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Organizing knowledge to compete☆
Impacts of capacity building programs on firm organization

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ABSTRACT

A growing literature aiming at explaining differences in productivity and access to global export markets across firms has focused on the internal organization of firms. This paper contributes to this literature by evaluating the impact of a program that aims at enhancing competitiveness of small and medium enterprises in Brazil by providing coaching and consulting on management and production practices. Specifically, the paper tests whether the program induces treated firms to reorganize knowledge by adding more layers of different skills and competencies to their workforces. Using a unique firm-level data set, the number of layers of knowledge of the firms are compared before and after the program. The impact of the program is identified by relying on an instrumental variable approach, exploiting the quasi-experimental roll-out of its implementation, which was carried out at different times across Brazilian regions. The analysis finds that the program had an effect and that this effect is heterogeneous. The program is particularly effective in promoting the reorganization of small and medium firms. The results confirm another finding of the literature, namely that in re-organized firms wage inequality increases. Finally, these results are used to discuss how the change in firms' organization is positively correlated with export performance.

1. Introduction

Enhancing productivity is the key to achieve sustainable growth. Although our knowledge on the determinants of productivity is still limited (Syverson, 2011), there are strong reasons, supported by empirical evidence, suggesting that firms' organization matters. Production requires the organization of several inputs (e.g. land, machines, raw material, labor, information, among others), including the knowledge of workers. From a firm's perspective, optimizing its productivity means organizing these inputs efficiently. The lack of capacity for reaching this efficiency may explain important differences in productivity across firms and countries (see Bloom and Van Reenen, 2007, 2010; Bloom et al., 2010).

Since the pioneering work of Roberts and Tybout (1997), Clerides et al. (1998) and Melitz (2003), trade literature has emphasized that firms' productivity is heterogeneous not only across sectors, but also within them.[1] Caliendo and Rossi-Hansberg (2012) suggest differences in the way firms organize knowledge as one source of heterogeneity. Their model is built in the spirit of Garicano (2000) in which production requires organization of knowledge and inputs.[2]

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[1] Firms' heterogeneity has been at the center of a rich theoretical and empirical literature focusing on explaining the relationship between firms' productivity and their export performance (Melitz and Trefler, 2012).

[2] Knowledge is costly to acquire and organization is required to coordinate who learns what and how to solve different production problems in order to optimize gains from specialization in a firm.

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The model suggests that the way firms organize knowledge plays a key role in their capacity to compete with other firms, domestically and abroad. The moment firms introduce new products, their market size determines which organization is compatible with their scale of production. Larger demand will enable firms to reorganize their production by adding new layers of managers and economizing knowledge from production workers.[3] By assuming that employees can act as production workers or managers, this framework can also be connected to the literature that finds a positive association between management's quality and firms' performance (see Bloom and Van Reenen, 2007; Mion and Opromolla, 2014; Bloom et al., 2013).[4] These findings have important implications by suggesting that firms' performance may be enhanced by policies that create incentives to improve management practices and change the way firms organize their knowledge for production.

Although there is an increasing empirical literature showing the importance of management and organization on firms' performance, there is limited evidence on the effectiveness of programs aiming to improve firms' organization. This paper aims to contribute to this literature by analyzing the effect of Peiex (Portuguese acronym for Industrial Extension Project for Exporting) on firms' organization, based on hierarchy of knowledge. Peiex is a program from the Brazilian Export Promotion Agency (Apex-Brasil) that focuses on enhancing Brazilian small and medium firms' (SMEs') competitiveness by providing coaching and consulting on best management and production practices.[5] This paper is closely related to Bloom et al. (2013), who find significant effects of a management consulting program on firms' performance in India.[6] This paper also complements the findings of Caliendo et al. (2015a), which suggest that failure to reorganize while expanding could lead to a missing opportunity of productivity improvements, and Caliendo et al. (2017), who analyze the effects of exporting on the organization of production within firms.

We measure how firms organize knowledge based on occupations that require different levels of skills and competencies, following the conceptual framework in Garicano (2000) and Caliendo and Rossi-Hansberg (2012). Consistent with this framework we show that firms organize knowledge following a hierarchy in a pyramid shape, which is compatible with the hypothesis that production workers learn the standard production problems and managers deal with more exceptional ones. Our analysis uses a unique matched employer-employee firm-level data set covering the full manufacturing sector in Brazil with a panel of about 310,000 firms (an average of 236,645 firms per year), with information on more than 7 million employees, from 2007 to 2010, and more than 3500 treated firms.

