effectively find that the growth rate of investment in R&D is strongly correlated with variables as the budget from the Science, Technology and Innovation Administrative Department (Colciencias), the growth rate of GDP or the profit growth rate of large companies. Consequently, there could be possible to do some practical inferences to justify some policy measures: for example, a significant budget increase to Colciencias or assign to "Science and Technology" 10% of royalties (Ministerio de Educación, 2012).

However, in reality, things do not work that way. Investment in R&D in a given year – assuming well calculated – should correspond to the sum of thousands of investment projects actually executed by thousands of traders who took thousands of different decisions aimed at investing capital resources to a wide range of activities – generically packaged and labeled as "Science and Technology" – hoping to recover the investment by far and assuming different levels of risk.

Clearly, trying to discover, by analyzing data, a mysterious law hidden in the time series that governs the behavior of the variable in the data for R&D is a lack-of-scientific reasoning, sheltered by a mathematical garb apparently objective and accurate.

2.1 Fundamentals of Systems Dynamics

A school of modern thought has come to very similar conclusions and has structured them in such way that has been gaining more followers in the most advanced scientific and technological research centers on the world, such as the Massachusetts Institute of Technology (MIT).

This is System Dynamics and specifically Operational Thinking; originally proposed in 1993 by Barry Richmond (Richmond, 1993). System Dynamics "is the use of informal mental maps and formal simulation computer-based models to discover and understand the endogenous sources of systems behaviors" (Richardson, 2011). Specifically, Operational Thinking is a skill that can be learned and developed from System Dynamics, and is part of a set of other skills such as dynamic thinking, closed-loop thinking, generic thinking, structural thinking, continuous thinking and scientific thinking (Morecroft, 2007).

2.2 Operational Thinking

This research has been consumed from the perspective of Operational Thinking. This skill allows the performer to see how the world functions and not how it should works based on theories.

A classic example to illustrate the contrast between operational and non-operational thinking that Richmond uses is: an economic research article had published the results obtained by a renowned economist based in a sophisticated econometric model to predict milk production in USA. The model incorporated lots of macroeconomic variables connected together by a complex system of equations. However, nowhere appeared cows.

It is not very difficult to find out that, in the process of milk production, cows are essential. The first thing a researcher trained in operational thinking would have done is to focus precisely on cows: the loops associated with farming and farmers' decisions, the productivity of each cow, the amount of farmers, their aggregate productivity, etc.

Operational Thinking provides a solid framework for the analysis of a complex problem such as the performance of investment in R&D in Colombia. It is possible to set the limits of the system, analyze the decision-making process of employers, detect driven or hindered feedback loops, understand the processes of structuring, financing and executing investment projects, analyze the role played by government incentives and interact with the capital market.

As for modelling milk production, cows are essential, to model investment in R&D, Colombia needs projects and managers capable of structure, fund and execute them.

2.3 Industrial Engineering: tackling the problem

"Economist, as social scientists, intend to build *theories* of socio-economic systems, usually by means of gathering and analyzing *data*. Engineers, on the other hand, intend to produce designs and solve problems, frequently by mean of *models* that are built in *operational* terms. This difference means a very different way of thinking, two different epistemologies" (Olaya, 2012).

Consequently, Industrial Engineering (Institute of Industrial Engineers, 2014) must take an active role in finding a business response (at the firm level) to the problem of low productivity (macro and micro) applying advanced techniques such as systems dynamic modelling and strategic modelling based on understanding business dynamics (Sterman, 2000).

In this vein, the problem is addressed by identifying the main bottleneck that prevents the growth of investment in R&D in Colombia: There is not a massive supply of investment opportunities in R&D because structured projects are not viable and attractive to Colombian firms. And no investment projects are structured in R&D because companies do not have access to highly qualified human capital that is required in the phases of structuring, financing and executing.

3 COLOMBIA: DIAGNOSIS

The symptoms of Dutch disease are already present in Colombia: a premature deindustrialization, low level of exports with contents of medium and high technology, and conversely, the increasing growth of imports of machinery and equipment with high added value. Thanks to the extraordinary flow of foreign capital, the country has become a net exporter of mining-commodities with low added value and high risk due to price fluctuations beyond the control of the Colombian authorities (El Heraldo, 2014). 59.9% of exports during 2014 in Colombia were from the mining-sector (DANE, 2014) and the end of this bonanza looms (Portafolio, 2013).

3.1 Competitiveness

Colombia was ranked 51 among 59 countries in global competitiveness ranking of IMD in 2014 where the United States (1), Switzerland (2) and Singapore (3) occupied the top positions (IMD WCY, 2014). Furthermore, Colombia was ranked 69 (among 148 countries) in the World Economic Forum Global Competitiveness Index (World Economic Forum, 2013), which defines competitiveness as "the set of institutions, policies, and factors that determines the level of *productivity* of a country."

3.2 Productivity

The efficiency of a productive process can be defined by the ratio between the value added from a good or service production system and the resources used to generate them (Carro Paz & González Gómez, 2012). As an example, an employee is more productive than another when at the same time (resource) does more things (production) (Laborde & Veiga, 2011). The productivity level determines both the level of prosperity that can be reached by a country, and the investment return rates in the economy (World Economic Forum, 2013).

