Quality infrastructure and innovation in the Brazilian information technology services: evidence from the National Innovation Survey

Marcello Carvalho dos Reis, Maria Fatima Ludovico de Almeida*
Postgraduate Program in Metrology, PUC-Rio, R. Marques de São Vicente, 225, Gávea, Brazil.

*Email: <fatima.ludovico@puc-rio.br>

Abstract. The objective of this work is to contribute to the advancement of knowledge about the innovation capacity of information technology service companies in Brazil, with emphasis on the role of the quality infrastructure functions in strengthening this capacity. We have drawn the data from the National Innovation Survey 2014 (Pintec 2014) to answer how the companies in this sector perceive the importance of quality infrastructure functions in their cycles of innovation, to highlight the benefits derived from the existence of such infrastructure in Brazil.

Keywords. Quality infrastructure; innovation systems; information technology services; National Innovation Survey; Brazil.

1. Introduction
The research and development (R&D) and quality infrastructure of a region are of fundamental importance for the formulation of public policies in Science, Technology, and Innovation (ST&I) and implementation of effective strategies for consistent application of resources by public and private organizations from several sectors of the economy. The literature review on innovation systems points out that different sources of knowledge, technology, and learning are used by innovative firms, either for launching new products, improving processes, or meeting standards and/or technical regulation requirements [1-8].

Monitoring these sources of knowledge, technology, and learning, and other related factors allows the analysis of the innovative capacity and innovation performance of firms in different sectors of the economy. It also contributes to the formulation and evaluation of national, regional, or sectoral innovation policies. Thus, the main objective of National Innovation Surveys in many countries is to develop sectoral, regional, and national indicators and metrics to periodically monitor and evaluate innovations generated by local firms and their impacts, as well as the barriers the companies faced during their innovative activities. For this work, we highlight the importance of quality infrastructure functions as support innovation by firms operating in the sector of information technology services in Brazil.

The quality infrastructure of a country provides a set of techniques and procedures oriented to encode, analyze, and normalize different aspects of new, or substantially modified, product or process. It gathers three primary functions, including metrology, standardization and technical regulation, and...
conformity assessment and its mechanisms (testing, certification, labeling, among others). Besides, three complementary functions are also part of this infrastructure, namely technological information, management system technologies, and intellectual property [9].

Based on the assumptions that: (i) the existence of a national quality infrastructure supports innovative companies operating in the sector of information technology services; (ii) innovation is imperative for these firms; (iii) different sources of technology and learning are used by innovative firms, either for launching new products, improving processes, or meeting standards and technical regulation requirements; and (iv) there are gaps identified in the literature regarding the central theme of this research, namely investigation on the role of the national quality infrastructure for innovation by firms operating in the focused sector; the central question addressed in this paper is: "How companies from the sector of information technology services perceive the importance of quality infrastructure functions in their cycles of innovation?".

We have drawn publicly available data from the National Innovation Survey 2014 (Pintec 2014) concerning the respondent firms operating in the focused sector that have implemented innovations from 2012 to 2014 [10].

This article is structured in five sections. Besides this introduction, section 2 conceptualizes innovation systems and national infrastructure technologies as the theoretical basis for discussing the role of core and complementary functions of the national quality infrastructure in strengthening the innovation capacity of firms belonging to the sector of information technology services in Brazil. Section 3 describes the methodology adopted for developing the study and the primary data source - Pintec 2014, published by the Brazilian Institute of Geography and Statistics (IBGE). In Section 4, the main results are discussed. Finally, Section 5 synthesizes its concluding remarks.

2. Theoretical background
The literature review and documentary analysis covering the period of 1998-2018 encompass two main themes: (i) innovation systems; and (ii) infrastructural technologies (core and complementary functions).

Initially, we present conceptual frameworks of innovation systems, focusing on [1-8]. These frameworks demonstrated their usefulness for investigating the role of quality infrastructure in strengthening innovation capabilities in those firms belonging to the sector of information technology services in Brazil. Then, we conceptualize infrastructural technologies aligned to the quality infrastructure framework postured by [9].

2.1. Innovation systems: concepts and typology
The definition of the national innovation system by Lundvall [2] was adopted during the applied phase of the research, as follows:

"the national innovation system is the flow of technology and information among people, companies, and institutions, which is key to the innovative process on the national level. According to innovation system theory, innovation and technology development are results of a complex set of relationships among actors in the system, which includes enterprises, universities, and government research institutes" [2, p.3].