This measure of hierarchy of knowledge takes into account different levels of competencies and skills of workers limited to 4 layers. If a firm already has 2 layers and decides to hire more workers at the same layers, which means same occupations previously available at the firm, we assume that there is no change in the knowledge-based hierarchy of the firm. Hence, this is not about increasing the number of directors or manager positions itself; neither are we assuming that the more managers, the better. Instead, increasing the number of layers in this case means that a firm is incorporating workers with different levels of skills and competency, with specialized knowledge in solving different problems at the firm. The idea is that controlling for the number of employees, firms that expand reorganizing knowledge can become more competitive by having lower marginal cost as a function of the necessary knowledge among production workers and gains of productivity through specialization. Apart from the fact that workers in new layers have more average years of schooling, the concept of occupation also takes into account the use of their knowledge by considering their tasks at the firm. Thus, we capture one type of organization, but one which matters for performance.

To identify the effect of the program, we rely on an instrumental variable approach and exploit the exogenous variation provided by a staggered geographical roll-out for its implementation. The program was implemented in late 2008/2009 through regional units around the country. A critical eligibility rule is that firms should submit an application form to its correspondent regional unit and be a "potential exporter," which means be part of a sector in which there is evidence of exporting activity. Our identification strategy exploit these rules to develop an exogenous instrument which is helped by the fact that only 10 out of 27 states had opened regional units in the first two years of the program. Given that we use state and firm fixed effects the crucial assumption for our identification comes from the randomness of the timing of the program roll-out.

The results suggest that the program impacts the organization of the treated firms as follows: 1) Firms that receive the program are more likely to reorganize their production by adding a layer of hierarchy of knowledge, which is measured by hiring a worker in an occupation for which similar knowledge did not appear previously in the firm employee structure. The program increases the predicted number of layers of hierarchy of knowledge for small and medium firms, defined as those firms between 10 and less than 100 employees two years before the program started. Nonetheless, the result is not significant for micro firms (with less than 10 employees) or large firms (with 100 or more employees), suggesting some heterogeneous effects of the programs based on the initial size of the firms; 2) The reorganization of those firms is associated with an expansion of hours hired on previously existing layers of knowledge and a rise in wage inequality between layers of hierarchy based on knowledge. We then explain the findings by emphasizing that adding layers of knowledge is an organizational change that is correlated with outcomes relevant to firms' performance. We show that controlling for numbers of employees, firms that have more layers of knowledge are more likely to be exporters. These results are supported by several robustness tests.

The remainder of this paper is structured as follows. Section 2 describes the data and provides some descriptive statistics. Section 3 explains how Peiex's program works and describes the identification strategy adopted to evaluate its effects. Section 4 shows the empirical results followed by the robustness check and a discussion on the meaning of these results for firms' performance. Section 5 concludes the paper.

2. Data and descriptive statistics

This paper is based on a unique firm-level data set that resulted from merging three different sources of information in Brazil: 1) the *Relações Anual de Informações Sociais* (RAIS), a linked employer-employee data set from the Brazilian Ministry of Labor;[7] 2) the

[3] In their model, the introduction of new products is randomly assigned.

[4] These authors suggest that lack of market competition, firms' ownership structure (e.g. family-managed companies where CEO succession is determined by primogeniture), labor regulation, multinational status, education, lack of delegation and barriers to access finance are among the reasons why some firms do not adopt management practices that optimize productivity, especially but not only in developing countries.

[5] Brazil has a long tradition of programs aiming to support small business, by providing training on entrepreneurship and management consulting. For example, SEBRAE (Portuguese acronym for the Brazilian Service of Support for Micro and Small Business), a private entity of public interest that offers courses, consultancy, training, and sectoral publication to SMEs, started its activities in 1972.

[6] In a randomized controlled trial (RCT), Bloom et al. (2013) show that receiving consulting on better management practices raised by 11% the productivity of treated firms. In addition, the decision making in these firms became less centralized and they also increased the use of computers.

[7] RAIS is a register of all formal firms in Brazil. It provides information about the size of the establishment, geographic distribution and workers, such as wage, education, age and gender.

SECEX/MDIC data set, which provides firms' exporting status and 3) the Peiex data, identifying the firms that received assistance from Peiex.[8]

The database was merged using a unique identifier at the firm level.[9] It covers the period between 2005 and 2010. We focused on manufacturing firms and adopted the sectoral definition of CNAE 2.0 (Portuguese acronym for National Economic Activity Classification) that is equivalent to the International Standard Industrial Classification of All Economic Activities (ISIC, Rev.4.).[10] Also, given that for the analysis we need information on firms for at least two subsequent years, we kept firms that are in RAIS for at least 2 years.[11] We measure firms' organization following Caliendo et al. (2015b) and Helpman et al. (2017) to classify the number of layers. We use the *Classificação Brasileira de Ocupação* (CBO) definition of occupation, which is composed by 9 different categories according to similar level of authority, skills, and competencies.[12] Table 1 describes the original categories and the way we aggregated them for the analysis. This classification was used to define the number of "knowledge-based" layers in each firm. If a firm has employees belonging to only one of these categories (e.g. production workers), this firm will have a single structure, without hierarchical layers of knowledge. If there are employees in two of these categories (e.g. production workers and senior staff), this firm will have one layer of knowledge-based hierarchy. We provide further details on the proxy for hierarchy in the Appendix A.2.

