Building Public Policies to support the Diffusion of Light Emitting Diodes (LED): The role played by metrology, the science of measurements

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Overview
The first attempts at standardizing specific requirements and measurements for LED were observed in the middle 1990s, around 20 years after LED products started entering into market – especially with regards to safety and quality requirements, essential aspects for their commercial insertion, so that consumers have confidence in the usage of this new source of lighting. In Brazil, the companies of the lighting industry rely on the expertise of the National Institute of Metrology, Quality and Technology (Inmetro) for the execution of tests and measurement services for the development of luminaries. The offer of such services avoids that companies, especially small and medium-sized, spend significant amounts on equipment installation, as it was mentioned while calculating the cost of metrological services, which also requires specialized staff and infrastructure. This study will be dedicated to analyzing the role played by metrology in supporting the Brazilian LED industry, emphasizing the impacts exerted by Inmetro.

Keywords – LED, lighting, metrology, public policies.

1. LED market outlook

Light-emitting diodes (LED) are included in the state-solid lighting (SSL) technology[1], whose utilization has been growing at a remarkable speed for the past 40 years, both regarding the amount of products utilized as much as their spread for different sectors: housing and public lighting, displays and electronic devices, in the automotive industry, in medical devices, toys and so on.

Though the light industry has been a quite stable segment since the 19th century, it is now going through a major change, induced by population growth and a greater demand for energy efficiency products. According to studies developed by McKinsey & Company (2011 and 2012), data foresee that world population will reach up to 7.7 billion in 2020. This growth will cause an explosion in urban population and, consequently, a greater usage of lighting, since cities consume more light than rural areas.

Recent data provided by the Boston Consulting Group (BCG)[2] show that, in 2014, the global lighting market reached up to US$ 112 billion and, until 2020, this number will raise up to US$ 133 billion, a medium growth of roughly 3% per year.

Nonetheless, due to its highly heterogeneous characteristics, the lighting market has not been receiving a lot of attention, despite its vast size. Therefore, in order to facilitate the understanding of such specific characteristics, this market should be analyzed under three perspectives of application: general illumination, automotive illumination and backlight illumination. However, it is important to highlight this market is undergoing a deep and rapid change, driven by two trends: the growing adoption of light emitting diodes (LED) technology and the increasing popularity of connected lighting systems.

The general lighting market is the dominant one, representing around 75% of the total, and it is subdivided into housing, commercial, hospital, industrial and public lighting. This sector has reached revenues of approximately 75 billion Euros in 2011, with the expectation of reaching up to 83 billion Euros in 2020 – the BCG estimated that this

[1]LED lamps of unique base with incorporated control devices, on the contrary of other lamps that use heated metallic filaments or electric discharges in gases to produce light, produce light through the phenomenon known as electroluminescence, being, for that called solid state lighting (SSL) (Inmetro, 2013).
[2]Based on the report "How to win in a transforming lighting industry" (2015).

number reached up to € 72 billion in 2014. Such growth will be guided by the strong increase of the construction sector, mainly in emerging countries.

The automotive lighting sector represents around 20% of the total, with revenues estimated in more than 18 billion Euros in 2020 – in 2014, this number has already reached € 17 billion, according to BCG. This segment's trajectory keeps a deep similarity with the general lighting sector: it is related to a sound growth of the demands for cars in emerging countries.

Finally, the lighting sector of backlight, which includes screens for laptops, monitors, televisions and other portable devices, represents around 5% of the market. The main characteristic of such niche is the strong penetration of LED lighting, that reached 50% of this market in 2010, with the expectation of reaching the peak of 100% in the next years[3] (McKinsey & Company, *op. cit.*).

Another factor that has been considered as a world trend is the growing concern with environmental issues and climate change. Because of these concerns, governments have been trying to banish less efficient products (like incandescent lights), and have also been setting new energy efficiency requirements for green buildings. In this path, energy efficiency technologies for lighting, such as LED, have received more attention.

Besides the trends of price reduction in the sector of backlight, there has been a reduction in the costs of LED chips and packaging[4] (which still represents one of the most significant production costs), mainly in the components that were designed for usage in medium power, suitable for general lighting.