The Cobb-Douglas equation can be expressed as follows (Ros, 2014):

$$Y_t = L_t^{\alpha} * K_t^{1-\alpha} * A_t$$

Where α corresponds to the product elasticity of labor (L), i.e., how intensive is an economy in this productive factor (value between 0 and 1). Therefore, (1-α) represents the intensity of the economy on the other factor of production: capital (K). The growth rate of product Y can be decomposed into three factors: capital productivity (K), labor productivity (L) and total factor productivity (A or TFP). Each of these terms are related in the following equation (Eslava & Meléndez, 2009):

$$\frac{\Delta Y}{Y} \approx \alpha \frac{\Delta K}{K} + (1-\alpha)\frac{\Delta L}{L} + \frac{\Delta A}{A}$$

"One of the standard ways of measuring gains in efficiency is to calculate increases in total factor productivity (TFP), i.e., the efficiency with which one economy transforms its accumulated production factors into production" (Pagés, 2010). The TFP then functions as a measure of the synergies generated by the combination of productive factors (capital and labor), by incorporating applied knowledge and technical progress in the production process.

Let productivity then be defined as the efficiency of use of productive factors towards the production's value added from any company. It is possible to measure the productivity of a company through its productive factors and, in this sense, the definition adopted is aligned with definitions previously raised.

3.3 Productivity Gap

The depth diagnosis of the productivity problems in Latin America conducted by researchers from the Interamerican Development Bank (IDB) (Pagés, 2010) (Crespi, Fernández-Arias, & Stein, 2014) leads directly to the concept of productivity gap.

As there are different productivities, there are different gaps with respect to each one: capital productivity gap, labor productivity gap and total factor productivity (TFP) gap. They are expressed as a relative difference between productivity levels of countries, companies or individuals.

Overall, the total labor productivity of Colombia related to US productivity is accounted for approximately 20%. "This means that five workers in Colombia are required to achieve the same level of product that achieves an American worker in one hour" (Consejo Privado de Competitividad, 2007). This trend has continued through the years; in the last 50 years, labor productivity has not exceeded 30% (Mitchell, 2010). Similarly, a large proportion of the population is employed in the informal sector and on average this sector has the lowest productivity of the economy influencing it drastically and negatively (Pagés, 2010).

Low productivity has implications on the Colombians life quality as well as the state's finances via lost taxes and cost overruns from labor informality and throughout not collected contributions to health and pensions (Pagés, 2010).

Additionally, developed economies report fewer business hours, because this go hand in hand with quality of life of workers and their productivity. Norway works 27 hours a week, France 35 and the Netherlands 36. In Latin America, Chile is working on average 38 hours a week, 40 hours Ecuador and Colombia approximately 53 hours. "The global trend in the hours a person must labor a year demarcates that each time the days are reduced, as is shown that longer hours means lower productivity" (Ruiz Granados, 2014) (Translated by Author).

Additionally, the productivity gap is the main obstacle to fully exploit the opportunities offered by trade liberalization and free trade (see 3.4.2 Global Value Chains) and therefore should be the strategic focus of policies for productive development (Pagés, 2010). To solve this problem, the IDB proposes that the solution to low productivity is carried out inherently through investment in R&D focused on a Productive Transformation (Crespi, Fernández-Arias, & Stein, 2014).

3.4 Productive Transformation

Increasing productivity means finding better ways to use more physical and human capital available in the region (Pagés, 2010). In Colombia, a sustainable way out is to adapt the production system to the new realities of deep integration into the global economy through the Global Value Chains. This collective effort is called Productive Transformation. This concept has been developed among others by economist Ricardo Hausmann (Hidalgo, Klinger, Barabási, & Hausmann, 2007) and involves determining which products - within the universe of products in the global economy, or "Space Product" - should prioritize one country, depending on its current and potential productive capacity (Hausmann & Klinger, 2006). This requires a complex coordination of efforts between the public sector and the private sector along with a relatively high investment.

To measure the productive transformation is possible to use the TFP. In terms of one firm, it can be understood that the growth in revenue is dependent on investments (or changes) in capital and investment in human talent, among other factors. This way, it is possible to keep track and control on how effective is being productive transformation both micro level and macro level.

There is the case study of Continental Europe - Austria, Belgium, France, Germany, Luxembourg and the Netherlands - in the late 90's and 2000's on an actual productive transformation. Since 1970 and even before, this Europe conducted a rapid economic transformation in which went from 73% in labor productivity relative to the United States to even surpass the States in 1989 until 2008. Given the global development conditions from that time, Continental Europe took almost 20 years (1970-1990) to close the productivity gap by 27 percentage points (Mischke, Regout, & Roxburgh, 2010) and therefore gives a cursory glance about what Latin America would be facing.

3.4.1 Product Space

Countries move through space product developing goods close to those they currently produce. Most countries can achieve its strategic focus only passing empirically through infrequent distances, which may help explain why poor countries have problems developing more competitive exports and fail to converge to the income levels of rich countries (Hidalgo, Klinger, Barabási, & Hausmann, 2007).

"In the space of product, a product can be thought of as a tree and the set of all products as a forest. A country comprises a collection of firms or, for example, monkeys living in different trees and exploit these products. Similarly, the productive transformation process then involves moving from a poor part of the forest where trees have limited fruits, to the best parts of the forest. This means that the monkeys would have to jump distances, which means restructuring the capital (human, physical and institutional) towards goods that are different from those that are currently under production. The traditional growth theory assumes that there is always a tree to reach; and therefore, the forest structure is irrelevant. However, if this forest is heterogeneous, with some dense and more desert areas, and whether monkeys can jump only limited distances, then the monkeys could be limited to moving in the forest. If this is the case, the structure of this space and orientation of a country to itself become relevant in its development" (Hausmann & Klinger, 2006).

Another important aspect is the sophistication of the product and its representation in the product space. The more a product is closer to the center of a sector conglomerate the more it will be closer to higher levels of technological sophistication. There are companies, industries or countries at the periphery and thus have access to less sophisticated products (Hausmann & Klinger, 2006). In these cases it is highlighted a cheap workforce, an elementary supply chain and therefore easy-to-replicate products in poor or low-industrial-development countries.