We follow a similar structure of CBO's skills classification to define the knowledge-based hierarchy, with few adaptations. This definition is based on the complexity of tasks and the knowledge required for each occupation. The CBO, as well as ISCO, does not classify the level of skills for CEOs (CG1) due to the large heterogeneity in terms of required skills (e.g. a small, as well as a large firm, will likely have CEO positions with diverse level of skills). Yet, CEOs have the highest average salary across firms and the power to make the most strategic decisions. Thus, we keep them in the top of the hierarchy (H5). The CBO defines Professionals (CG2) as skill level 4, followed by Technicians (CG3) with skill level 3, and white collars (CG4, CG5,) and production workers (CG7, CG8, CG9) with skill level 2. We follow a relatively similar hierarchy, but we also split white collars (clerks CG4 and CG5) from production workers (CG7, CG8 and CG9), based on the purpose of their tasks, as well as their average level of schooling.[13] These groups of workers have different knowledge, where clerks and service workers have more specialized knowledge than production and maintenance workers. Table 2 shows that share of workers with college- or post-graduation-degrees follows our hierarchy of knowledge, with the exception of CEOs, which are the ones with highest salaries. Our hierarchy is also consistent with the division of tasks suggested by Caliendo and Rossi-Hansberg (2012).

The classification used to establish the number of layers embeds different levels of knowledge, skills, and competency by occupation.

Table 1
CBO classification.

Structure categories	CBO[(a)]	Skills CBO[(b)]	Hierarchy[(c)]	Layer[(d)]
(1) CEOs and managers	CG 1	–	H5	L4
(2) Professionals (Senior staff)	CG 2	4	H4	L3
(3) Technicians (middle-level)	CG 3	3	H3	L2
(4) Clerks and services (white collars)	CG 4 and CG 5	2	H2	L1
(5) Production workers (blue collars)	CG 7, CG 8 and CG9	2	H1	L0

Note: (a) Categories of knowledge observed in the structure of the firms; (b) CBO occupations included in each category of knowledge. CBO occupations: CEOs and Managers (CG1), Professionals (CG2), Technicians and associate professionals (CG3), Clerks (CG4), Service workers (CG5), Production workers — discrete process (CG7), Production workers — continuous process (CG8); Maintenance workers (CG9). Agriculture workers (CG6) and armed forces (CG0) were excluded; (b) Level of skills required for each task according to the CBO classification, determined by the Brazilian Ministry of Labor (4 is the highest and 1 is the lowest level). (c) Knowledge-based hierarchy used in our paper. (d) Layers of knowledge in the structure of the firms. For example, a firm with workers in occupations across these five categories of knowledge would have four hierarchical layers. A firm with workers in two categories of knowledge would have one layer.

For example, according to the International Standard Classification of Occupations (ISCO) "Professionals" (CG 2) are workers that "increase the existing stock of knowledge, apply scientific or artistic concepts and theories, teach about the foregoing in a systematic manner, or engage in any combination of these three activities." Also, "Technicians and Associate Professionals" (GG 3) "perform mostly technical and related tasks connected with research and the application of scientific or artistic concepts and operational methods, and government or business regulations." Imagine a small firm composed by blue-collar workers and the firms' owner.[14] The moment this firm hires workers classified as professionals (CG 2) or technicians (CG 3), it is incorporating a specialized level of knowledge in their structure that was not previously there.

Fig. 1 shows the hierarchies of firms in Brazil.[15] The layers are represented using a square. The vertical axis reports the average hourly wage of employee in each layer and the horizontal axis represents the average hours employed normalized by the top layer, according to the number of layers of the firms.[16] Therefore, these axes are respectively the height and the length of the square, which represents the payroll of firms by layers. In Garicano (2000), they represent the hierarchical organization of firms with the shape of a pyramid, which he referred to as pyramidal organization. It results from the fact that knowledge is non-overlapping and the organization is characterized by the problem-solving ability of workers up to the top layer (Caliendo et al., 2015b). Overall, the predicted shape is observed. Firms hire more producer workers (H1) and fewer workers in the top layers (H2, H3, H4, and H5). On average, the higher the position of the workers in the hierarchy, the higher her wage, which suggests more knowledge associated with problem solving skills.

[8] *Secretaria de Comércio Exterior* (SECEX) from the Ministry of Development, Industry and Trade (MIDC). A list of exporting firms by year is publicly available on www.mdic.gov.br.

[9] The information of the treatment is available at the firm level. In cases where firms have more than one plant, we define the geographic location of the firm as the location of plant with the larger number of employees. In Peiex's cases, the majority of treated firms (about 90%) are relatively small with a unique plant.

[10] The Peiex program targets manufacturing firms. We used CNAE 2.0, 2 digits, from 10 to 33, which defines manufacturing.