LEDs have, then, entered into the policy design of various countries all over the world, mainly interested in improving the efficiency of energy consumption. In various countries, mandates have been issued to promote the mandatory replacement of incandescent lights, opening a wider space for other lighting technologies, with a sound contribution from LED products.

For its commercial insertion, nonetheless, it is essential that LED products comply with safety and quality requirements, especially so that consumers have confidence in the usage of this new source of energy (Yuan *et al*., 2013). In fact, as Estrada-Hernández et al. (2009) pointed it out, the light emission principle of LEDs is completely different from the one of conventional lamps, what imposes, then, the need of new measurement paradigms.

The first attempts at standardizing specific requirements and measurements (mainly regarding safety and quality aspects) for LED were observed in the middle 1990s, around 20 years after LED products started entering into market.

In Brazil, the LED industry relies on the expertise of the National Institute of Metrology, Quality and Technology (Inmetro) for the execution of tests and measurement services for the development and improvement of luminaries. The offer of such services avoids that companies, especially small and medium-sized, spend significant amounts on equipment installation, which also requires specialized staff and infrastructure.

This study will be dedicated to shed some light to the important role played by metrology in supporting the Brazilian LED industry, especially in terms of market access and fair competition.

2. Metodology

To properly build our analysis, key stakeholders in the LED industry were heard through interviews and through the application of a questionnaire in order to identify how important metrology and related aspects are to the development of this industry. The research addressed some topics related to how the National Metrology Institute (NMI) must get prepared for the challenges that industry will face over the coming years.

Additionally, a Cost/Benefit Analysis (CBA) has been built. Our goal here was to try to identify the returns obtained by the policies conducted by Inmetro in this process, i.e., whether the benefits provided by the services

[3]According to data made available by Technavio, for example, the mobile computing device segment dominated the market during 2015, with a market share of 82%.

[4]Procedure held in the initial of the LED value chain, which involves the encapsulation and protection of the chip using either epoxy resin or silicon.

made available to the LED industry compensates the costs and investments engaged by the Institute. The objective here is to call attention to the need that this type of initiative be included in public policies to be designed to the sector.

Although the CBA is a widespread quantifying method, there is no specific methodology for assessing the different impacts of a certain project, especially if it shows a non economic nature (social, environmental, etc.). This is why the joint use of more than one technique and methodology (for example, the use of complementary qualitative assessments) has become quite usual.

In an attempt to explain the main difficulties in its application, as well as complementary and alternative ways to overcome them, the Office of Management and Budget (Office, 1992) prepared a manual whose guidelines refer to quantifying the effects of a program and/or policy. If this is difficult to quantify, it is advisable to submit any relevant quantitative information, beyond the description of non-quantifiable effects. In this sense, when quantification of certain types of costs/benefits is either difficult or impossible, you can select other auxiliary methods. The techniques depend on different contexts and technical structure of the institution in charge.

Regarding public investment, particularly in R&D, Griliches (1958) was perhaps the pioneer to develop mechanisms to estimate their rate of social and private returns. In its simplest model, innovations developed by the public sector contribute to reduce the production costs of goods sold in a competitive market. In less competitive markets, the Griliches model also considers the producer surplus to measure the rates of return. Tassey (1997), followed by Link and Scott (1998, 2011), proposes two methodological alternatives: the spillover and the counterfactual methodologies.

The methodology used to evaluate the performance of private R&D subsidized by public resources is called spillover methodology. Applying this methodology to evaluate R&D performed in the private sphere and supported with public funds is appropriate because its result is only partially suitable for the company, the remainder being transferred to the whole society. The extent of the spillover of this knowledge with public good characteristics and their effects on the estimates for the rate of return in the private sector compared to a "minimum rate of return" determine whether the public sector should subsidize or not the research in the private sector.

The counterfactual methodology, on the other hand, is used to compare the current technological state (status quo) with the situation in which the technology does not receive public investment. Tassey (*op. cit*) advocates the use of a "counterfactual methodology for economic impact assessment", to analyze a situation in which the public investment could, somehow, have been alternatively performed by the private sector and thus the generated technology could also have been developed by the private sector.