In Colombia, for example, in 2013 the textile and clothing industry were drastically affected by smuggling, laundering, massive imports and the cheap dollar (Semana, 2013). Part of the explanation of contraband product entering the country comes from the fact that about 1 million people working in the sector (about half as informal) labor in a relatively low level of sophistication with an approximate salary of $284 CHF. However, the same activity (low level of sophistication) can be performed in Peru $256, in Mexico for $130, in China for $122, Indonesia for $89 and Pakistan for $71, to give some examples.

That is why the productive transformation process is aligned with product space and companies' ability to "jump" across the product space. It is at this point where productive transformation, closing the gap in productivity and investment in R&D are connected. The more innovation and value added a product contains, the higher the productivity needed to produce it in terms of labor and capital. This process also involves a process of assisted dip into global value chains.

3.4.2 Global Value Chains

The Global Value Chains (GVC) are value chains generated through the interaction between different countries to put a product on the global market. GVC in developing countries can play an important role in growth and economic development. The added value generated by trade in developing countries "contributes, on average, about 28% of GDP, compared with 18% for developed countries". At the same time, "economies with increasing participation in GVCs have growth in GDP per capita of about 2 percentage points above average" (Ferrando, 2013).

The fact of transforming the productivity of a company and sophisticate its products involves a restructuration in its value chain and therefore a need to open up its market to the global context. This is how it happens to produce, for example, "plastic toys" such as balls or toys for children (low in sophistication and limited to the local demand) to produce "plastic toys" such as computers or cell

phones (high in sophistication and international demand). The development of sophisticated products also involves a system of international suppliers specialized in raw material for certain products and innovation.

3.4.3 Innovation

From Griliches (1979) and Smith (2006) has been possible to provide a relatively comprehensive picture about the process of innovation inside a company. Like the production of goods, the production of ideas can be explained by a function of knowledge production (Griliches, 1979). In this case innovation is the result of the company's investments in R&D and the accumulation of previously existing knowledge; in addition to investments in human capital, training, equipment, and software licensing, among others. Among the approaches to the results of innovation include: productivity measures, the number of patents and other intellectual property rights, scientific publications and innovations figures compiled from surveys of innovation applied directly to companies (Smith, 2006).

For example, an input of one nation's innovation capacities would be R&D as a percentage of its GDP. In terms of expenditure on R&D, Latin America and the Caribbean can demonstrate a significantly lower investment respect to developed countries. In addition, countries with the best results in the world are those that have managed to converge with other developed countries over the last 20 to 30 years: Israel (4.3%), Finland (3.9%) and Korea South (3.7%). Finally, on average, R&D in developed countries is funded mostly by the private sector (60%) while the proportion in Latin America is lower (35%) (Crespi, Fernández-Arias, & Stein, 2014).

Another way of measuring innovation in an economy is through patents per million inhabitants. In this sense, Costa Rica date 40 patents per million people while Bolivia and Paraguay register a value of 0.7. Neighboring countries such as Colombia, Ecuador and Venezuela recorded data of 3.4, 3.5 and 8 respectively (Arias & Martínez Anaya, 2014).

Investment in Latin American companies in innovation represents only 0.5% of gross revenues, compared to 2% in OECD countries (Crespi, Fernández-Arias, & Stein, 2014). In fact, the evidence in the case of the United States shows that investment in R&D accounts for about 40% of productivity growth since the Second World War (Reikard, 2011).

This situation gets more complex for Latin American SMEs. "While all firms in developing economies invest scarce resources in R&D compared to companies in developed economies, it is even less likely to be small businesses that decide to innovate in relation to the larger. Large companies can distribute the high fixed costs of innovation in higher sales volume, and have better access to financial services, technology, consulting services and markets specialized human capital" (Pagés, 2010) (Translated by Author).

3.5 Articulating Colombian actors

Beyond highlighting the valuable individual efforts (through initiatives and policies) of each actor of the Colombian productive system, the reason to show them is to highlight the need for a joint and coordinated work focused on a real productive transformation.

"In line with trends in developed countries, subsidies in Latin America have increasingly focused on promoting cooperation between different actors in the innovation system. In fact, countries are progressively moving from individual project support business innovation to support

projects involving university-industry interaction, and towards more comprehensive programs that cover entire sectors, such as technology clusters" (Alvarez, Crespi , & Cuevas, 2012).

3.5.1 Productive Transformation Program

In response to the shortcomings in the productive system, the Colombian Ministry of Commerce, Industry and Tourism created in 2007 the Productive Transformation Program (PTP). Nowadays it is controlled by Bancoldex, a public bank responsible for funding, among others, productive transformation in Colombia. PTP is a program of the National Government to "transform the Colombian industry and promote the development of enterprises in 20 strategic sectors of the national economy" (PTP, 2014).

These 20 sectors were selected aiming to turn them into world-class sectors in a relatively short time. The sectors were chosen using a methodology proposed by McKinsey, the international consulting firm hired by the National Government (PTP, 2014).

In each of these sectors, "a public-private partnership was structured to identify obstacles, the necessary public goods and coordination problems; and produce an action plan to resolve them, supported by a consulting firm. However, the program rules clearly bounds the nature of the conversations that can take place in the dialogue at sector level: it is not possible to discuss about subsidies, protective or other market interventions. While there has been partly success in some sectors (e.g., cosmetics), critics argue that the weak point of the program is about failures of public-private coordination" (Crespi Fernandez-Arias, & Stein, 2014) (Translated by Author).

