DOI: 10.20396/rbi.v17i2.8649844

Artigo

The impacts of innovations in the diversification of the Brazilian industry: an analysis based on Pintec and Cempre

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Received: 09 July 2017 Revised version: 30 November 2017 Accepted: 20 July 2018

Abstract

The article aims to associate the differences in the pattern of diversification with the differences in the pattern of innovation of the Brazilian industrial sectors. The neo-Schumpeterian literature advocates that the establishment of sectoral patterns of innovation influences the rates and directions of technological change in a distinctive way among sectors. This is an empirical study, based on the statistical information of the Innovation Survey (Pintec 2011) and the Central Register of Companies (Cempre 2010), to investigate the relationship between innovation and diversification, in order to contribute to the understanding of the sectoral patterns of diversification of the Brazilian industry. The statistical results suggest that the introduction of innovations to a large extent has led industries to concentrate their business lines on activities that have some 'proximity' in their production functions, independent of innovative activities. Notably, certain sectors, such as 'science-based' ones, assume typical behaviour of 'diversification based on technological activities'.

Keywords | Technological innovations; diversification; Pintec; Brazil

JEL Code | L25; O31

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Os impactos das inovações na diversificação da indústria brasileira: uma análise com base na Pintec e no Cempre

Resumo

O artigo tem por objetivo associar as diferenças no padrão de diversificação com as diferenças no padrão de inovação dos setores industriais brasileiros. A literatura neo-schumpeteriana preconiza que o estabelecimento de padrões setoriais de inovação influencia os ritmos e as direções da mudança tecnológica de forma distinta entre os setores. Trata-se de um estudo empírico, com base nas informações estatísticas da Pesquisa de Inovação (Pintec 2011) e do Cadastro Central de Empresas (Cempre 2010), para investigar a relação entre inovação e diversificação, no sentido de contribuir para o entendimento dos padrões setoriais de diversificação da indústria brasileira. Os resultados estatísticos sugerem que a introdução de inovações, em grande medida, tem levado as indústrias a uma concentração de suas linhas de negócios em atividades que guardam alguma 'proximidade' em suas funções de produção, independente das atividades inovativas. Notadamente, certos setores, como os 'baseados em ciência', assumem comportamentos típicos de 'diversificação baseada em atividades tecnológicas'.

Palavras-chave | Inovações tecnológicas; diversificação; Pintec; Brasil

Códigos-Jel | L25; O31

1. Introduction

In an empirical analysis of the characteristics of innovations and innovating firms in the United Kingdom, Pavitt (1984) identifies important similarities and differences between sectors in the sources, nature and impact of the innovations of UK firms. In his description of the sectoral patterns of technical change, in terms of generating innovations and intersectoral technology flows, the author explains the intersectoral differences of rate and direction of technological change. He postulates that sectors vary in relative importance of product and process innovations, in process technology sources and in size and patterns of technological diversification of innovating firms. According to the author, the possibilities of technological diversification (proportion of innovations outside of their main activity sector, composed of three digit SIC – Standard Industrial Classification) vary according to the relative importance of product and process innovations to the sector. For an analysis of intersectoral transfer of technologies, the author admits that, when the firm's innovation is bought and used in the same sector, what is product innovation for the firm will be a process innovation for the sector; conversely, when the firm produces and uses its capital goods, a process innovation in the firm will be a product innovation for the sector. In any way, product innovation predominates both for firms and for sectors.

In the author's view, as innovation patterns are cumulative, their technological trajectories will be largely determined by what the innovating firm has done in the past, that is, what its core business is. Therefore, different main activities generate different technological trajectories associated with sectoral specificities, typified in three basic categories: supplier-dominated sectors; production-intensive sectors (including scale-intensive producers and specialised suppliers); and science-based sectors.

Studies that discuss the diversity of innovative results in Italian (ARCHIBUGI; CESARATTI; SIRILLI, 1991) and Spanish industries (URRACA, 1998; 2000), from the point of view of sectoral patterns of technical change, confirm the propositions of Pavitt (1984) and Pavitt, Robson and Townsend (1989). Nevertheless, according to Campos and Urraca-Ruiz (2009), who follow Arocena and Sutz (2003), it cannot be said that the standard of technical change found in developed countries applies rigorously to the Brazilian industry and those of other developing countries, due to market and technological specificities related to the processes of knowledge generation, innovation and learning.

Although there are numerous empirical studies on diversification in Brazil (NEGRI; SALERMO; CASTRO, 2005; RABELO; COUTINHO, 2001; RUIZ,

1996; 1997; 2012; HOLANDA FILHO, 1983; REISS, 1980; MILLER, 1981; RIBEIRO, 1969), little has been investigated about the effects of sectoral differences in terms of relative importance of product and process innovations on the diversification patterns of the Brazilian industry.

Recent research has contributed to establishing a classification of the Brazilian industrial sectors that is different from the classifications of developed countries.[1] For example, Furtado and Carvalho (2005) suggest a sectoral classification that is distinct from that of the Organisation for Economic Co-operation and Development – OECD, according to its technological intensity (R&D/Value Added), because they observed different patterns of technological efforts in relation to developed countries. Campos and Urraca-Ruiz (2009), in turn, make an important methodological contribution in the development of a structure of analysis of sectorial patterns of innovation, adapted from Pavitt (1984) and Pavitt, Robson and Townsend (1989), to examine the regularities in the innovative profile of the Brazilian industry in relation to differences of rate and direction of technological change. These studies were based on the Pintec 2000 database – the first nationwide innovation survey, produced by the Brazilian Institute of Geography and Statistics – IBGE.

The work of Campos and Urraca-Ruiz (2009), in particular, seeks to reveal the sectorial patterns of innovations of the Brazilian industry, according to its sources of innovation, forms of learning and knowledge, results of innovations, technological trajectory and sector structure/performance. Additionally, the present work aims to advance in this field of research, performing a complementary analysis about the behaviour of Brazilian industries in terms of their sectoral patterns of diversification. Using Pintec data on innovations and comparing them to the diversification of companies in the Central Register of Companies(*Cadastro Central de Empresas* – Cempre), both carried out by IBGE, it is possible to verify, first, what level of diversification Brazilian companies present, and, then, the degree to which the implementation of new products and processes is associated with the diversification of productive activities, according to the sectoral patterns postulated by the literature.