In other words, the benefits of public investment can be characterized as the cost that the private sector avoided expending. However, it is not always possible for the private sector to make the investment – especially in R&D – in the same way that the public sector, keeping the same quality. In this sense, the avoided costs represent the expenses the private sector would have had with the development of a substitute technology and the loss of value due to the lack of quality of the alternative technology when compared to the technology developed through public investment.

In the case of metrology, this aspect becomes more evident. Based on the broader social benefit of metrology programs, whose character of public good requires huge investments, as well as elements of integration, it is expected that such activities be conducted, at the national level, under the aegis of a central government agency. Swann (1999) argues that a national system of measurements that exceeds certain minimum level can offer significant advantages to firms in that country since the metrology institutes that carry out these activities not only perform research, but also assist in the incorporation of the results achieved by those who do not have a broader understanding of basic research. The author, moreover, supports the role of the state in the provision of these resources, since "measurement systems financed by the public sector encourage the types of innovation introduced that disrupt the stability and familiarity" (p. 36).

Therefore, rates of return of counterfactual benefits and the cost/benefit rate would be achieved, in practice, through extensive interviews with managers, researchers and those stakeholders of the sector. Their calculation would be made based on the answers to the fundamental question in the assessment: are public investments a more efficient mean to generate/enhance certain technology than private investment could have been had they been realized?

In recent years there has been, among economists, an important development of methods based on interviews, such as the counterfactual or choice models. These experimental techniques "simulate a market situation, making respondents more 'comfortable' to express their assessments - hypothetical - about the real improvements in specific environments" (Pearce and Turner, 1990).
The next section will present the results of our research based on the above methodology.

3. The impacts of metrology applied to the LED sector in Brazil

3.1 - Introduction

In 1988, the average number of lamps in every Brazilian home was divided as such: 6 incandescent and 1.3 fluorescents lamps. After the 2001 "blackout"[5] and the energy rationing, the market of energy efficient lamps experienced a great boost. In 2005, the number of lamps present in each home in Brazil reached the mark of 8 units, being 4 incandescent and 4 fluorescent lamps, on average. The market of fluorescent lamps has grown about 30% per year since 2001 and from 2006 to 2007, the increase was from 20% to 25%. Despite this growth, over 50% of residential lighting is reached through incandescent lamps (Mansor *et al.*, 2010).

According to the Brazilian Association of Lighting Industry (Abilux), the number of LED lamps sold in Brazil jumped from 4 million units in 2011 to 81 million in 2015, but still represents less than 15% of the total consumption (about 600 million). The growth in the use of this technology can be explained by the withdrawal from the market of incandescent bulbs, the large increase in the price of electric energy in the last two years and the sharp fall in the price of LED products, which favors its adoption. Nonetheless, Abilux estimates that the participation of Brazilian companies in the national LED market is still less than 10%.

Also with respect to the LED technology, it is noteworthy that their participation gained a new impulse in the country, especially from 2010 onwards, when the Mines and Energy Ministry (MME) issued two documents setting out minimum levels of efficiency to incandescent lamps[6]. Until 2010, according to the MME Department of Energy Planning, about 300 million incandescent lamps were sold every year in Brazil, and they would be gradually replaced by more efficient lamps, like CFL (compact fluorescent lamp), tubular fluorescent lamps, halogen or even LED.

In addition to the political aspects and business development for the LED products, Brazil has advanced in the definition of technical requirements to promote greater safety and quality for LED products traded in the country. In this context, it is worth mentioning the publication by Inmetro of two Technical Regulations on Quality (TRQ). The first is "LED lamps with integrated control based device" (Inmetro, 2014) and the second is dedicated to "LED-Lighting Public Road" (Inmetro, 2017), both with the goal of establishing the technical requirements such products must comply with, aiming at promoting energy efficiency and safety.

In order to comply with the technical requirements established at the above mentioned documents, some tests have to be performed by a reliable laboratory, as for instance: power, dielectric strength, insulation resistance, photometric characteristics, light intensity; thermal tests, durability test, resistance to ultraviolet radiation.

The basis for meeting these requirements occurs through advances in metrology. So, Inmetro works in two main axes: 1) measuring the colorimetric and photometric properties of LED fixtures mounted; and 2) studying the colorimetric, photometric, electrical and thermal properties of LED, aimed at assembling a system of metrological characterization. In this context, the optical metrology applied to LED plays a fundamental role and will be the main focus of our analysis.