Another shortcoming identified about the impact of this government program, besides the one previously cited, is the lack of a strategic focus. When it is spoken of a program designed to "improve", "speed", "encourage" or "modernize" productivity, one can fall into the mistake of leaving the performance to subjectivity. Officially declaring that "Productive Transformation is a process that allows entrepreneurs to achieve extraordinary results from thinking differently and acting different" is a subjective and *light* look of the problem addressed. Especially when it is argued that "this process - the productive transformation - has no end, because the country needs to be in constant growth of its economy and employment" (PTP, 2014) (Translated by Author).

One reason for deepening in terms of productivity - and more specifically in terms of the productivity gap and in terms of low investment in R & D - is to provide a strategic focus to the need for a real productive transformation. It is not the same having a plan to "improve" the productivity of an economy - leaving improve the subjectivity of only 2% or 3%, increasing from 25% to 27% in productivity - to have a plan to "close the productivity gap" (closing a gap that objectively is more than 75% or 80% compared to the US).

Furthermore, the individual efforts of this organization are not aligned with obtaining tax benefits associated with investing in R&D working with research groups (see 3.5.2 Tax benefits for R&D in Colombia) and, at the same time, proposes a structured methodology, but untenable for companies.

One of the methods proposed by the PTP, consists on an external consultant expert on productivity working with one selected company. This process of "productive transformation" consumes 80 hours of contracted consulting, costing a total of $18,580,667 COP (6,727 CHF proximately) per company: it must contribute 40% and PTP

contributes the remaining 60%. That is, every hour of consulting costs, on average, $232,258 COP (84 CHF proximately). That investment in money and time does not guarantee a tangible result beyond the "implementation of at least one (1) action of improvement" (PTP, 2013).

Such a process is unsustainable because all the capital invested in consulting can just "improve" the company in a few aspects but does not guarantee a real productive transformation or closing the productivity gap between one company respects to another. At the same time, such cost is not affordable for a small or medium enterprise to pay for expert advice hours necessary to structure, find financing and executing a project of productive transformation (Winch & Arthur, 2002).

3.5.2 Tax Benefits for Investment on R&D in Colombia

"Persons who invest in projects qualified as research and technological development, according to the criteria and conditions set by the National Council Tax Benefits in Science, Technology and Innovation shall be entitled to deduct from their income, one hundred seventy five percent (175%) of the amount invested in such projects in the taxable period in which the investment was made. This deduction may not exceed forty percent (40%) of the liquid income, certain before subtracting the value of the investment" (Congreso de Colombia, 2011) (Translated by Author).

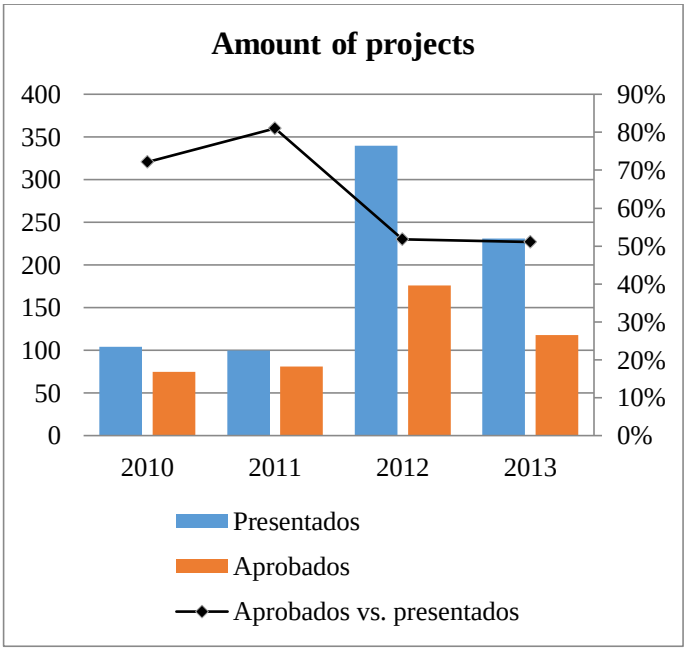
On June 16th, 2011 came into force in Colombia Act 1450, 2011, "by which the National Development Plan 2010-2014 is issued". Article 36 of this law amended Article 158-1 of the Tax Statute changing not only the amount of deduction (increasing the quota deduction of 125% to 175% and net income cap of 20% to 40%), but other issues related to the research groups and their connection with investment projects in scientific research and technological development (Congreso de Colombia, 2011). On December 2014, Act 1739 added "Innovation" to the type of investment projects and stated that investments could (instead of have) be made through research groups, among others (Congreso de Colombia, 2014).

The receipt of projects is managed through two modes: "convocatoria" and "ventanilla":

- The "convocatoria" or call consists on providing a timetable for the publication of projects to Colciencias to start – once the period closes –the rating process.
- The "ventanilla" consists on receiving projects without closing date for receipt, limiting the simultaneous rating of projects.

When projects are submitted by "convocatoria", each is evaluated by an expert pair and then all are taken at the same time, to a panel of business and researchers experts who simultaneously approve or disapprove each project in the call. This step is the difference between both modes: in "ventanilla" mode there is no panel of experts because it functions as a first in, first out method. Then, the projects approved go through a Pre-Council consisting of directors in Science and Technology and National Council Tax Benefits in Science, Technology and Innovation (CNBT) delegates. Finally, they turn to CNBT who it is the one that makes the final decision on which projects and how much amount is approved.