That said, this article aims to associate differences in the diversification pattern with differences in the innovation pattern of the Brazilian industrial sectors. The basic argument is to consider that technological diversification depends on the intensity of the innovative activities performed by firms and the relative emphasis between process technologies (incorporated in the production systems themselves) and product

1 The study of Ferraz, Kupfer and Haguenauer (1995) represented the first analytical effort of constructing (adapting) an industrial taxonomy as proposed by Pavitt (1984) for Brazil.

technologies linked to different sectors (PAVITT; ROBSON; TOWNSEND, 1989). It is assumed here that the sectoral pattern of technological activities of the firms that operate in different sectors, as well as sectoral technological links, conditions the degree and the pattern of technological diversification. This work is based on neo-Schumpeterian literature, which defends that the establishment of sectoral patterns of innovation influences the rates and directions of technological change in a distinct way between sectors.

An empirical investigation, based on such statistical information available, on the relationship between innovation and diversification is necessary for the analysis of the dynamics and organization of the productive activities of innovating companies, in order to contribute to the understanding of intersectoral differences in the direction of technological changes in the Brazilian industry. To this end, the following analytical techniques have been adopted: the Pearson correlation coefficient (r), to measure the 'association' between the variables, and the least square method, for the 'causality' between them.

The study is structured as follows: the subsequent topic exposes the theoretical and empirical foundations of the analysis of sectoral patterns of diversification. Section 3 presents the methodological procedures of the work. In the fourth section, the behaviour of Brazilian industrial sectors is examined in order to check for diversification patterns. Finally, conclusions are drawn.

2. Theoretical foundations

The results of several empirical studies on the relationship between technology and the behaviour of firms vary greatly according to the theoretical and methodological specifications and the variables adopted in the analysis. Here, we aim to identify what we call 'diversification based on technological activities' as an exploratory and partial measure of the concept of 'technological diversification' formulated by Pavitt (1984) and Pavitt, Robson and Townsend (1989). The literature on this topic also discusses the concept of 'production diversification' of firms with productive activities in closely related product markets; however, the factors explaining such diversification will not be investigated in this work.

Considering the theoretical implications that emerged from the investigations of Pavitt (1984) and Pavitt, Robson and Townsend (1989), it is necessary to qualify their concepts of technological diversification of firms, as they serve as a basis of comparison between other studies on the same issue:

a. Specialisation – it is measured by the proportion of technological activities in the same three-digit SIC category, in which the sector principal of production is located;
b. Narrow diversification – large proportion of technological activities in the same two-digit category but with sector principal of production in different three-digit categories;
c. Broad diversification – large proportion of innovative activities in two-digit categories that are different from sector principal of production.

The application of all these concepts of diversification depends on the richness, the details and the availability of statistical data on the technological and productive activities of individual firms. It should be emphasized that 'narrow diversification' and 'broad diversification' will also not be the focus of the present work due to the limitations of the statistical data published by IBGE; more detailed information can be obtained by special tabulation (Pintec and Cempre) in future studies. In any case, both will be treated in the restricted sense of the term, without reference to their direction, i.e., as only 'diversification based on technological activities' either within or beyond the industrial sector in consideration.

The theoretical foundations and some empirical results of studies regarding diversification and its links to innovation are discussed below.

2.1. Diversification of firms

For Penrose (1959), the diversification of productive activities of a firm occurs through the manufacture of completely new products, provided that it implies some significant difference in its production programs (productive bases) and distribution. Therefore, a firm can have several productive bases, and even when they are related to each other by common elements, be it knowledge or technology, they will be treated as different bases, if there are substantial differences in their technological characteristics.

In Penrose's (1959) view, the opportunities for diversification in a firm are considerably expanded when they are linked to the specialised knowledge of a technology that is not, in itself, very specific in relation to any single type of product, such as knowledge on different types of engineering or industrial chemical processes.

The traditional literature seeks to explain the possible directions of the diversification process as part of firms' strategies in compensating the risks and the uncertainties associated to specific product markets, from the notion of 'technological proximity' between the original activities of the firm and the new activities to which it intends to expand (PAVITT, 1984; FAI, 2001). Teece et al. (1994), for example, postulate that firms build up laterally (related activities) from what they already have (common capabilities), through enterprise learning and competences development, as well as complementary assets (services such as marketing, competitive manufacturing and after-sales support).

In this perspective, diversification has been explained from the point of view of the product market (RUMELT, 1974; TEECE, 1982; WERNERFELT, 1984; PORTER, 1985; TEECE; PISANO; SHUEN, 1997). Firms' evolutionary and resource-based approaches adopt the notion of similarity and 'coherence' from the perception that firms diversify into related product markets or other areas that are 'close' to their current competences profile, in the sense that there are certain common technological and market characteristics between their product lines (TEECE et al., 1994; DOSI; TEECE; WINTER, 1992; PRAHALAD; HAMEL, 1990).

However, diversity in technological competences, at least on the part of the largest companies, has become broader than the varied range of products, with some companies even deliberately reorienting and restricting their range of products, such as the electronics and chemical industries. Pavitt, Robson and Townsend (1989) note that, in most sectors, there has been a concentration of the technological activities of firms in their principal output activity, reflecting the differentiated nature of technological knowledge, as well as the technological interdependence between firms and sectors. Piscitello (2005) cites other empirical evidence that shows a recent reduction in the diversity of firms' products, but with continued increase in the diversity of their technological bases (MARKIDES; WILLIANSON, 1994; GAMBARDELLA; TORRISI, 1998). It is believed, therefore, that few products are made with simple processes and several simple products present technological diversity. It is probable, then, that the growing technological diversity within firms takes place in those markets whose products are exposed to radical market changes much more often than technological competences are exposed to radical technological changes (FAI, 2001). In the evolutionary perspective, which highlights the importance of technological trajectory, technological diversification occurs independently of product diversification. The diversification itself of their technological basis will probably benefit firms with the exploitation of new technological possibilities (NELSON, 1959).