According to [4], several new concepts emphasize the systemic characteristics of innovation as follows: (i) technological systems [5]; (ii) regional innovation systems [6]; and (iii) sectoral systems of innovation [7;8]. For this work, we assume the concept of a sectoral system of innovation defined in [8]:

“A sectoral system of innovation is composed of the set of heterogeneous agents carrying out market and non-market interactions for the generation, adoption, and use of (new and established) technologies and for the creation, production and use of (new and established) products that pertain to a sector (sectoral products)” [8, p.4].

Therefore, knowledge, technology, and learning can spread from the interactions between people and organizations with specific skills and expertise (e.g., competence on quality infrastructure functions), adding value to the individual organizations and the whole sector.
2.2. **Infrastructural technologies**

In this item, infrastructural technologies integrate the quality infrastructure framework as conceived by [9]. The quality infrastructure ensures that new products, including services, and processes, will suitably integrate supply chains to satisfy final customer requirements and to comply with voluntary standards or technical regulation requirements.

Infrastructural technologies are classified as core and complementary functions of the quality infrastructure. The core functions comprise: metrology, standardization, technical regulation, and conformity assessment. The complementary functions embrace: intellectual property, management system technologies, and technological information. Below are descriptions of the main concepts of the core and complementary functions adopted in previous works [11;12]:

- **Metrology:** is the science of measurement. No testing would be possible unless the characteristics of the product or service in question can be measured in a way that compares them against a physical or chemical reference of known values. Therefore, adequate methods for measuring the properties of products and services are fundamental to the quality assessment process;

- **Standardization and technical regulation:** is the process of developing and implementing technical standards. Standardization can help to maximize compatibility, interoperability, safety, repeatability, or quality. It can also facilitate the commoditization of formerly custom processes. A technical standard is a document that describes the main features of a product, service, or system and the essential requirements that it must meet. Compliance is voluntary. In turn, a technical regulation is a document issued by an authorized body that details product characteristics, production methods, including administrative provisions, for which compliance is mandatory;

- **Conformity assessment procedures:** are technical activities such as testing, verification, inspection, certification, and accreditation, which confirm that products or processes fulfill the requirements laid down in regulations and standards;

- **Intellectual property:** includes inventions, literary and artistic works, symbols, names, images, and designs used by the trade. The property covers two main areas: (i) industrial property (patents, trademarks, industrial designs, geographical indications, and plant variety protection); and (ii) copyright (literary and artistic works, computer programs, internet domains, and immaterial culture);

- **Management system technologies:** Initially, management system technologies focused on adopting quality management (ISO 9000 series) and environmental management (ISO 14000 series) standards and development of management system technologies to comply with these standards requirements. Today, they also include social responsibility and the principles of sustainability in their broad sense;

- **Technological information:** can be understood as any information or knowledge of technological, economic, marketing, managerial and social nature, which contributes to the change and improvement of services, processes, or products, adding knowledge and intelligence required for decision making.

### 3. Methodology

The research methodology comprised three phases: (i) conceptual; (ii) applied; and (iii) conclusive.

The conceptual phase encompassed a systematic literature search on articles published between 1998 and 2018 by accessing Scopus, Web of Science, Science Direct, and others. This search covered the central research themes – innovation systems and national quality infrastructure – and its findings were the basis for the subsequent discussion on the role of metrology, standardization, and conformity assessment in strengthening the innovation capacity of the firms of the focused sector.

The applied phase covered the following steps: (i) firstly, the identification of the class and groups of the National Classification of Economic Activities (acronym in Portuguese, CNAE) related to the sector of information technology services; (ii) revision of the analytical grids defined in previous
academic works [11;12] by ten experts from PUC-Rio; (iii) access to public data from the National Innovation Survey (Pintec 2014) focusing on the selected Pintec 2014 and the CNAE groups previously identified; and (iii) analysis, interpretation and discussion of results, according to the analytical grid defined in the second step.

In the final phase, general conclusions were drawn concerning the main question posed in the introduction of this paper, and suggestions were made for future research work.

It is important to mention that the National Innovation Survey (Pintec) is based on the innovation measurement framework proposed in the Oslo Manual [13]. It was inspired by the experience of the harmonized model proposed by Eurostat, and the third and fourth version of the Community Innovation Survey (CIS), which allows comparability of information with internationally accepted references.