[11] For some of the estimations it was necessary information from firms with two lags. We used information from 2005 and 2006 to generate lag variables used in the regressions and kept firms that are in RAIS in at least three subsequent periods ($t-2$, $t-1$ and t).

[12] The concept of competence adopted by CBO has two dimensions: (1) It is a function of the complexity, scope and responsibility of activities in employment or another working relationship; (2) It is related to the characteristics of the work context as an area of knowledge, function, economic activity and production process.

[13] ISCO classifies CG9 as skill level 1.

[14] Further details on ISCO classification are available at the webpage of the International Labor Organization (ILO) at www.ilo.org.

[15] These are firms in the manufacturing sector that appear in RAIS at periods t and $t-1$, from 2007 to 2010. For further details see descriptive statistics in the previous subsection.

[16] It refers to the average number of hours with respect to the top layer for each firm. Firms with more layers are usually larger and more productive, consequently they usually pay higher wages for workers in similar layers when comparing with other firms with less layers.

Table 2
Share of workers with college degree or more and total share of jobs, by occupation.

Classification	CBO	2007		2008		2009		2010	
		Educ (%)	Job (%)	Educ (%)	Job (%)	Educ (%)	Job (%)	Educ (%)	Job (%)
CEOs	CG1	44.0	2.4	44.9	2.4	45.2	2.5	45.2	2.5
Professionals	CG2	74.4	2.6	73.9	2.7	74.6	2.8	78.1	3.0
Technicians	CG3	15.1	7.4	15.8	7.5	16.9	7.8	17.2	7.8
Clerks	CG4, CG5	7.7	14.9	7.9	15.2	8.3	15.7	8.5	15.7
Production workers	CG7, CG8, CG9	0.9	67.5	1.0	67.2	1.0	66.3	1.1	66.8
Clerks and production workers disaggregated by occupation.									
Clerks	CG4	10.5	8.8	10.8	9.0	11.1	9.5	11.3	9.5
Service workers	CG5	3.7	6.1	3.7	6.2	4.1	6.2	4.3	6.2
Production	CG7	0.8	49.2	0.8	49.7	0.8	48.8	0.9	49.6
workers	CG8	1.3	13.9	1.3	13.8	1.5	13.7	1.5	13.4
	CG9	1.9	4.5	2.2	3.8	2.3	3.8	2.6	3.8

Note: "Educ" refers to the share of workers in this group of occupations with college- or postgraduation-degree. "Job" refers to the share of total job in the respective group of occupations.

Table 3 provides the descriptive statistics of the variables used in the empirical analysis based on the pre-treatment years (2007–2008) sample. First, we present the number of levels of knowledge, which defines the layers of hierarchy of knowledge.[17] Over pre-treatment years, Peiex's treated firms have on average more hierarchical layers of knowledge than firms that did not received Peiex support, hereafter referred to as "untreated firms." We then present the average number of employees. This variable was built considering the number of employees hired in a year by the firm, weighted by the period (number of months) they were hired. Therefore, if an employee was hired for six months she receives a weight of 0.5. On average, Peiex's treated firms are slightly larger than untreated firms. Firm's age is a proxy for the age of the firm that takes into account the maximum time of employees' experience working at firms available in RAIS over time. Peiex-treated firms are also older than untreated firms. Number of subsidiaries refers to the number of plants apart from the one with the largest number of employees, which we consider as being the firm's headquarters. Although the treated firms have almost twice as many subsidiaries than average it is noticeable that the median is zero for both groups, and it changes to 1 only for treated firms in the 90th percentile.

A second group of variables refers to employees' characteristics. Wage is the average monthly wage (in R$ of 2010). The average wage, as well as the median wage, is larger in untreated firms. Schooling is the average years of formal school attendance, workers experience is the average time (in years) of experience of employees and share of engineers and R&D workers is the share of employees classified in these occupations according to the CBO.

A third group of variables is related to managers' characteristics. Following Mion and Opromolla (2014), we build a variable to capture information related to potential spillovers brought from managers with previous experience in exporting firms. "Manager exp M_n" such that $n=\{1,2,3\}$ are dummy variables that identify those firms that hired managers (according to the based-knowledge hierarchy definition)[18] at period t who were working in another firm that exported at period $t-1$, according to different level of occupations.[19] The share of firms that hired these managers is small (less than 1%), but it is larger for Peiex's firms.