In the discussion of the relationship between diversification and innovation, many empirical studies try to explain the effects of technological diversification from the point of view of technologically specialised firms *versus* diversified firms (GARCIA-VEGA, 2006; CANTWELL; VERTOVA, 2004; BRESCHI; LISSONI; MALERBA, 2003; AUDRETSCH; FELDMAN, 1999; GRANSTRAND, 1998; SCHERER, 1984). According to Garcia-Vega (2006), empirical research seems to support the assumptions that technological and product diversification have a different impact on the economic performance of a firm. Some studies emphasize that product concentration can enhance innovation for the firm, either because of the expansion of the spectrum of its technological capabilities, resulting in more complex and developed products (GAMBARDELLA; TORRISI, 1998), because of the ability to exploit and broaden its corporate coherence over time – that is, the greater the intensity and exploitation of interconnectivity between a firm's technological bases and its products, the more it can innovate (PISCITELLO, 2005) – or to compete in a narrow range of products (GRANSTRAND; PATEL PAVITT, 1997). However, the very effort to improve product quality may require some diversification of technological bases (FAI, 2001; GARCIA-VEGA, 2006); in other words, companies need to expand their innovative activities in more than one technology (BRESCHI; LISSONI; MALERBA, 2003).

Other investigations point to an adverse impact on innovation as product diversification increases. For example, Heeley and Matusik (2004) report that a broad technological portfolio combined with narrow market diversification strategies present incremental innovations (innovations used in the same technological area), while high technological and product diversification lead to innovations in platforms (innovations used in different technological areas). In general, according to Breschi, Lissoni and Malerba (2003), in these studies, it is assumed, on the one hand, that the most technologically specialised firms are more innovating than the most diversified ones, assuming that the firms that focus their R&D on a small number of technological fields can profit from the specialisation of their research activities. In contrast, it is believed that the most technologically diversified firms can achieve certain advantages in competitive markets, such as the ability to survive and grow as an innovator, and/or vice-versa (survivor principle). In addition, Pavitt, Robson and Townsend (1989) refer to aspects related to transaction costs (opportunism and uncertainty) and technical interdependencies in process technologies, both involving suppliers, customers or business partners.

Breschi, Lissoni and Malerba (2003) also highlight that several studies in the field of industrial organization and technical changes have recently turned to the issue of nature and determinants of product and technology diversification of firms. The range of firms' technological and productive activities is far from being driven by the search for short-term profits and firms exhibit some coherence in the technological and productive activities in which they are involved. The authors suggest that knowledge 'relatedness' is a key factor in affecting the technological diversification of companies. According to Garcia-Vega (2006), growing technological diversification can promote cross-fertilisation between different technological areas of a firm and create incentives to enhance innovation and elevate investments in R&D.

2.2. Sectoral patterns of diversification

Pavitt (1984) claims that it is highly difficult to establish a causal link between technological and production diversification. In other words, high innovation rates do not necessarily lead to heavily concentrated industries (production diversification). His understanding on patterns of diversification goes beyond the notion of 'proximity' between the business lines of firms, with respect to product diversification – Wernerfelt (1984), Barney (1991), Markides and Williamson (1994) and Robins and Wiersema (1995), for example, defend that product-related diversification outweighs unrelated diversification.

The works of Pavitt (1984) and Pavitt, Robson and Townsend (1989) advance significantly on the results of previous empirical studies that had discussed the patterns of diversification, finding that there are significant sectoral differences in the patterns of production and technological diversification. The study of Pavitt, Robson and Townsend (1989), as well as that of Granstrand (1998), confirms that the extent of (two digit SIC) production diversification of firms is not correlated with technology diversification. This is because firms may decide to maintain a technological capacity without the corresponding production, as a protection against opportunistic behaviour from suppliers, customers or partners and against an uncertain future (in terms of competitors' response and market size). Better yet, greater diversity in technology rather than in production can provide firms with certain competitive advantages associated with transaction costs – benefits from innovations (appropriability and learning) versus production returns (economic performance).

From the point of view of technological opportunities, in Pavitt's (1984) understanding, a firm's possibilities of diversification vary according to the relative proportion of its technological activities (with emphasis on product technology) that are made and used in other sectors (at the three or four digit level), different from that of its principal activity. In turn, technology-based input threats come from firms from any other sector, but with significant innovations made in their essential activities (at the three digit level). Furthermore, the success of innovations depends on the usual appropriability mechanisms of their productive and technological activities.

From his theory and taxonomy, Pavitt (1984) identifies some diversification patterns: science-based firms present a high potential for technological diversification, while production-intensive and supplier-dominated firms manifest a weak link between technological and production diversification. Regarding the production-intensive firms, diversification in production is relatively lower than in technology, perhaps because they do not exploit all opportunities for technology-based diversification upstream into equipment supply. Supplier-dominated firms, such as textile firms, diversify more in production than in technology, probably, as the author says, because of non-technological complementarities with other sectors and the high degree of dependence on external sources to the development of process technology (weak engineering capabilities and in-house R&D) – in the words of Pavitt, Robson and Townsend (1989), the opportunities for firm-specific technological advantage are few, and generally related to process, rather than product, technology.

In general, recent empirical results have confirmed the argument that 'coherence' is a common feature both in technological and in production diversification, through following coherent patterns in different periods (PISCITELLO, 2000), from the widest to the narrowest diversification (FAI, 2003). Piscitello (2000) verifies that the diversification of products carried out by large companies was more coherent in certain specific periods – approximately, the late-1970s and the mid-1980s. Technological diversification strategies, in turn, followed coherent paths predominantly from the end of the 1980s to the mid-1990s.

However, a comprehensive explanation of all aspects related to diversification is not an easy task. As Breschi, Lissoni and Malerba (2003) warn, the notion, determinants and measurement of firms' coherence still need to be fully developed, at both conceptual and empirical levels. Therefore, we believe that it is important to return to the fundamental contributions of Pavitt's (1984) theory and taxonomy.

2.3. Technological relatedness *versus* technological proximity

Pavitt (1984) stresses some limitations present in the empirical models that had tried, until then, to explain the direction of diversification and the connection between different productive activities of firms. According to the author, most of the empirical studies on the patterns of diversification actually referred to the notion of 'technological proximity' to explain production diversification. Moreover, several authors have recently emphasized the causal links ranging from innovation to the size of firms. Garcia-Vega (2006), Breschi, Lissoni and Malerba (2003) and Piscitello (2000) see that most of the empirical research that links diversification and innovation at the firm level is still based on product diversification measures. Such studies seek to show correlation between product diversification and different measures of innovation, such as the intensity of R&D (GRABOWSKI, 1968; TEECE, 1980), number of technicians (GORT, 1962) or number of patents (SCHERER, 1984). However, it should be considered that product diversification is a limited measure, which can hardly serve as a measure of technological diversification of firms.