The National Innovation Survey (Pintec) aims to develop innovation indicators and metrics based on the sectors of the National Classification of Economic Activities (acronym in Portuguese, CNAE) [14]. It is carried out by the Brazilian Institute of Geography and Statistics (IBGE) every three years for systematic updating of the innovation indicators by sector [10]. By following the period from 2012 to 2014, Pintec 2014 gives continuity to the series started with Pintec 2000, which collected information related to the triennium in 1998-2000, followed by Pintec 2003 (2001-2003); Pintec 2005 (2003-2005); Pintec 2008 (2006-2008); and Pintec 2011 (2009-2011).

4. Results and discussion
In this section, results from the applied phase of this work are presented in the following items: (i) CNAE groups related to the sector of information technology services; (ii) analytical grip linking Pintec variables and functions of the national quality infrastructure; (iii) results regarding innovative activities; (iv) results concerning sources of information; and (v) results regarding inter-organizational cooperation.

4.1 CNAE groups related to the sector of information technology services
To define the sample of this empirical study, the content analysis of the Pintec 2014 data indicated the number of companies classified under the CNAE 62 – ‘Information Technology Services Activities’ that have implemented innovations from 2012 to 2014.

Table 1 shows a total of 2337 innovative companies classified in the CNAE 62, distributed according to their respective CNAE groups (62.01; 62.02, 62.03, and 62.09). Companies that have implemented innovations from 2012 to 2014 represent 46.3% of companies belonging to the sector of information technology services.

| CNAE Division | Number of companies that have implemented innovations from 2012 to 2014 | CNAE Group | Number of companies that have implemented innovations from 2012 to 2014 |
|---------------|-------------------------------------------------|------------|-------------------------------------------------|
| 62 - Information Technology Services Activities | 2337 | 62.01 - Development of custom computer programs | 984 |
| | | 62.02 - Development and licensing of customizable computer programs | 377 |
| | | 62.03 - Development and licensing of non-customizable computer programs | 298 |
| | | 62.09 - Technical support, maintenance, and other information technology services | 678 |

Source: [10]. Extract from Table 1.1.1 (Pintec 2014).
4.2 Analytical grip linking Pintec variables and functions of the national quality infrastructure

This item presents the grid for analysis contemplating the variables of Pintec 2014 selected for the purposes of this empirical study. They are: (i) innovative activities; (ii) sources of information; and (iii) inter-organizational cooperation for innovation. For each of the Pintec 2014 variables, the respective categories were described, in a total of 30 categories, being eight related to the innovative activities; 14 to the sources of information; and 8 to the cooperation relationships with other organizations.

Based on the analytical grids presented in previous academic works [11;12], the relationships between Pintec categories of variables and the quality infrastructure functions were analyzed by ten experts from PUC-Rio, using as references the definitions of the Pintec 2014 guidelines [10] and the concepts presented in item 2.2 of this paper. A three-point scale (strong, moderate, or weak) for assigning the degree of intensity of these relationships was also defined by the experts. So, the relationships of the Pintec categories of variables with the quality infrastructure functions were classified as: (i) strong, if it has at least three strongly related functions; (ii) moderate, if it has at least two strongly related functions; (iii) weak, if it has at least one relationship with some function of the quality infrastructure; (iv) none, if it has no relationship (Table 2).

Table 2. Grid for analysis: relationships between Pintec 2014 variables and the quality infrastructure functions

| Variable (Pintec) | Category (Pintec) | Link | Quality infrastructure functions |
|-------------------|-------------------|------|---------------------------------|
|                   |                   |      | Core functions | Complementary functions |
|                   |                   |      | MET | STD | CON | INT | MNG | TEC |
| Innovative activities | Industrial design and other technical preparations | Strong | | | | | | |
|                     | Introduction of innovations into the market | Strong | | | | | | |
|                     | Training | Weak | | | | | | |
|                     | Machinery and equipment acquisition | Strong | | | | | | |
|                     | Software acquisition | Weak | | | | | | |
|                     | Acquisition of other external knowledge | Moderate | | | | | | |
|                     | External acquisition of R&D | Strong | | | | | | |
|                     | Internal R&D | Strong | | | | | | |
| Sources of information | Computerized information networks | Strong | | | | | | |
|                     | Fairs and exhibitions | Moderate | | | | | | |
|                     | Conferences, meetings, and specialized publications | Strong | | | | | | |
|                     | Testing and certification institutions | Strong | | | | | | |
|                     | Professional training centers and technical assistance | Moderate | | | | | | |
|                     | Research institutes or technological centers | Moderate | | | | | | |
|                     | Universities or higher education centers | Moderate | | | | | | |
|                     | Consulting firms and independent consultants | Strong | | | | | | |
|                     | Competitors | Strong | | | | | | |
|                     | Customers or final consumers | Strong | | | | | | |
|                     | Suppliers | Strong | | | | | | |
|                     | Other company in the corporate group | Strong | | | | | | |
|                     | Other internal areas of the company (except R&D department) | Weak | | | | | | |
|                     | R&D department | Strong | | | | | | |
| Inter-organizational cooperation | Testing and certification institutions | Strong | | | | | | |
|                     | Professional training centers and technical assistance | Moderate | | | | | | |
|                     | Universities and research institutes | Strong | | | | | | |
|                     | Consulting firms | Moderate | | | | | | |
|                     | Other company in the corporate group | Moderate | | | | | | |
|                     | Competitors | Moderate | | | | | | |
|                     | Suppliers | Strong | | | | | | |
|                     | Customers or final consumers | Strong | | | | | | |