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[5]In 2001 and 2002 Brazil experienced an energy crisis which particularly affected the Southeast and Midwest. In the words of Ali (2009, p. 189) "The 2001 rationing was the highest ever recorded in Brazilian electricity sector, only having similar events associated with wars or natural disasters. His impact was so strong in the collective unconscious that other failures in other sectors also began to be called 'blackout'."

[6]For more information see: http://www.mme.gov.br/documents/10584/904396/Portaria_interministral+1007+de+31-12-2010+Publicado+no+DOU+de+06-01-2011/d94edaad-5e85-45de-b002-f3ebe91d51d1?version=1.1and http://www.mme.gov.br/documents/10584/1139097/Portaria_Interministerial_nx_1008_2010.pdf/e6cab7cb-f58d-4aa9-9ce9-8a6028718759.

The objective of this case study, as explained before, is to shed some light to the important role played by metrology in supporting the Brazilian LED industry, especially in terms of market access and fair competition. For that, an evaluation of how the activities carried out by Inmetro impact the sector, with regard to the metrology applied to the LED industry is offered.

Inmetro's Division of Optical Metrology (Diopt) performs measurements in LED fixtures providing measurements of the quantity "luminous flux", information on distribution and on the optical yield curves, as well as guarantees the traceability of measurements of luminous intensity. For that, a goniophotometry system was set up in 2002 with the purchase of equipment from Germany for about US$ 500,000. Besides this amount, it was necessary to engage into investment for its set-up, which then became operational in 2004.

At the beginning there was no specific demand for measurement services concerning LED, situation that only changed after 2006 - especially with the rise in demand for services in LED fixtures. To meet this new market, the existing infrastructure began to be used and, therefore, no additional investment had to be made. Researchers and technicians from the laboratory based their work on international standards for introducing methodologies related to measurements in LED products.

From 2009 onwards, this demand for conducting photometric measurement services became more expressive for LED technologies: it is estimated that today, after the growth exhibited in recent years, measurements in LED products take more than 50% of the operating time of the equipment.

Regarding research activities about measurements dedicated to LED technology, it must be pointed out that there are still other initiatives aiming at advancing in the measurement of the colorimetric and photometric properties of LED lamps and at studying its properties. It is important to highlight that several studies had been made by the team, so Inmetro is able to provide the services that the industry needs now and will require in the near future. The perspective is that the demand for services of this laboratory will increase considerably in the upcoming years, especially after the publication of the Technical Regulations of Quality by Inmetro.

3.2 - Case study

In 2013, Inmetro applied a survey to firms of the LED sector in Brazil, with the main aim of identifying valuable information that could assist in the contribution of metrology to the referred sector. 140 firms were mapped, to whom a questionnaire was sent. 41 firms returned the filled form.

The majority of companies surveyed are concentrated in São Paulo State. This information illustrates a close situation to a scenario presented by another survey conducted by Abilux[7] in 2005, in which 58% of 604 companies analyzed were located in the Greater São Paulo.

The survey shows that Brazilian lighting industry has been highly dependent on imported parts and finished products from other countries. Other researches also show that, for the lighting industry as a whole, it is necessary to import components from abroad. And in the development of LED products[8] it is not different either. Among the companies that participated in this study, none was LED producer, including die[9]. These data indicate that none of companies develop LED in Brazil: only six companies produce LED, although they imported dies, the main component of LED. The majority of companies (30) buys LED abroad (complete, singly or in modules) and uses it to manufacture its products. Besides, five companies said they do not work with LED and, so, these companies have not answered other questions in the survey.

In relation of size of these companies, 44% of respondents are formed by micro and small companies. Additionally, there is a relatively equal distribution between ranges of revenues established and it became almost impossible to say anything about the structure of the lighting market due to the scope of this study. However, Abilux's research

[7]Research on the technological stage of the lighting industry was conducted in 2005 by Abilux, Sindilux and Sebrae/SP. Available at: http://www.abilux.com.br/pdf/diagnostico.pdf.