Traditionally, product diversification has been measured based on the proportion of products produced beyond the firm's principal activity (RUMELT, 1974), to explain the degree of 'proximity' between the business lines (related product market). The economic and managerial literature has paid greater attention to corporate diversification, focusing largely on the reasons for and nature of product diversification. According to Piscitello (2000), the notion of proximity contains a unidirectional dimension linked to the concept of corporate coherence, that is, it cannot be expected that firms have the same strategic vision – what is related diversification and coherent organization for a firm may not be so for another, says the author.

Technological diversification measurements, in turn, refer to the distribution of firms producing innovations (technological activities) outside of their principal activity, mainly at the two digit level (PAVITT, 1984; PAVITT; ROBSON; TOWNSEND, 1989). This new vision represents an additional theoretical and empirical contribution to the notion of technological proximity by explaining the differences in the sectoral patterns of technological and innovation development. In this perspective, relatedness is considered, according to Piscitello (2000), as a concept exclusively associated to the properties inherent to the sectors, that is, it can be unveiled in three dimensions: industry-, technology- and firm-specific.

Pavitt, Robson and Townsend (1989) suggest, then, investigating the extent to which a large, a small or a different type of technological opportunity (e.g. innovations and patents) is reflected in the degree of diversification. Therefore, they seek to understand the pattern and the path of technological activities of firms that produce in different two- or three-digit sectors and the degree to which their accumulated technologies are transformed into production. As a result, they identified various patterns among sectors, including a large proportion of technologically related activities that go beyond the measures often used by industrial economists[2] (closely related products market). Therefore, technological relatedness, according to the authors, is not confined to close proximity in three- or four-digit categories, but extends upstream (in relation to producer goods), horizontally (within mechanics, instruments, machinery, electric and electronics, and chemistry) and downstream (in users sectors), all of which are measured as broad diversification in other two-digit sectors. In other words, there is a general trend of increasing technological diversification: upstream in production technologies for scale-intensive and supplier-dominated firms; upstream, horizontally and downstream for chemical firms; and horizontally and downstream for mechanical engineering, instruments, and electric and electronics firms.

Despite the controversial discussions on the link between technology and production diversification, the present study is limited to examining the correlation between innovation and diversification within Pavitt's sectoral categories, from the empirical standpoint based on Pintec and Cempre. In order to do this, we shall attempt to measure and explain the level and regularities of the 'diversification based on technological activities' of Brazilian companies, according to the methodological procedures described below.

3. Data and methods

In order to test the relationship between innovation and diversification, the following analysis techniques were adopted: the Pearson correlation coefficient (*r*), to measure the 'association' between the variables, and the least square method, for the 'causality' between them. This measures, therefore, the extent to which the association observed between two variables exceeds what is expected (strong positive correlation from 0.70 to 1.0, for the significance level of 5% - P-value), if the industries diversify their activities in different three-digit categories from the National Classification of Economic Activities (*Classificação Nacional de Atividades Econômicas* – CNAE). Similar results are expected in the case of industries that concentrate their productive activities in a single three-digit CNAE sector, understood here as 'specialisation'.

In these terms, the equation (1) provides information on some of the determinants of specialisation or diversification by sectoral category.

2 The authors cite Scherer (1980), Doi (1985) and Hughes (1987), who had encountered, until then, unexpected statistical relations between sectoral technological intensity (R&D) and production diversification - the relationship was generally negative at the two-digit level or indeterminate at three digits.

$$DEP = \propto + \beta_1 INOVA + \beta_2 EGRUPO + \varepsilon \quad (1)$$

In order to verify separately whether innovation rates lead to specialisation and/or diversification, the statistical analysis was based on two models of multiple regression estimated with the same equation (1). In the first one (Table 1), the dependent variable (DEP) is the 'specialisation' indicator (DEP-esp) of companies with activities in a single CNAE group, in the second (Table 2), there is an indicator of 'diversification' (DEP-div) for companies with activities in different groups, both as a function of the independent variables 'new and improved product innovations' (INOVA) and 'participation of other companies of the group in the innovations' (EGRUPO), as shown in Table 1. The latter is the proxy for the participation of other companies of the group as responsible for the innovative activities so as to explain the technological connection between the productive units of the company. In addition, α is the constant term (line intersection), β_1 and β_2 are the gradients (line slope), and ε is the random error. Both variables, INOVA and EGRUPO, were used in separate statistical analyses for the specific set of variables corresponding to each of the four sectoral categories of industries.

As a result, a statistically significant correlation of $P < 0.05$ is expected between the variables. A specific parameter of statistical inference, the linear coefficient (intersection), can indicate a probable diversification in production, but one which is difficult to explain on account of other factors that are optionally not specified in the statistical model. This also occurs in the sectoral categories whose correlations between the variables are not statistically significant.

Specifically, the present work aims to test the hypothesis that the degree of specialisation/diversification is positively associated with high rates of innovation, particularly product innovation, by firms that operate in different sectors, according to different sectoral patterns that have been predicted in the literature. Thus, the basic hypothesis is to consider that the sectoral pattern of technological activities conditions the degree and the pattern of diversification, seeing that different opportunities based on technology for growth and diversification are open to firms.

This empirical research uses IBGE statistical data to establish a relationship between innovation indicators, based on Pintec 2011 (IBGE, 2013), for the period from 2009 to 2011, and indicators of diversification of industrial enterprises, according to information from Cempre, for the year from 2010 (IBGE, 2012a). The data from IBGE provide considerable information, albeit little explored in academic works, about the 'degree' of diversification, measured in product classes and industry censuses, in accordance with CNAE. It should be noted that the data on the diversification of Brazilian companies, disaggregated by size of companies and three-digit sectors, were obtained from DPE/IBGE upon request for special tabulation. For the due procedure of empirical analysis, a few important requirements were necessary:

1) readjusting certain industrial sectors regrouped by Campos and Urraca-Ruiz (2009), contained in Pintec 2000 (CNAE 1.0), according to the disaggregation from Pintec 2011, due to the new version of CNAE 2.0, established in 2007; and
2) grouping the variables conceptualized by IBGE which follow common classification criteria – activities in a single three-digit CNAE group, or in different groups.

Table 1 presents the definition of the variables used in this work, according to the conceptualisation adopted by IBGE (2007). Considering the count of companies with 'more than one local unit', it is possible to measure the 'specialisation' as an indicator of business lines in a single CNAE group, assembling together both the variables determined by IBGE, 'non-diversified companies' (with activities in a single Federation Unit) and 'spatially diversified companies' (located in different Federation Units), as they focus their business lines on economic activities with similar production functions. In turn, the 'diversification' indicator is comprised of companies classified as 'diversified by activity' and 'joint diversified' (diversified spatially and by activity), since they act in more than one group (IBGE, 2012a).