Furthermore, following Lazear et al. (2012) we build a proxy for managers' quality based on their wage distribution according to their occupation. These variables, (Manager $M_n - Q_j$) such that $n=\{1,2,3\}$ and $j=\{Q_4, Q_3, Q_2\}$, are dummies that take the value of 1 if a firm has a manager in occupation M_n and quartile Q_j of wage's distribution and 0 otherwise. It is noticeable that managers in the fourth quartile[20] (top managers) are rare in both groups. The share seems relatively close between treated and untreated firms, with more prevalent cases of managers (M1) in the third quartile (Q_3). In the estimations we also control for foreign managers, using the same classification described here.[21]

The fourth group of covariates is related to firms' sector and regional environment. First, in order to control for potential exporting neighbourhood-effect we used the variable "export-spillover." This equal to the sum of the total number of other exporting firms by micro-region (a territory classification from IBGE that divides Brazil in 555 geographical areas). The average is larger for untreated firms, for which results is mostly driven by São Paulo. The share of exporting firms in 2007 and 2008 is larger among treated firms, but the proportion of exporting firms is very small for both groups.

3. The Peiex program and the identification strategy

Peiex was launched in late 2008/2009 as a program of assistance services offered to medium and small firms by Apex-Brasil.[22] The program "aimed to boost competitiveness and raise the export awareness of micro, small and medium-sized enterprises" by providing capacity building and management coaching. The initiative was set up as a supplementary assistance for firms interested in taking part of export promotion services already provided by the agency (e.g. participation in trade fairs and business rounds — meetings with foreign buyers) but that were not prepared to take full advantage of these services yet (this could be seen as a pre-export preparation program).

The program offers consulting services in partnership with universities and institutes of technology in fields such as marketing, human resources management, finance, product design and trade. The existence of a Peiex center locally is crucial for the program. Although Peiex does not charge firms for these services, their condition is that owners and managers of these firms must be committed to attend interviews and standard evaluations to verify management

[17] A firm with 1 level of knowledge means that it has only workers in a similar group of occupations(e.g. production workers) with the minimum number of layers (L0). A firm with 5 levels of knowledge means that it has workers in all different occupations used to measure the organization of knowledge in the firm, as described in Table 1, with the maximum number of layers (L4).

[18] M1 for CEOs and directors; M2 for senior staff and M3 for supervisors.

[19] These variables take the value of 1 if a firm has hired a manager at period t who was working in an exporting firm at period $t-1$ and 0 otherwise.

[20] They are more prevalent among large/exporting firms.

[21] The number of foreign managers is even smaller for both groups and are note reported in this table of the sake of saving space.

[22] See further details at www.apexbrasil.com.br.