It is highlighted by the Science and Technology Colombian Observatory (OCyT), the significant growth that had the presentation of projects and the effective use of these tax benefits during 2012 compared to previous years. In terms of the deduction for investment, it went from receiving 101 projects in 2011 to 298 in 2012 (OCyT, 2013).



The CNBT made the decision to reduce the maximum base amount of deduction by half (from $1,000,000 million COP to $500,000 million COP) through its eighth agreement in August 2014 (CNBT. A8, 2014). This reduction in the total amount was possibly caused by the low amount of projects approved (334,800 million COP in 2012 and 159,837 in 2013) and opens the debate on whether enterprises are really taking advantage of tax benefits but specifically opens the debate on *how* to take the most advantage of them.

In this context, the tax benefits are an important initiative to promote a productive transformation. In contrast, Ecopetrol (the largest and primary petroleum national state-owned company) controls the Colombian Petroleum Institute - research and development center for the oil industry created in 1985 (Ecopetrol SA, 2014) – capable of structuring and executing projects in R&D; which is evident from the number of projects submitted and approved (13 out of 22 projects of the total projects submitted) (Colciencias, 2014). Other large companies have at their disposal R&D units specialized in structuring such projects and yet still the number of submitted and approved projects is very low. According to the National Observatory of Science and Technology (OCyT, 2013), of the 4,193 active research groups in Colombia during 2012, only 1.2% (50 groups) came from private companies.

For SMEs, again the situation gets more complex. Although the law is in favor of SME projects to access the tax deduction, they usually do not have a research group who structure, supervise or co-execute a R&D project (Crespi Fernandez-Arias, & Stein, 2014). Generally CEOs or planning managers devote most of their efforts into daily operational management and coordination tasks. They do not have the willingness to devote 2 or 3 months structuring an R&D project, do not have an operational unit to support them in this work and/or their training often does not correspond to the ideal type of human capital capable of doing so (Pagés, 2010). In short, there is no human resource capable of structuring such projects for companies with restricted access to research groups.

3.5.3 Young professionals

Here is where young professionals play a key role. Subjects of empirical and theoretical order support this position. For example, this subset of the population is considered qualified but inexperienced human capital because of their no or limited number of years of work experience. Accordingly, a good proportion of young people choose to prolong their studies to gain even more knowledge through activities of basic and applied research. They decide to postpone their entry into the labor market, which needs them but do not know how to actually use them productively.

The Administrative Department of Science, Technology and Innovation (Colciencias) promotes scientific research

and technological development through research, innovation, internationalization, social ownership and scholarship calls. In this sense, there is a scholarship called "young researchers" looking for "strengthen the capacities of National Research Groups entities by supporting young researchers" and has an annual budget of 15.3 billion COP (5.54 million CHF) (Colciencias, 2014).

It is necessary to organize young professionals in collaborative networks, and then train and prepare them for teamwork. There is a global NGO that assumed the mission of mobilizing young people to work in productive and social development projects worldwide. This NGO is called AIESEC: led and self-managed by young volunteers, has accumulated extensive experience in the market of "exchanges"; i.e. professional practices for recent graduates or students about to graduate.

"AIESEC is a global, non-political, independent, non-for-profit organization run by students and recent graduates of institutions of higher education. Our members are interested in world issues, leadership and management. AIESEC does not discriminate on the basis of race, color, gender, sexual orientation, creed, and religion, national, ethnic or social origin" (AIESEC in Colombia, 2014). The organization offers three programs for which focuses its membership to work: Global Professional, Global Citizen and Global Families. Let's focus on the first one.

Global Professional aims to promote professional exchanges through achieving and negotiating with foreign companies willing to include international human talent in their work force or through the negotiation of national human talent looking for an internship abroad. This program costs for a young interested person in Colombia approximately 400 CHF and includes a paid employment contract for six months with a company abroad, a seminar on cultural shock and the advice and support of the organization abroad.

By promoting its three programs, AIESEC functions as a highly efficient volunteering where young people develop skills in project management, planning, marketing, human talent, sales, public relations, corporate communications and social consciousness. Therefore, the potential offered to developing sustainable productive transformation projects is significantly large, considering the enthusiasm (Senge, 1990), low costs (Prieto, 2014) and practical-theoretical knowledge of a young talent of this kind.

3.5.4 Institutional incoordination

Productivity gap is a classic problem of coordination and optimization. To a large extent, it is also a communication problem: the mental maps of the different actors often prevent effective joint.

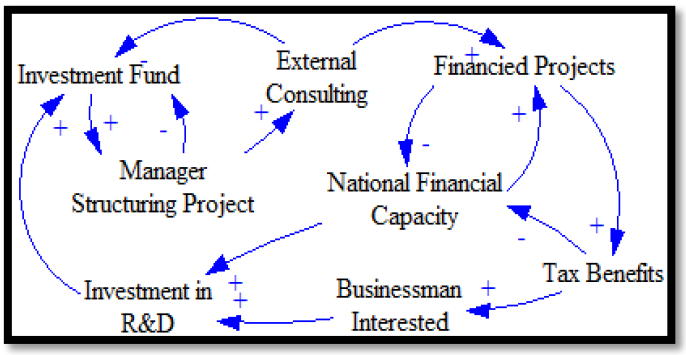
The opportunity cost of working in an uncoordinated manner is still very high (3.3 Productivity Gap). A suitable combination of knowledge (scientific, technological and empirical) facilitates the articulation of public policies and tools (such as tax incentives, subsidies, technology transfer, etc.) to generate new knowledge (applied research and experimental development) for structuring a large-scale investment projects to large, medium and small enterprises in the productive sector. We must find an intelligent way to articulate the actors of the production system; i.e. according to their own mental maps and their own interests.