TABLE 1
Variables of the statistical model

Variable/indicator	Definition of the variable	Source
DEP-esp: specialisation	Percentage of companies with activities in a single CNAE group out of the total number of companies	Cempre 2010
DEP-div: diversification	Percentage of companies with activities in different CNAE groups in relation to the total number of companies	Cempre 2010
INOVA: innovation	Percentage of companies that have innovated in new and improved products out of the total number of companies that have implemented innovations	Pintec 2011
EGRUPO: participation of other companies of the group	Percentage of other companies in the group as main responsible for product and/or process development out of the total number of companies that have implemented innovations	Pintec 2011

Source: Author, based on Cempre 2010 and Pintec 2011.

From Pintec 2011 we extracted data to represent the variables that define the pattern of innovation: (1) of product and process innovations (degree of novelty of the main product and/or main process); and (2) of the company responsible for the development of the product and/or process (the company or other companies of the group).

It is considered that there are differences in the patterns of technological development and innovation among the sectors, but we must also consider the differences in the patterns of technological development and innovation between developed and developing countries. Thus, the present work follows the propositions of an analysis structure developed by Campos and Urraca-Ruiz (2009), which adapted the taxonomy of Pavitt (1984) and Pavitt, Robson and Townsend (1989)[3] according to the sectoral standards of innovation observed in Brazilian industry, based on the data from Pintec 2000.

Campos and Urraca-Ruiz (2009) present some changes in the Pavittian standards for the Brazilian case, namely the: (i) inclusion of the 'Rubber and plastic' and 'Coke, nuclear and biofuels' sectors in the 'supply-dominated' category; (ii) inclusion of the 'Pulp and other derived products' sector in 'specialised suppliers'; and (iii) inclusion of the 'Tobacco' sector in 'Scale economy-intensive'. In addition to these suggestions for grouping Brazilian industries in the sectoral patterns of innovation, certain sectors need to be reordered according to the changes of CNAE 2.0, incorporated in Pintec 2011, as demonstrated in Table 2.

In qualitative terms, similar to the concept of a technological base or production base, formulated by Penrose (1959), the agglutination of the industrial activities of companies by IBGE satisfies homogeneously, at the lowest level of aggregation, the conditions of similarity of productive functions - complementary and related machines, processes and raw materials. In the economic censuses and other IBGE research, the different categories at a (three-digit) CNAE group level, for example, comprise economic activities with significantly different production function (IBGE, 2007). However, within a given three-digit industry, several 'technological bases' (e.g., in the manufacture of inorganic chemicals, CNAE group 20.1, there are other four-digit technology bases, such as chloride and alkalis, class 20.11, fertilizers, class 20.13, and industrial gases, class 20.14).

3 Pavitt, Robson and Townsend (1989) propose a revision of the previous taxonomy, which includes the 'information-intensive' category and eliminates the 'supply-dominated' category, whose sectors were reordered as 'scale-intensive' or 'information--intensive'. However, for the Brazilian case, there are still too few investigations to corroborate such propositions (CAMPOS; URRACA-RUIZ, 2009).

TABLE 2
Classification of Brazilian industrial activities, according to categories of sectoral patterns of innovation

Industrial sectors	Division/Group CNAE 2.0	Tag
1. Supplier-dominated sectors		
Extraction and mining	05+06+07+08+09	SD1
Food	10	SD2
Beverages	11	SD3
Textiles	13	SD4
Wearing apparel	14	SD5
Leather, luggage, handbag and the like, footwear	15	SD6
Products of wood	16	SD7
Paper, paper products and paperboard	17.2+17.3+17.4	SD8
Printing and reproduction of recorded media	18	SD9
Coke and biofuels	19.1+19.3	SD10
Rubber and plastic products	22	SD11
Non-metallic mineral products	23	SD12
Metal products	25	SD13
Furniture	31	SD14
Other manufacturing	32	SD15
2. Specialised-supplier sectors		
Pulp	17.1	SS1
Machinery and equipment	28	SS2
Precision, medical and optical equipment	26.5+26.6+26.7+26.8	SS3
Parts and accessories for motor vehicles	29.3+29.4+29.5	SS4
Other transport equipment	30	SS5
3.Scale-intensive (economies of scale and mass production) sectors		
Tobacco products	12	SI1
Refined petroleum products	19.2	SI2
Iron and steel	24.1+24.2+24.3	SI3
Casting and non-ferrous metal products	24.4+24.5	SI4
Motor vehicles, trailers and semi-trailers	29.1+29.2	SI5
4.Science-based and R&D intensive sectors		
Chemical products	20	SB1
Pharmaceutical and medicinal chemical products	21	SB2
Electronic components, computers and peripherals, and consumer electronics	26.1+26.2+26.4	SB3
Communication equipment	26.3	SB4
Electrical equipment	27	SB5

Source: Adapted from Campos and Urraca-Ruiz (2009) according to CNAE 2.0 (IBGE, 2007).
Note: The sector 'maintenance, repair and installation of machinery and equipment' (33) was not classified in the industrial groups because it seen as technical assistance.

It is important to clarify the definitions of product and process innovations, as well as their technological impacts on the firms and/or sectors. Product innovation requires a great deal of innovative resources on the part of the company, and it also has the ability to bring process innovations along with it. The concept of process innovation, in turn, refers to the implementation of a new or substantially improved 'method of production' or 'method of product delivery', including significant changes in techniques, equipment and/or software in production-support activities. Moreover, the installation of new machines and equipment, different from the models used by the company, which substantially improve its technological performance or that are necessary for the implementation of new products, is a process innovation (IBGE, 2012b).

4. Sectoral patterns of diversification of the Brazilian industry

The data from Pintec 2011 demonstrate the rates of product and process innovation, disaggregated from a sectoral standpoint in Brazil. In Pintec 2011, out of the total of 116,632 companies of the extractive and processing industry with 10 or more people occupied, 41,470 had implemented new or significantly improved products or processes, corresponding to a general innovation rate of 35.5%, against 38.1% in Pintec 2008.