Notation 1: MET – Metrology; STD – Standardization and Technical Regulation; CON – Conformity Assessment; INT – Intellectual Property; MNG – Management System Technologies; TEC – Technological.

Notation 2: ■ the category has a strong relationship with the function; □ the category has a weak relationship with the function.

Sources: Adapted from [11;12]. According to the sectoral characteristics of innovative companies.
4.3. Results regarding innovative activities

Figure 1 shows the results referring to the degree of importance that information technology service companies (that have implemented product or process innovations) assigned to their innovative activities. The percentage values indicate the proportion of companies that attributed the degrees of medium or high importance to each innovative activity, according to the analytical grid (Table 2). Emphasis will be placed on discussing the importance of activities most strongly related to the functions of the quality infrastructure, as follows: (i) introduction of innovations into the market (51.8% of companies assigned medium or high importance to this innovative activity); (ii) machinery and equipment acquisition (50.5%); (iii) industrial design and other technical preparations (28.4%); and (iv) external acquisition of R&D (only 5.0% of the companies).

![Figure 1](image1.png)

**Figure 1.** Percentage of information technology service companies that implemented product or process innovations that assigned a medium or high degree of importance to each innovative activity

4.4. Results regarding inter-organizational cooperation

Cooperation is markedly more present in high-tech sectors given the relatively greater technological complexity of its products and processes and shorter life cycles. Figure 2 shows the proportion of information technology service companies that have implemented product or process innovations that attributed a degree of medium or high importance to cooperative relationships.

![Figure 2](image2.png)

**Figure 2.** Percentage of information technology service companies that implemented product or process innovations that assigned a medium or high degree of importance to each cooperative relationship

All categories of inter-organizational cooperation presented strong or moderate links to the functions of the quality infrastructure. The following categories showed stronger links, and the companies assigned medium or high importance to them, as follows: customers and final consumers
(87.9% of companies assigned medium or high importance to these partners; (ii) suppliers (59.3%); and (iii) universities and research institutes (38.2%).

4.5. Results concerning sources of information

Figure 3 displays the results concerning the degree of importance that information technology service companies (that have implemented product or process innovations) assigned to the use of different sources of information in their innovative activities. The percentage values indicate the proportion of companies that attributed the degrees of medium or high importance to each source of information.

Here, again, we highlight the importance of sources of information most strongly related to the functions of the quality infrastructure, as follows: (i) computerized information networks (93.8% of companies assigned medium or high importance to this source of information); (ii) customers or final consumers (88.1%); (iii) conferences, meetings, and specialized publications (59.4%); (iv) competitors (58.5%); and (v) testing and certification institutions (32.7%).

Due to space limitations, the results of the empirical study were partially discussed in this section. Nevertheless, all results of the empirical study are published in the first author’s MSc. Dissertation, on which this paper was based [15].

5. Final remarks

In this paper, an attempt was made to investigate the importance of quality infrastructure functions in the cycles of innovation of companies operating in the information technology services in Brazil.

The analytical grids defined in previous academic works [11;12] were revised by ten experts from PUC-Rio, who considered the specificities of the sector and highlighted the strong links between the mentioned functions and the categories of Pintec 2014 variables. The functions of the quality infrastructure were then individually associated with the categories of each variable (see Table 2).

Based on the results presented, it is possible to conclude that the innovative companies in the sector of information technology services attributed a high and medium degree of importance to those categories of Pintec variables, which are strongly linked to the functions of the quality infrastructure.

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Disclaimer
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