4 METHODOLOGY

The challenge of coordinating actors and engage a productive dialogue through a common language with Colombian

businessman to address the process of productive transformation of their firms involves the use of methods of systems dynamics modelling (section 2.3 Industrial Engineering towards the problem). The main reason is to find effective ways of communication through generic parameterized enterprise models (Winch & Arthur, 2002) to put the language of academia at the same level of employers and encourage them to invest in innovation. Hence it is so important to use tax benefits and value generation tools to mitigate the risk of transforming a company and, on the other hand, to encourage investment in R&D.

Set out below is the causal diagram of the methodology made through simulation software Vensim PLE. The objective of presenting this diagram is to show how the problem of low investment in R&D (and hence the gap in productivity) is a problem of operational thinking (Olaya, 2012) that econometric methods have failed to solve.



In this sense, projects are the base of the R&D investment of this proposal. That is why the methodology is going to be presented according to the phases of one R&D investment project. These phases are Structuring, Financing and Execution.

4.1 Structuring phase

The structuring phase of an investment project involves the step of organizing ideas and mechanisms for achieving proper resources and subsequent execution. The approximate duration of this proposed structuring phase is 2 years made through Master's studies.

4.1.1 Master's Degree in Productive Transformation

The aim of offering the future R&D project manager this Master allied with a university is twofold:

- Provide necessary technical tools so that the young manager can measure productivity in a local SME and an international firm.
- Receive practical training to develop the necessary skills to structure, fund and execute R&D projects.

In their article "User-parameterized generic models: a solution to the conundrum of modeling access for SMEs" (Winch & Arthur, 2002) Daniel Arthur and Graham Winch conducted tests of generic simulation models so that managers of SMEs parameterize them through a collaborative process. The purpose was to develop a tool to support decision making for managers who had taken up the challenge to make *major changes* in their organizations.

They concluded that this type of model offers great potential for modeling the mental map of the manager and establish a coherent strategy of the future imagined by him. "It may therefore be the only viable option for many small companies to benefit from the modeling of dynamic systems and scenario planning" (Winch & Arthur, 2002).

The article also highlights how expensive is the dynamic modeling and how access to it by SMEs may be possible

by, among others, this situation: modeling exercises are taken by students as zero-cost "consultants" through the process of formation of MBA or PhD.

Consequently, skills in dynamic simulation of real SMEs will be acquired in order to evaluate, in a controlled laboratory environment, endogenous causes, impact of the decisions and the behavior of the critical success factors.

Industrial engineers trained as project managers would have access to other sophisticated analysis tools such as time series, multivariate data analysis, decision theory, system dynamics, business valuation, and systems thinking among many others. A project of R&D has the attraction to practically apply the knowledge gained at the bachelor in dispersed forms.

The parameters used for structuring each project would be those stablished by the National Council Tax Benefits in CTI (CNBT), who defines the outlines of a Scientific Research and Technological Development project. The project manager must strictly adhere to these rules to maximize the likelihood that the project is "qualified" positively by the CNBT, which subsequently opens the doors to tax benefits and the capital market.

Project financing methodology will be implemented as the way to fund capital for the project. This advanced technique of corporate finance - developed in detail by John D. Finnerty in 1996 - is to structure a loan for a project that benefits the developers or partners, seeking minimally resorting to bank credit and using private equity as the main source of funding.

This financing structure is designed to efficiently allocate financial returns and risks, so that it is mutually acceptable between parties. Thus, a project should include all assets necessary for it to be financially independent and an operationally viable unit. This means that the project needs to have an unquestionable ability to generate cash to pay its indebtedness (Gómez Torres, 2014).

This process of coordination and optimization is only possible if each of the actors manages to communicate in a common highly sophisticated language. One of the most attractive challenges of this research is that such language can be achieved by Dynamic Systems Modeling.

Once a manager successfully conclude his certified training (during his first year), he should have developed expertise in structuring, financing and executing projects of productive transformation (R&D); as well as has a "toolbox" to start his own project.

4.1.2 Local Immersion

After his first year, he would do a 6-month immersion into a low productivity local enterprise to apply everything he has learned; for example, how to measure productivity.

A structuring dialogue between the project manager and the businessman based on how to close the productivity gap – and therefore higher profits generating new sources of growth to the firm – allows to undertake collaborative work on structuring the R&D project. In general, this dialogue consists on carefully mixing the theoretical, academic and explicit knowledge from the project manager with the practical, empirical and tacit knowledge of the businessman to achieve a common goal.

This exercise presents challenges of communication between the manager and the businessman; especially when analyzing the incoming of third private equity investors. It is possible to mitigate this risks by:

1. The potential tax benefits. Working with research groups is possible to obtain significant savings in terms of income tax by investing in R&D.
2. Safety retain his own share participation in the company. The project financing methodology proposes that the final result of an investment project is the return on investment; having the company assets as backup. The shareholding is not committed because the risk is borne by the assets.
3. The insertion of the firm into global value chains. By having access to a foreign company with high productivity, the manager has the ability to connect the businessman with international companies to establish relationships as partners, customers or suppliers.

During this period, the manager would have had the time to start his project based on the immersion in the local company; and this would be the principal input for his international immersion as well as for his Master's final project: The Productive Transformation (R&D) Investment Project.

4.1.3 International Immersion

The last 6 months of the structuration phase would consists on the project manager going to a foreign company to (i) make an international immersion and (ii) to finish his Master's final.

The productive transformation should raise the level of technological sophistication in the value chain of the company analyzed. Through the assisted immersion of the project manager in a company that reaches international standards, he will have a holistic view of the environment and would have basis on how to develop high productivity in the local firm; and therefore take the opportunities offered by global value chains.