[8]LED products are those produced using LED in any of its components.

[9]LED die is a chip where light generation takes place. This chip needs to be encapsulated and electrically connected for provide means to dissipate heat and to direct light. This whole assembly is called LED package. This is the form in which the LED is used in practice to elaborate products like, for example, light fixtures.

conducted in 2005 indicated a predominance of micro and small enterprises – about 40% of total (LEVANTAMENTO, 2005)[10].

To estimate the size of the market for LED products in Brazil (especially on the supply side), firms were asked about the participation of these products in their total sales. In most companies, LED products have a low representation in relation to total revenue. For 27 companies (75% of respondents), the revenues obtained from LED products represent less than 25% of its total sales and only 8 companies (22%) work more intensively with LED (revenues over 50%).The average percentage of annual revenue with these products is around 21.8%[11]. This overview indicates that LED technology still has great potential to be explored. Lastly, to understand how Brazilian companies see this opportunity interviewees were asked to estimate their revenues with sales of LED products/components in the next 5 years. In average, these firms intend to increase their revenues from sales of LED products/components up to 26 percentage points over the next five years[12].

About business outlook with products and components with LED technology, the large majority (97%, or 35 companies) reported they have plans to launch new LED products or improve those currently in use. This supports the companies' intention to increase the share of revenues from LED products/components in total sales.

Through the data collected on the lighting market, and the survey conducted with the companies from the LED sector, it was found that the share of revenues obtained from this technology in their total revenue is still small[13], and that on their majority import the main components for the production of LED. Generally, those companies aimed, at that time, at increasing the participation of LED products in their total sales and indicated the intention to introduce new products in the following five years. Such intention is confirmed through the information that in 2012, most of these companies spent on R&D[14] and on training of labor force higher levels than the percentage of the manufacturing industry (Pintec 2011).

The information gathered made it possible to get knowledge about some aspects of the LED industry such as: demands for testing services of LED products/components, suppliers of these services, costs of such services, as well as their related benefits.

The result of this study shows that most companies recognize that improvements in metrological field and or technical regulations may increase their revenues. And, as indicated, these improvements would avoid unfair competition with products of low quality, or which do not meet the requirements of existing standards, in addition to increasing the acceptance and credibility in the market.

However, with regard to such benefits, it was not possible to quantify them satisfactorily, because only two companies were able to quantify this benefit in monetary terms and the others just qualified this benefit, such as those mentioned in the paragraph above.

With the aim of quantifying these benefits through a cost-benefit analysis, at the time of application of the referred survey the social cost related to photometric services was calculated. It should be noted that this analysis was restricted to measurement services provided by the Laboratory of Radiometry and Photometry (Laraf) of Inmetro, since other laboratories had a very small demand for services related to LED technology.

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[10]In the Abilux's research, 17% of 604 companies interviewed not answered the question about average annual revenues. Also this research, firms that received until R$ 2.133 million were classified as micro and small enterprises; those that received between R$ 2.133 million to R$ 10 million were classified like middle enterprises; and those big companies were those that obtained more than R$ 10 million of annual revenues.

[11]This number represents approximately R$ 4.17 million.

[12]Bearing in mind that the average percentage of annual revenues with LED products/components represents 21.8% currently, this number could represent up to 47.8% of revenue in 5 years.

[13]The average percentage of annual sales with these products was around 21.8% in 2012.

[14]Among the 36 participants from the LED sector, 26 (72%) companies responded that they perform some R&D activity and 10 (28%) stated that they don´t. Comparing with the data of Pintec 2011, it can be seen that this number is far above the reality of the manufacturing industry, where 24% of companies perform some R&D activity, and also of the industry focused on manufacturing of electronic components, including those that manufacture diodes emitters (LEDs), where the number was 39%.

At first, the social cost that corresponds to the value of the service was calculated, considering the opportunity cost of capital[15] and the amount of salaries consistent with the level of qualification required by Inmetro to perform such activities.