From the standpoint of the sectoral pattern of innovation, as can be seen in Figure 1, the 'scale-intensive' and 'science-based' sectors are strongly active in introducing completely new products, as verified by Pavitt (1984), with special highlight to the following industries: automotive (SI5 – 44.2%), precision, medical and optical equipment (SS3 – 33.4%), chemicals (SB1 – 18.2%), pharmaceutical and medicinal chemical products (SB2 – 22.9%), and electronic components, computers and peripherals, and consumer electronics (SB3 – 31.2%) – see appendix 1.

However, according to Pavitt (1984), the sectors differ in relation to the distinctive characteristics of their technical production systems. Commonly, product and process innovations are more or less balanced in industries that operate with continuous process technology (e.g., food and beverages, metal, building materials, especially glass and cement). However, in the Brazilian case, the so-called 'supplier-dominated' sectors (SD) present an average, relatively low, balance of 0.68[4] between product and process innovations. In turn, process innovations predominate over

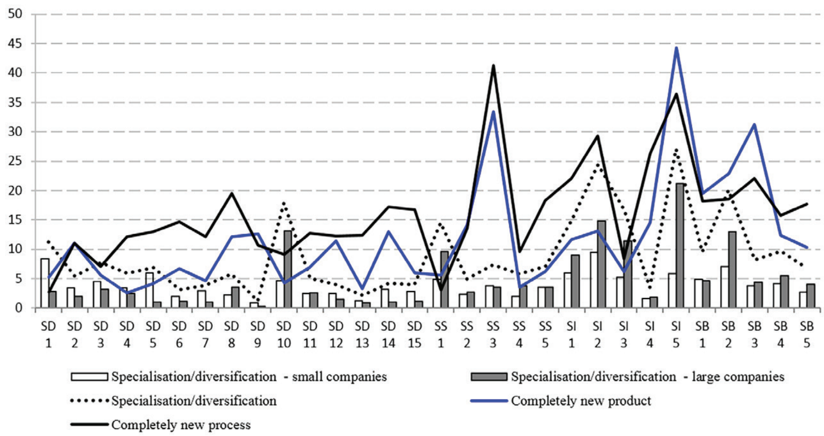
4 Balance calculated from the proportion of product innovations in relation to process innovations.

product innovations in industries characterized by assembly operations, such as shipbuilding and vehicles – in fact, the balance of product innovations in relation to process innovations in the 'specialised suppliers' sectors (SS) was 0.87 and, in 'scale-intensive' (SI), 0.7 on average. This behaviour reflects the nature of the competition and the typical technological dynamics of the sector that push companies to actively participate in the introduction of product and process innovations that affect their products, mainly through the continuous search for improved quality (new components and incorporating performance control software with on-board computer integration) and new production methods (modularisation-subcontracting), respectively.

In the case of the 'science-based' sectors (SB), the relative balance between product and process innovations is usually mixed (1.02 in such Brazilian industries). The data on the Brazilian industry are consistent with the assumptions of Pavitt (1984) and Pavitt, Robson and Townsend (1989), when innovation is combined with size of the firm (Figure 1). In the 'supplier-dominated' sectors, companies are, in fact, small, with rare exceptions (SD8 and SD10), whose results corroborate the assumption that, in general, any increase in the size of the firm cannot usually be attributed to innovations, given that few of them are generated in the sector – due to low opportunities and technological requirements. As for the 'specialised suppliers', there is also a strong presence of small businesses, perhaps because of the low entry barriers by numerous users. In the other sectoral categories, companies are generally large and typically diversified, and which become large on the basis of their accumulated skills, as a result of either the appropriation of more abundant (science-based) technological opportunities or of (scale-intensive) technological requirements of efficient production.

In order to perform an analysis of the Brazilian industries in relation to the sectoral pattern of diversification, some requirements become necessary in view of the limitations in the statistical information used in this study. In the conceptual and analytical terms adopted by Pavitt (1984) and Pavitt, Robson and Townsend (1989), the proper understanding of the direction and other characteristics of technological trajectories, according to categories of innovating companies, requires at least a statistical analysis from the correlation matrix of the sectoral distribution of technological activities of companies according to their principal activity. Since the IBGE data does not offer information regarding the distribution of innovative activities (product and process innovations) by the principal activity sector of the innovating company, we opted to relate (cross) information about innovations according to the main responsible firm for their development, i.e., the company or other company of the group.

FIGURE 1
Percentage of companies that implemented innovations of completely new product or process (2009-2011) and indicators of specialisation/diversification (2010), according to size of companies by industry sectoral categories
Brazil



Source: author, based on Pintec 2011 and Cempre 2010.
Notes: small companies comprise micro and small businesses, which employ up to 49 people; large companies cover medium and large companies with more than 50 employees.

When the analysis focuses on the structure of participations, there is no doubt that it displays the active involvement in development and implementation of new or improved products and processes by the company or by other companies of the group, but still made in Brazil. These innovative activities are measured by Pintec and refer to the scientific, technological, organizational and commercial steps, including investment in new forms of knowledge, aimed at the innovation of products and/or processes, through direct or other determinant activities for the realization of R&D, such as design, construction and test of prototypes or pilot installations, including software development for scientific and technological purposes (IBGE, 2012b).

That said, from the parameters estimated in Table 3, there are no significant correlations (P < 0.05) between 'specialisation' and the indicators of innovations of new and improved products, which are developed by the companies responsible for the technological activities at the CNAE group level, in the different sectoral categories, in the period from 2009 to 2011.

These results may suggest that industries are concentrating their business lines on economic activities with similar production functions, regardless of the development and implementation of innovative activities in their companies. Furthermore, the linear coefficient α, in all sectoral categories, indicates the percentage of 'specialised companies' which is not explained by the product innovations developed by themselves, but by other factors or reasons related to the expansion of production (productive specialisation).

TABLE 3
Association analysis: specialisation (DEP-esp) and innovations of new and improved product (INOVA) with participation of other companies of the group (EGRUPO)

Independent variables	Association (r)	Causality*			
		Intersection (α)	Variable X		R-Square
			Coefficient (β)	P-value	
1. Supplier dominated**		6.63			0.3228
$INOVA_1$	-0.5181		-0.0819	0.6308	
$EGRUPO_1$	-0.5560		-0.0685	0.3456	
2. Specialised suppliers***		3.58			0.2968
$INOVA_2$	-0.3661		-0.0500	0.4672	
$EGRUPO_2$	0.1345		0.0287	0.5664	
3. Scale-intensive***		13.94			0.2761
$INOVA_3$	0.1376		0.0594	0.5871	
$EGRUPO_3$	-0.3568		-0.2009	0.4880	
4. Science-based***		3.76			0.3037
$INOVA_4$	0.2582		0.3311	0.5002	
$EGRUPO_4$	-0.2680		-0.1986	0.4961	

Source: author, based on Pintec 2011 and Cempre 2010.
Notes: * Multiple regression as per equation (1); number of observations: **(15) and ***(5).