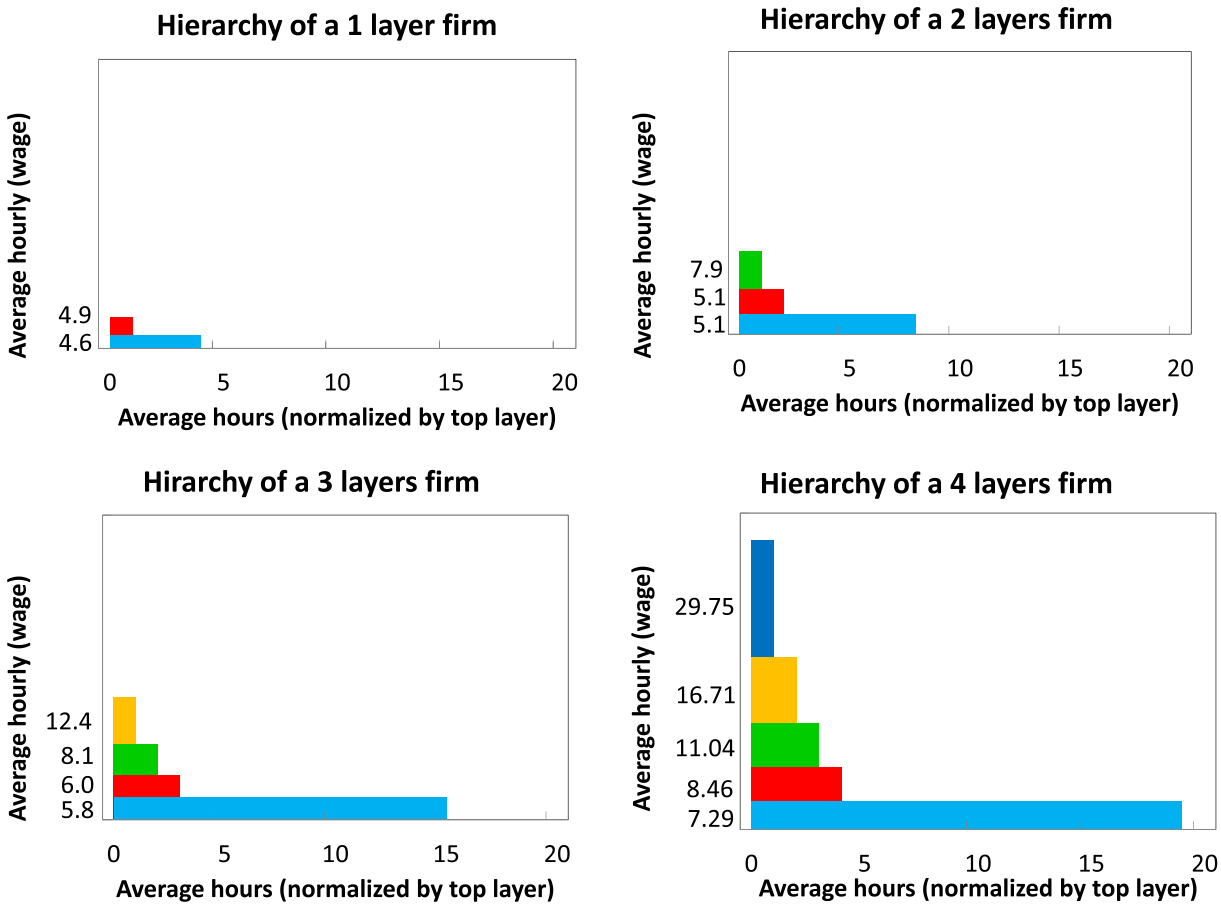

Fig. 1. Hierarchies of Brazilian (manufacturing) firms normalized by the top layer (2007–2010).

procedures adopted by them. After applying for the assistance, firms receive a visit from a Peiex extension agent who will explain them the methodology of the program. Once these firms confirm their interest in participating to the program, they receive a standard competitive strength assessment covering different areas of the enterprise (e.g. strategic organization, human capital, finance and costs, sales and marketing, international trade, product design, production and innovation) with a final report identifying their strengths and weaknesses. This assessment is followed by a plan with suggestions to be implemented focusing on improving firms' competitiveness.[23]

An important feature of eligibility which will be exploited in the identification is the fact that firms interested in receiving this assistance must complete a registration form made available by the Peiex team and their partner organizations[24] and submit the application to the nearest regional unit of attendance. These regional units – NOs (Portuguese acronym for Project Operational Units) – were opened in a staggered manner across few Brazilian states, starting in late 2008/2009. Yet, firms started to receive assistance only in 2009. Table 4 shows the number of NOs in each state according to the semester-year they were implemented. More than half of the Brazilian states did not have a Peiex NO until 2010.

Most of these units are concentrated in the South and the Northeast (with the exception of the state of Minas Gerais in the Southeast). An interesting feature from the perspective of a quasi-experiment is that states like São Paulo, Santa Catarina and Rio de Janeiro, which together represent a large share of total firms (approximately 45%), exporting firms (almost 60%) and GDP in Brazil, received units only in December 2010, August 2011 and September 2011, respectively.[25] Therefore, these states have no NOs operating between 2009 and 2010.

These NOs are composed by a manager, an industrial extensionist manager, firms' extensionists and trainees. After being selected, the staff are required to attend courses on Peiex's methodology and trade. The first step of the assistance is based on interviews with managers and visits to the plant in order to get further information for an assessment of the strengths and weaknesses of the firms following Peiex's standard methodology. Based on this information, the extensionists propose a plan for introducing some improvements in fields related to strategic management, human resources, finance and cost, marketing, production, design and trade. In cases where the extensionists have no knowledge to give the necessary support for implementing the project, according to the program's methodology, external consultants from universities and technological centers would be hired to provide the assistance.[26]

[23] The role played by extension agents (in Portuguese, *técnico extensionista)* is widely known in Brazil as associated to specialists in agriculture who provide assistance to transfer knowledge on production best practices and new technologies available. In Brazil these services became popular with Embrapa (Portuguese acronym for the Brazilian Research Corporation) and Emater (Portuguese acronym for Institute for Technical Assistance and Knowledge Extension).

[24] This includes industrial associations and universities in Brazil.

[25] Due to the fact that we are using annual data we considered the year of implementation based on the semester the NO was implemented in the state. It takes time for these agencies implement the program. Those NOs installed in the first semester of the year were considered as being over the year. São Paulo was installed in December 2010. Therefore, it is considered as implemented in 2011.

[26] Fig. 4 in Appendix A.1 summarizes Peiex's methodology according to different steps.

Table 3
Descriptive statistics (2007–2008).