In order to calculate the social cost of photometry services applied to LED luminaries, the use of 16 men/hour of two technicians (8 men/hour each) and 1 men/hour of a supervisor were considered, being the time distributed between the measurement of photometry itself (using the goniophotometer), the analysis of results and the preparation of the report. The proportional value of a salary of R$ 5,000 for mid-level technical and R$ 15,000 for the supervisor with recognized experience (senior) was also considered in this analisys. In addition, direct and indirect production costs were computed. In order to calculate the depreciation of equipment (goniophotometer), a useful lifetime of 10 years and an approximate cost of US$ 500,000[16] were estimated. Given these values, the social cost of photometry services applied to LED luminaries was R$ 4,110.38 in 2016.

In general, the social cost is always higher than the price charged, as in the case of Inmetro for the photometric service. According to information from the Operational Support Department in Scientific Industrial Metrology (Samci) of Inmetro, the amount charged by the measurement service to public fixtures is R$ 1,260.00, and R$ 750.00 to indoor lamp. Despite being the same service and spending, on average, the same amount of hours, the amounts charged by type of lamp are different, benefiting manufacturers of indoor lighting fixtures, which typically are small-sized companies. In addition, the Inmetro's laboratory performs measurement services for analysis and development of luminaries, whose value (R$ 560.00) is charged for every 4 hours of service. From 2015 onwards, these values were adjusted, though remained under the social cost calculated in 2016 (R$ 4,110.38), the new values were calculated as such: R$ 2,000.00 for photometry involving public luminaries, R$ 1,200.00 for indoor luminaries and R$ 900.00 for the service of measuring for analysis and development of luminaries.

Comparing the social cost with the values described above, it is possible to observe that the private sector had an "appropriated" benefit. To estimate the value of this benefit, the amount of services provided by the institution between 2008 and 2016 was calculated, related to LED technology. It has been identified in that period that 91 services were offered[17] for LED photometry, both public as fixtures for indoor and photometry measurement related to the analysis and development of fixtures, which provided Inmetro a total revenue of R$ 222,890.00 (Table 1).

Table 1 - Revenue from services offered by Inmetro (2008-2016)

Services	Quantity	Total Revenue (R$)
Public luminaries	103 luminaries LED	140,140.00
Indoor Luminaries	56 luminaries LED	45,150.00
Measurement for analysis and development	55 periods	37,600.00
TOTAL (R$)		**222,890.00**

Source: SAMCI. Internal elaboration.

In the measurement service for analysis and development a unit value for a period of 4 hours was considered, i.e., in the last nine years Inmetro held 55 periods of 4 hours related to that service. For the service of photometry of public and indoor fixtures the amount of fixtures was considered.

Thus, between 2008 to 2016, the amount earned by Inmetro with these services was R$ 222,890.00, but if Inmetro had charged for these services the value of the social cost previously calculated, the revenue of the Institute during the period considered would have been about R$ 766,585.87 value three times higher than the one effectively earned[18] (Table 2).

[15]The rate of return to capital in the economy that could be invested with no risk. Typically, the fee for the opportunity cost used in Brazil is 6% per year.

[16]Considering the exchange rate in 30/12/2016 (US$ 1 = R$ 3.25), the value of the equipment expressed in Reals was R$ 1,625,000.00. The equipment worklife (10 years) converted into hours of operation summarized 20,160 hours, indicating that the amount of depreciation per hour of operation of the goniophotometer is R$ 80.61.

[17]Each service involved one or more lamps, or one or more measurement periods for analysis and development.

[18]In terms of CBA, this number represents that the private sector was benefited in value 3.44 higher than they invested on.

Table 2 - Revenue with the services provided by Inmetro considering the value of the social cost (2008-2016)

Services	Quantity	Social cost (R$)	Total Revenue (R$)
Public luminaries	103 luminaries LED	4,110.38	423,369.14
Indoor Luminaries	56 luminaries LED	4,110.38	230,181.28
Measurement for analysis and development	55 periods	2,055.19	113,035.45
TOTAL (R$)			**766,585.87**

Source: SAMCI. Internal elaboration

The amount of R$ 543,695.87 that corresponds to the difference between revenue forecasted considering the social value and the revenue effectively earned, in a way, may be considered an incentive for producers / retailers of LED fixtures. Besides, the services offered by Inmetro avoid that firms engage into high investments to build the proper infrastructure to set-up a similar laboratory of photometry.