In the analysis of the association between innovation (Pintec 2011) and diversification of Brazilian industries (Cempre 2010), according to Table 4, there are certain typical behaviours of 'diversification based on technological activities', that can be observed only in the 'science-based' sectors. In this category, the correlations of technological activities (new and improved product innovations), being developed and implemented by other companies in the group, reveal technological links in the diversification of the industry. It is observed that, although diversification is slightly positively correlated with product innovations (r = 0.2, but significantly representative – $INOVA_4$), there was a strong correlation with the participation of other companies in the business group ($EGRUPO_4$) in the development of innovations in the 'science-based' industries (r = 0.977, significant to $P < 0.05$), that is, there is a diversification of activities in different three-digit CNAE categories of certain industries of the grouping.

In addition, in Table 4 there is a strong sensitivity (angular coefficient β = 1.38) of diversification in the 'science-based' sectors in different three-digit CNAE categories, with the increasing involvement of other companies of the same group in innovations ($EGRUPO_4$), that is, the more the sectors increasingly involve (in the order of 1%) other companies of their industry in innovations, more diversified they become (diversification increases by 1.38%). It is likely that such companies are part of diversified units in other three-digit sectors. Furthermore, when considering the linear coefficient α (-2.59), it appears that 'diversification based on technological activities', and not production diversification, marks the main characteristic of the pattern of diversification of the 'science-based' sectors, as expected. In other words, such sectors would tend to a disinvestment (alienation) of their productive activities if product innovations were nil or, otherwise, diversification would probably require a minimum effort in innovations (a rate of estimated innovation greater than 5%).[5] The pharmaceutical and medicinal chemical industry (SB2), responsible for 9.3% of specialised and 10.8% of diversified companies (totalling 20.1%), stands out, as demonstrated in Figure 2 – see appendix 1.

In the case of the 'scale-intensive' sectors, both the incidence of other companies responsible for innovative activities in the group and the rates of new and improved product innovations in their industries showed positive, but not significant, correlations with the diversification indicator (Table 4). The industries, in this case, present a rate of diversification (linear coefficient α = 4.86), compared to the average 10.9%, which does relate to the innovations they develop. This type of behaviour corroborates the signals of specialisation or diversification in production (Figure 2), mentioned earlier.

Even if the industries have carried out important product innovations in the 'specialised suppliers' sectors, such as machinery and equipment (SS2 – 29.5%) and precision, medical and optical equipment (SS3 – 58.7%), the levels of specialisation and diversification were very low, 5% and 7.3%, respectively, (Figure 2).

5 According to equation (1), for a zero diversification (DEP-div = 0), the innovation rate (INOVA) would be 5.2%, with the smallest observed participation of other companies in the group (EGRUPO = 1.4%), according to estimated parameters of Table 2 (DEP-div = -2.59 + 0.1277 INOVA + 1.3859 EGRUPO).

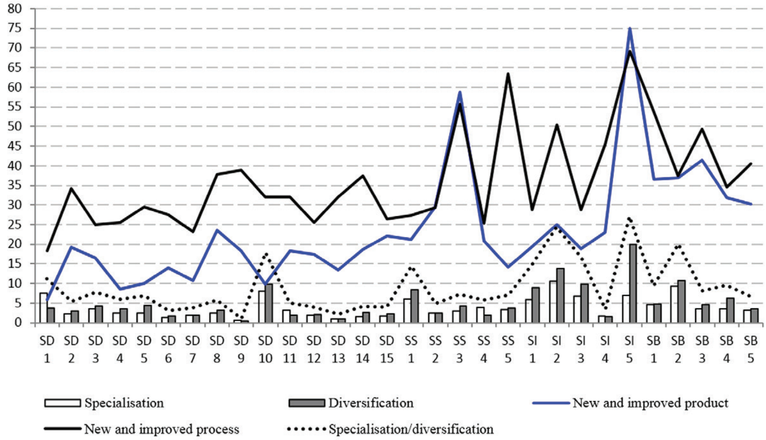
TABLE 4
Analysis of the association: diversification (DEP-div) and innovations of new and improved product (INOVA) with participation of other companies of the group (EGRUPO)

Independent variables	Association (r)	Causality*			
		Intersection (α)	Variable X		R-Square
			Coefficient (β)	P-value	
1. Supplier-dominated**		6.00			0.1950
$INOVA_1$	-0.3815		-0.1787	0.1313	
$EGRUPO_1$	-0.1381		-0.2874	0.4077	
2. Specialised suppliers***		4.50			0.2814
$INOVA_2$	-0.0281		0.0676	0.6279	
$EGRUPO_2$	-0.4073		-0.9119	0.4701	
3. Scale-intensive***		4.86			0.5867
$INOVA_3$	0.7603		0.1546	0.6708	
$EGRUPO_3$	0.7325		0.2266	0.8572	
4. Science-based***		-2.59			0.9951
$INOVA_4$	0.2002		0.1277	0.0557	
$EGRUPO_4$	0.9772		1.3859	0.0026	

Source: author, based on Pintec 2011 and Cempre 2010.
Notes: * Multiple regression as per equation (1); number of observations: **(15) and ***(5).

Not with standing the possibility of studies on the degree of diversification by CNAE division (two digits) or group (three digits), the statistical information disclosed by IBGE does not shed light on the number of local units per diversified company, nor the different levels of classification of the economic and technological activities in which companies operate. In addition, in order to test the effects of innovations on diversification, the alternative proxies considered – indicators of product and process innovations in only one sector of principal activity and participation of the company and other companies of the group in their development and implementation – are variables of imperfect measures of 'technological diversity', reasons that render the empirical analysis of this article somewhat limited. The proper understanding of the directions of technological and production diversification should emerge from a more detailed analysis of the performance or productive and technological participation (development of product and process innovations) of industrial companies in three- and two-digit CNAE sectors. Data on local business units from companies that are merely within or beyond the three-digit category (CNAE group) do not allow for the measurement of upstream and downstream movements of diversification, nor of their extension, 'narrow diversification' or 'broad diversification', in the sense used by Pavitt, Robson and Townsend (1989).