A global provider of professional exchanges plays a crucial role at this stage. AIESEC – Global NGO specialized in this activity – is specialized on tracking companies abroad interested in having highly trained, young and globalized human capital, in order to implement projects focused on the diagnosis of their own compared productivity and competitiveness.

Trained manager could have access to processes, technologies and management systems so that he is able to compare the productivity of the company with any of the same industry in the world: it would be possible to measure the productivity gap and analyze its endogenous reasons.

The manager may build then a global perspective on supply chain processes, machinery, quality of human capital, skills and other productive factors. Once the project is finished and he has delivered a management report to the international firm, the project manager returns to his country.

4.1.4 Finishing the Project Structuration

At this point, the Master studies, the local immersion and the international immersion have allowed the manager to develop expertise that make him highly skilled human capital for now finance and execute his R&D project.

To begin this stage, the structured project must have information that involves closing the productivity gap, competitive intelligence and sustainable technological, social, environmental and financial strategies. As for the gap in productivity, the manager, through its international previous experiences and throughout his working experience in the local enterprise, has earned enough parameters to gen-

erate implementation strategies of equipment (technology), personal (training), work environment, leadership and teamwork, among others; while has productivity indicators measured by him in both companies - as monetary units produced per worker or return on investment in CAPEX (capital investment expenditures or capital), among others.

As a final step, every project structured by a manager in all cases would be subjected to rigorous examination of an expert consultant in investment projects in R&D. That person should be member of a research group. The main reason is to ensure the support of a professional and, in the case of research groups, facilitate future support for obtaining tax benefits during the funding phase.

The salary and studies of the manager would be paid through Colciencias - who is responsible for carrying out R&D in the country - program “young researchers”. Similarly, the project once finished can also be passed to Bancoldex – because of its role in the productive transformation - who can take care of (i) move the project to the capital market or (ii) fund according to its investment capacity.

4.2 Funding phase

Once the structure of the investment project is finished, it is needed to look for its respective funding in the private or public market. This phase is to identify viable funding sources in different capital market actors, other resources from national or local government and other institutions interested in promoting investment in R&D; whose can help to improve the project risk profile or to achieve financial closure by subsidies or grants.

This process can take from 2 months to 1 year depending on the skills of the manager, availability of time for this phase and the opportunities available in the public and private sector. It is also of note that this phase will consider the time a project would be in the process of approval with the CNBT; which is part of funding as well. In short, this phase would consist manager seeking project financing.

4.3 Execution phase

The funding resources would be deposited in a trusteeship account, so that cash disbursements are exclusively available to the project under strict rules approved by the Monitoring Board (See 4.3.2 Monitoring Board).

Typical activities in the execution phase will focus on the implementation of complex processes such as installation of advanced technological equipment and sophisticated machinery in parallel with the normal operation of the company. Training of administrative staff and operators will also be necessary, in order to qualify highly sophisticated human capital.

4.3.1 Reinvestment in Structuring

This Methodology proposes to reinvest a proportion of each project once financed to fulfill two strategic objectives:

- To reinvest in training new project managers.
- To ensure program’s long-term sustainability.

The plan would be to generate a horizontal "loan" between projects, so that it secures future funding for new projects in the structuring phase; which is a bottleneck in the current organization of private investment in R&D in Colombia. For example, Project 1 has just been funded with two million francs and 1% of this money (20 000 CHF) would be invested in structuring Project 2. Once financed Project 2 after CNBT approval and capital market funding, 1% of

this money would go to pay Project 1's "loan" during structuring; and another 1% would go to structure a new Project 3.

4.3.2 Monitoring Board

Each project would be managed by a Monitoring Board which should ensure full implementation of the project and agree the conditions in the contract between the company, investors and the project manager.

For this reason, this body will consist of four members:

- The project manager, who now assumes its role as executor contributing his personal and professional commitment and expertise to the project itself.
- A representative of the Executive Board, the CEO or the manager of the local SME that is about to be transformed.
- A representative of a research group to supervise or co-execute the project.
- A representative of the investors, who may be a Private Equity Fund, an angel investor or other capital market player; in case they are needed.

The trusteeship agreement shall define in detail the conditions for the Monitoring Board to authorize disbursements depending on the progress of the project. Similarly, this group would be responsible for ensuring that the entire project is executed in accordance with the relevant organization and that all modifications deemed necessary must be duly justified and approved by its members.

4.3.3 Competitive Intelligence

Global Value Chains analysis begins. This aims to take a strategic look on where would it be better to aim the sophistication of each SME's product or service. Under this stage, the project manager and/or businessman willingness and availability would be needed to travel to highly productive companies (like the company the project manager was working at the stage of structuring, for example), to understand their processes; and manage potential cooperative alliances with these companies. This stage requires a global view of the potential market and suppliers as well as a thorough research on existing patents in the market and equipment - in terms of cost and availability - needed to produce them.

Once the businessman has a holistic view of the market, it comes what is known as "technology foresight". This definition fits the analysis and studies on the technical, scientific, economic and social trends and conditions of the technology's future reality to anticipate it in the present. This will require access to valuable (and possibly expensive) technological global information.

Once they have a global view of the market and the technological trends are estimated, a technological strategy is performed. This step consists of choosing what technology works best for the local enterprise particularly in technological terms from knowledge acquired in previous stages.

4.3.4 Productive Transformation

The biggest investments would be made during the productive transformation phase in regard of machinery, technology and formation of improved human capital. To explain the productive transformation each enterprise would have to face, let's introduce the term "technological vector".