Variables	*N*	Mean	sd	p10	p25	p50	p75	p90
Untreated (Peiex=0)								
Levels of knowledge (L)	451,977	2.21	1.18	1	1	2	3	4
Size (Employee)	453,068	30.36	286.14	1.00	2.25	6.00	15.67	41.42
Firm's age	453,128	11.85	8.92	3.22	5.27	9.66	15.83	22.49
Wage	453,068	856.05	644.61	476.57	560.98	712.01	958.33	1342.28
Schooling	453,128	9.61	2.08	6.51	8.45	9.80	11.17	12.04
Number exporters region*	453,128	1.92	1.68	0.00	0.00	1.61	3.18	4.51
Share engineers and R&D	453,128	0.34	10.63	0.00	0.00	0.00	0.00	0.00
Worker experience	453,017	18.06	7.85	8.76	12.90	17.41	22.41	27.97
Number of subsidiaries	453,128	0.12	1.74	0.00	0.00	0.00	0.00	0.00
Manager exp M1	453,128	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Manager exp M2	453,128	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Manager exp M3	453,128	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Manager M_1 N-Q_4	453,128	0.01	0.10	0.00	0.00	0.00	0.00	0.00
Manager M_1 F-Q_4	453,128	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Manager M_2 N-Q_4	453,128	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Manager M_2 F-Q_4	453,128	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Manager M_3 N-Q_4	453,128	0.01	0.09	0.00	0.00	0.00	0.00	0.00
Manager M_3 F-Q_4	453,128	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Exporting firms 2007 (share)	453,128	0.05	0.22	0.00	0.00	0.00	0.00	0.00
Exporting firms 2008 (share)	453,128	0.05	0.22	0.00	0.00	0.00	0.00	0.00
Other programs apex (share)	453,128	0.01	0.11	0.00	0.00	0.00	0.00	0.00
Treated (Peiex=1)								
Levels of knowledge (L)	5794	2.71	1.21	1	2	3	4	5
Size (Employee)	5795	33.20	113.17	2.50	5.17	11.83	27.67	63.00
Firm's age	5796	12.48	8.89	3.49	5.91	10.74	16.61	22.74
Wage	5795	774.80	340.37	490.20	556.20	673.12	877.77	1187.05
Schooling	5796	9.81	1.75	7.40	8.84	9.97	11.08	12.01
Number exporters region*	5796	1.71	1.40	0.00	0.69	1.61	2.64	3.74
Share engineers and R&D	5796	0.22	3.81	0.00	0.00	0.00	0.00	0.00
Worker experience	5783	17.26	5.97	9.94	13.29	17.01	20.76	24.90
Number of subsidiaries	5784	0.24	2.05	0.00	0.00	0.00	0.00	1.00
Manager exp M1	5796	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Manager exp M2	5796	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Manager exp M3	5796	0.01	0.10	0.00	0.00	0.00	0.00	0.00
Manager M_1 N-Q_4	5796	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Manager M_1 F-Q_4	5796	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manager M_2 N-Q_4	5796	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Manager M_2 F-Q_4	5796	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manager M_3 N-Q_4	5796	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Manager M_3 F-Q_4	5796	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Exporting firms 2007 (share)	5796	0.10	0.30	0.00	0.00	0.00	0.00	0.00
Exporting firms 2008 (share)	5796	0.10	0.31	0.00	0.00	0.00	0.00	1.00
Other programs apex (share)	5796	0.05	0.22	0.00	0.00	0.00	0.00	0.00

Note: The descriptive is based in a pooling data from 2007 to 2008, which is defined as a pre-treatment period. Treatment status is defined as firms that did not receive any support from Peix's program (Untreated) and firms that did receive Peiex (Treated Peiex) over 2007–2010 period. Managers are classified by occupations equivalent to CEOs and Directors (M1), Senior staff (M2) and Supervisors (M3). N and F refer to their nationalities, where N (Nationals) and F (Foreigners). Managers Q_4 refers to dummy variables for those in the top quartile of wage distribution in the respective occupation. We also control for manager's variables (Managers Q_2–Q_3) in the second and third quartile of wage distribution. We do not report the result for these variables for the sake of saving space.

Table 4
Number and schedule of implementation of Peiex's regional units (NO).

Region	Estado	2007		2008		2009		2010	
		First	Second	First	Second	First	Second	First	Second
Northeast	Ceará	0	0	0	1	1	1	1	1
Northeast	Pernambuco	0	0	0	1	1	1	1	1
Northeast	Alagoas	0	0	0	1	1	1	1	1
Northeast	Sergipe	0	0	0	1	1	1	1	1
Northeast	Bahia	0	0	0	1	4	4	4	4
Southeast	Minas Gerais	0	0	6	6	6	6	6	6
South	Paraná	0	0	0	3	3	3	3	3
South	Rio Grande do Sul	0	0	0	7	7	7	8	8
Center-West	Goiás	0	0	0	1	1	1	1	1
Center-West	Brasília	0	0	0	1	1	1	1	1
Total		0	0	6	23	26	26	27	27

Note: The units were implemented in different municipalities inside the states. First and Second refer to the semester of the year in which the NO was implemented. São Paulo received a unit only in December of 2010, which was operating in 2010. Only 9 states, in addition to the Federal District (Brasília), received units. The other 16 states did not received NOs over 2009–2010 period.

Table 5
Distribution of firms across states, by exporting and treatment status.