FIGURE 2
Percentage of companies that implemented new and improved product and process innovations (2009-2011) and indicators of specialisation/diversification (2010), according to industry sectoral categories
Brazil



Source: author, based on Pintec 2011 and Cempre 2010.

5. Conclusions

The differentiated behaviours of diversification of the industrial sectors, through the measurement and analysis of their relationship with the innovative activities carried out by Brazilian companies, constitute the objective of this article, with a focus on the intersectoral differences in the direction of technical change of the industry. This research was carried out with an empirical analysis of the data of the Industrial Survey of Technological Innovation (Pintec 2011) and the Central Register of Companies (Cempre 2010), by applying the Pearson correlation coefficient (*r*) and the least square method. The analytical framework adopted in this study is considered valid by the availability, objectivity and replicability of the data (MONTGOMERY, 1982), which allow temporal comparisons between studies carried out in different countries.

The econometric analysis found that the impacts of the introduction of new and improved products that produced the most effects on the productive activities of firms were limited and restricted to certain categories of industries. In the analysis of development and implementation of innovations, the estimated parameters of 'association' and 'causality' suggest that industries in general have concentrated their business lines on economic activities that have some 'proximity' to each other in their production functions, regardless of the innovative activities.

Notably, in the association between innovation (Pintec 2011) and diversification (Cempre 2010) of Brazilian industries, certain sectors, such as 'science-based', assume typical behaviours of 'diversification based on technological activities'. In this category, the correlations of technological activities (new and improved product innovations), being developed and implemented by other companies in the group, reveal technological links in the diversification of the industry. It seems to be a valid prediction to say that 'diversification based on technological activities', and not diversification in production, stands as the main characteristic of the diversification pattern of the 'science-based' sectors.

Therefore, paraphrasing Pavitt, in sectors that mainly carry out product innovations, in Brazil, the 'specialised suppliers' industries, mainly in mechanical engineering and instruments engineering, are relatively small, relatively little diversified in technological terms within and beyond of their three-digit category (CNAE group), with the exception of pulp (SS1), but they contribute significantly both in product and process innovations. In the 'science-based' sectors, industries are mostly large, diversifying relatively beyond their three-digit CNAE category, are associated with developed innovations, and produce a relatively high proportion of product innovations.

Comprehensive investigations into other aspects of the diversification of Brazilian industrial companies lack more detailed studies regarding the regularities in the behaviour of industries in different sectoral categories, including individually. In view of the limitations of the statistical information disclosed by IBGE regarding the different levels of classification of the CNAE economic activities in which they act and innovate, the technological paths of diversification of Brazilian innovating companies, i.e., 'narrow' and 'broad diversification', are yet to be explained.

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Acknowledgements

The author thanks the RBI editors and anonymous peer-reviewers for the valuable contributions and suggestions; the Board of Research of IBGE, for making available the Special Tabulation of statistical information; and Luci Nychai, for the support in analytical statistics.

Appendix 1 - Research data

(in %)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DF1	8.4	2.8	5.2	2.7	7.5	3.7	5.9	18.4	0.0
DF2	3.4	2.0	11.1	11.0	2.4	3.0	19.2	34.3	0.2
DF3	4.5	3.2	5.6	7.1	3.5	4.2	16.5	25.0	1.1
DF4	3.5	2.5	2.6	12.1	2.4	3.5	8.6	25.6	0.9
DF5	6.0	1.0	4.1	12.9	2.4	4.5	10.0	29.6	0.5
DF6	2.0	1.2	6.6	14.7	1.3	1.8	14.0	27.5	0.0
DF7	2.9	1.0	4.6	12.1	2.0	1.9	10.7	23.3	6.9
DF8	2.2	3.5	12.1	19.5	2.5	3.2	23.5	37.9	0.5
DF9	0.9	0.3	12.6	10.6	0.6	0.6	18.3	38.9	0.0
DF10	4.7	13.1	4.3	9.1	8.0	9.8	9.9	32.1	0.0
DF11	2.5	2.6	6.9	12.7	3.1	1.9	18.3	32.0	0.7
DF12	2.5	1.5	11.4	12.2	2.0	2.0	17.4	25.6	0.0
DF13	1.3	0.8	3.3	12.3	1.1	1.0	13.5	32.0	0.2
DF14	3.2	0.9	12.9	17.2	1.5	2.6	18.7	37.4	0.2
DF15	2.9	1.1	6.0	16.8	1.8	2.2	22.2	26.4	0.6
FE1	4.8	9.6	5.6	3.1	6.0	8.4	21.2	27.4	0.0
FE2	2.3	2.7	14.2	13.5	2.4	2.5	29.5	29.3	1.4
FE3	3.8	3.5	33.4	41.2	3.0	4.3	58.7	55.6	5.4
FE4	2.0	3.7	3.5	9.6	3.8	1.9	20.9	25.3	2.4
FE5	3.5	3.5	6.2	18.3	3.3	3.8	14.2	63.5	3.2
IE1	6.0	9.0	11.7	22.1	6.0	9.0	19.4	28.8	5.5
IE2	9.5	14.8	13.0	29.3	10.6	13.8	25.1	50.4	0.0
IE3	5.3	11.4	6.2	8.4	6.7	9.9	18.9	28.8	0.8
IE4	1.6	1.8	14.5	26.3	1.8	1.7	23.1	45.4	0.0
IE5	5.9	21.2	44.2	36.4	7.1	20.0	75.0	69.1	15.9
BC1	4.8	4.6	19.5	18.2	4.6	4.9	36.5	53.7	2.1
BC2	7.1	13.0	22.9	18.6	9.3	10.8	37.0	37.4	6.1
BC3	3.8	4.4	31.2	22.0	3.5	4.6	41.5	49.4	1.4
BC4	4.2	5.4	12.3	15.8	3.5	6.2	31.9	34.5	3.6
BC5	2.7	4.1	10.3	17.6	3.2	3.5	30.2	40.4	1.5

Source: Pintec 2011 and Cempre 2010.

Notes: (1) Industrial sectors according to Table 2; (2) specialisation/diversification - small businesses; (3) specialisation/diversification - large enterprises; (4) completely new product innovations; (5) completely new process innovations; (6) specialisation; (7) diversification; (8) new and improved product innovations; (9) new and improved process innovations; and (10) participation of other companies of the group in the development of innovations.