This definition comes from the need to change the structure of a company through investment in 4 productive development factors. These are capital, labor, technology

and raw materials. In this sense, one project seeks to reach a strategic distribution investment in the four factors by product, based on the analysis of competitive intelligence previously made. Strategic changes in the technological vector of a company imply to do more with the same, getting better results, with few - but significant - improvements.

The advantages of using a low labor force and highly sophisticated in technology vector, which is the one implied in this paper, are closely connected with the synergies and work environments – both intangible – generated between workers through the interaction of ideas. That is, closing the labor productivity gap by only contracting high-quality human capital, although at first seems to rise unemployment, it necessarily involves the acquisition of skilled human capital, which promotes higher education and thus generates positive externalities on society by improving the quality of education and productivity. The same applies to the productivity of capital and technology. Thus, it is possible to deduce that closing different productivity gaps will necessarily empower TFP because this is a measure of the synergies generated between other productivities. Perform a productive transformation means a work of intense human capital and talent.

4.3.5 R&D Strategy

Once transformed the labor and capital of a company, the R&D strategy is performed. This aims to promote the incursion of new knowledge in the company and additionally aims to limit the need for abrupt productive transformation in the future. This strategy should take also into account a sustained investment over time towards R&D to ensure constant innovation.

This would be the last phase of each project. From here, it opens the possibility that its project manager can return to work on a new R&D project for a new enterprise or that the newly-transformed company hire him as the new R&D vice president.

5 SYSTEMS DYNAMIC MODELLING

This methodology was modeled using systems dynamics simulation software iThink. The goal was to find scenarios of sustainable solutions and sensibility analysis towards the problem of the Colombian productivity gap.

5.1 Systems Dynamic Simulation

Before starting with the presentation of results obtained by the baseline scenario analyzed, it is important that the reader has in mind what the real purpose of the dynamic simulation tool is. The success of simulation does not lie on the availability and quality of the numerical results of the decision variables, but on the modeling process itself and how it has allowed a deeper understanding of the endogenous causes that determine the behavior of the analyzed system. "A system dynamics model is not a data model, is a model of decision rules" (Olaya, 2012).

5.2 Baseline scenario

With initial parameters stated by a baseline scenario, a simulation model for 10 years was run. The simulation was programmed to stop each year and thus have the possibility to take decisions in regard to invest on new projects and consultants or recruit new (or more) project managers each month.

Changing the recruitment rate throughout years, at the end of year 10, 6,045 project managers were working: 1600 in

structuration, 686 in funding and 3759 in execution. This results in a total of 5079 productive transformation projects; which means a positive impact for more than 5,000 companies in the real sector and sustained R&D for the Colombian economy. At the end, the fund (where the money is deposited) reaches values of 51,412 CHF (return on the initial investment (51-1.8) / 1.8 = 2740%) and investment in R&D for the country totaled 4.86 billion CHF. Results may vary depending on parameters and decisions taken during simulation.

5.3 Sensibility Analysis

Money in the investment fund (initial value of 1.85 million CHF financed by Colciencias) goes for forming new project managers and paying external consultancy. Fund's unique income flow would be reinvestment of projects once they are funded. In this case, after several scenarios simulations, to guarantee sustainability in the fund, it is necessary to keep track on how fast new managers are been recruited respect to how fast projects get financed. In that sense, with initial parameters, recruiting more than 18 managers each month would make the fund unsustainable. However, constantly recruiting 18 managers each month for 10 years would end up on 617 realized projects and a total R&D national investment of 1.64 billion CHF.

6 CONCLUSIONS AND SCOPE

Colombia opened its economic market (through Free Trade Agreements) before its own companies were prepared to face competition of business companies five times more productive and products with high added value difficult to develop in the country.

For this reason, over the next ten years it will be both necessary and urgent to find a practical and sustainable solution to facilitate the widespread dissemination of methodologies to drive massive investment in R&D, adapted to the Colombian environment. Methodologies for structuring, financing and executing investment projects made to fit each manufacturing or agribusiness company, depending on its size, its productive capacity, its financial muscle and its location in global value chains.

While the country needs urgent productive transformation of private sector, the synergistic interaction of all the actors involved in the task of closing the productivity gap is also necessary. The document "Bases Development Plan 2014-2018" published in November 2014 by the Colombian National Planning Department, incorporates strategies oriented in that direction. Cross-cutting strategies include the chapter on Strategic Competitiveness and Infrastructure (pages 58-94), where effectively the problem of low productivity is recognized and proposes a Productive Development Policy (page 68), which includes programs to (DNP, 2014):

- Internationalize the productive sectors of goods and services.
- Promote the integration into global value chains.
- Strengthen the technological capabilities of firms.
- Developing an ecosystem for Science, Technology and Innovation (CTI), with capabilities and financing.
- Train researchers and innovators to lead the CTI transformation of the country.
- Improve the quality and impact of research and transfer of knowledge and technology.
- Promote technological development and innovation as a driver of business growth and entrepreneurship.

In terms of Activities of Science, Technology and Innovation (ACTI), the new Development Plan defines a specific

product: *intervention tools* (adjustment mechanism of public policies) to increase public-private investment in CTI. "The most tangible result of this effort is the development of relevant projects in each of the priority areas, knowledge generation with greater impact at international level and the development of new technologies and marketable products" (DNP, 2014) (Translated by Author).

The objective in CTI is jumping from 0.5% (in 2013) to 0.9% (in 2018) in the participation of CTI as a percentage of GDP, which means a volume of investment in CTI activities of 14 billion CHF (The Economist Intelligence Unit, 2014). All this results in a favorable environment to implement in the short term, the methodology proposed in this paper.

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