On the other side, so that Inmetro complies with his role as a reference metrology institute a series of investments had to be made, using public resources.

In this particular case, such investments become important since it is desirable to strengthen the lighting industry, enabling it to compete and meet the requirements demanded by national and international market. Moreover, this incentive corroborates the social importance of public lighting, which plays a fundamental role in the quality of life and safety of cities.

4. Final remarks

The result of this study shows that most companies recognize that improvements in the metrological field and/or technical regulations may increase their revenues. And, as indicated, these improvements would avoid unfair competition with products of low quality, or which do not meet the requirements of existing standards, in addition to increasing the acceptance and credibility in the market.

In Brazil, the companies of the lighting industry rely on the expertise of Inmetro for the execution of tests and measurement services for the development of luminaries. The offer of such services avoids that companies, especially small and medium-sized, spend significant amounts on equipment installation, as those described while calculating the cost of metrological services, which also requires specialized staff and infrastructure.

Moreover, Inmetro, since its foundation, has been the reference Metrology Institute for the country and, therefore, a series of investments have been made with funds from civil society so the Institute would be capable of fulfilling its functions. Just with the acquisition of the goniophotometer, for example, Inmetro invested around US$ 500,000.

In this sense, the payment made by companies to hire the services of photometry performed by Inmetro, between 2008 and 2016, provided revenues of R$ 222,890.00 to the Institute. The difference between the amount actually charged by Inmetro for the supply of photometry services and the amount taking into account the social cost of services has been appropriated by the private sector (R$ 543,695.87). Furthermore, it is noteworthy that had the investment been held by the private sector, the appropriated benefits probably would not be as equally distributed among the various market participants.

This practice has often been used for a number of countries to support the growth of local industry. Bonelli (2006) points out that, in recent years, there have been new ideas and explanations for the development process that focuses on structural change in the center, emphasizing two main aspects: diversification of the productive structure (and exports) and technological innovation (or, more generally, the accumulation of knowledge). In this context, industrial or competitiveness policies also called 'microeconomic interventions' have been shown very relevant.

The situation of the lighting industry in Brazil tends to be aggravated after a government decision[19] initiated from June 30th 2013 onwards, a banning on the production and import of incandescent larger power lamps which will be concluded on June 30th, 2017, when the lower power lamps will have to be banned as well. Thus, national lighting industry that predominantly manufactured incandescent bulbs, need to reposition themselves in this new context, especially regarding LED technology.

[19]Ministerial Decree No. 1007 of December 31th, 2010.

For this, the role of technological innovation will be a key factor. The fact that companies, that participated in the mentioned study in 2013, have made efforts toward increasing the participation of LED products in their total sales, expecting to introduce new products in the next five years, in addition to invest in R&D and labor force training above the average of the manufacturing industry according to data from Pintec 2011, are clear signs that the industry has worked out in order not to miss the window of opportunity.

The literature also shows that innovation has positive impacts on exports, and hence on the growth of firms, therefore on countries. De Negri and Salerno (2005 apud BONELLI, 2006) point out that:

> (i) Technological innovation and spending on R&D increases the chances of the company to enter the international market and increases the volume of exports of innovating firms, besides being more relevant exactly on the most dynamic markets in world trade, which are the more technologically advanced products– as is the case of products based on LED technology;
> (ii) Innovative Companies offer jobs of better quality (higher wages and greater residence time worker employment);
> (iii) Technological innovation allows obtaining profit margins greater than those of non-innovative firm's profit. These margins are translated into the possibility of selling the same products at higher prices to its competitors;
> (iv) Innovative companies have grown, both in terms of revenues and employment, a situation that contradicts common sense.

Thus, this study showed the role Inmetro has played in supporting Brazilian lighting industry through the supply of metrological quality services, especially focused on LED technology. It is worth highlighting that such performance is aligned with the core mission of the Institute, to provide confidence to the Brazilian society in measurements and products, promoting innovation and competitiveness.

For all that, Inmetro aligns to the major global metrology institutes, as a key agency for Brazilian innovation and competitiveness, an institution of scientific and technological expression, where knowledge has been consolidated as a consistent link to facilitate interaction between scientific and technological development and business sector, which is fundamental to the rise of innovations.

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