Region	State	Firms (2007) (%)	Firms (2010) (%)	Unit NO (09–10)	Peiex's treated (2009) (%)	(2010) (%)	Exporting firms (07–08) (%)
North	Rondônia	0.61	0.63	–	*	*	0.51
North	Acre	0.13	0.13	–	*	*	0.06
North	Amazonas	0.45	0.48	–	*	*	1.10
North	Roraima	0.05	0.06	–	*	*	0.12
North	Pará	1.04	1.04	–	*	*	1.66
North	Amapá	0.07	0.07	–	*	*	0.03
North	Tocantins	0.26	0.29	–	*	*	0.02
Northeast	Maranhão	0.50	0.54	–	*	*	0.16
Northeast	Piauí	0.53	0.57	–	*	*	0.13
Northeast	Ceará	2.52	2.80	1	6.06	6.74	1.24
Northeast	Rio Grande do Norte	0.80	0.88	–	*	*	0.26
Northeast	Paraíba	0.81	0.86	–	*	*	0.37
Northeast	Pernambuco	2.33	2.49	1	*	0.99	0.75
Northeast	Alagoas	0.36	0.39	1	0.75	0.82	0.15
Northeast	Sergipe	0.43	0.48	1	1.20	1.22	0.14
Northeast	Bahia	2.65	2.78	4	8.17	10.26	1.40
Southeast	Minas Gerais	12.48	12.58	6	24.69	23.62	6.86
Southeast	Espírito Santo	2.04	2.11	–	*	*	1.52
Southeast	Rio de Janeiro	4.88	4.95	–	*	*	3.89
Southeast	São Paulo	29.53	29.06	–	*	*	46.66
South	Paraná	8.89	9.35	3	16.72	17.20	8.26
South	Santa Catarina	9.49	9.86	–	*	*	8.46
South	Rio Grande do Sul	11.16	11.33	8	35.35	33.46	14.01
Center West	Mato Grosso do Sul	0.75	0.81	–	*	*	0.32
Center West	Mato Grosso	1.38	1.55	–	*	*	0.82
Center West	Goiás	3.00	3.27	1	4.44	3.92	1.04
Center West	Distrito Federal	0.56	0.63	1	2.16	1.48	0.05
Total (%)		100.00	100.00	–	100.00	100.00	100.00
Total		232,159	247,187	27	2410	3518	24,161

Note: (*) States with less than 10 treated firms. There were only 11 outlier firms treated by Peiex over 2009–2010 in other states in our sample. Among these firms only 4 have no subsidiaries. In total, 2364 firms received assistance between 2009 and 2010, while 46 firms received assistance only in 2009, and 1154 firms received assistance only in 2010. In total, 3564 firms received assistance between 2009 and 2010.

Due to the fact that Peiex was not designed as a randomized experiment, the main issue for the identification of its impact on treated firms is potential selection bias. It may be that firms with higher probability of changing their organization's structure are more likely to ask for and receive the program and this is likely a source of endogeneity. Let us consider the following equation:

$$Y_{it} = \alpha + \beta T_{it} + \gamma X_{it} + \epsilon_{it} \quad (1)$$

where Y_{it} is the number of levels of knowledge-based hierarchy of firm i at period t, T is treatment status (Peiex assistance), X_{it} is a matrix of covariates, ϵ_{it} is the error term. Assuming T as a binary variable, we can only observe $(Y_1|T = 0)$ or $(Y_1|T = 1)$ and this generates a missing data problem (Heckman, 2001). If (T) is correlated with (ϵ) there are unobservables that determine both treatment and outcome, β will be inconsistent and biased under the OLS estimation.

To address this issue, further knowledge with respect to the design and implementation of the program is necessary. In the case of Peiex, an important eligibility rule is that firms should complete a registration form and submit it at the regional units. Up to 2010, there were 27 operating units distributed around the country and these were opened in a staggered manner. Brazil has 27 states (including the Federal District, Brasília) and only 10 of them had Peiex's regional units operating by the end of 2010. Table 5 shows their distribution and number of assisted firms by targeted state in Brazil. There is a strong correlation among these variables.

Given that firms' locations were not influenced by Peiex regional units (all firms in our sample – treated and untreated – were previously established, at least two years before the programs' implementation, and the large majority were established for more than 2 years before the program) geographic proximity of these units is exogenous to the firm and we use the variation of the implementation of these regional units across Brazilian regions as an instrument to deal with selection into the program.[27] It could be that regions with a larger number of firms are those that benefited most by the number of regional units or that locations with more organized firms were able to lobby for receiving more units and this level of organization could be correlated with firms' organization. It also could happen that the program tries to compensate the lack of firms' organization and install regional units in regions with very few firms. Table 5 shows that this does not seem to be the case. São Paulo, which is by far the state with the largest number firms in Brazil, did not receive NOs over this period, neither many states in the North region, those that have a small share of firms and exporters. The decision of excluding São Paulo was strategic, as Peiex's team considered the first years of the program (2009 and 2010) as a pilot. São Paulo had a large number of firms already receiving other-than-Peiex support by Apex.

In addition, Table 6 shows that there is a weak and not statistically significant correlation (at 5% confidence level) between the share of exporting firms or the average changes in number of layers and the share of Peiex regional units at the state level prior to the program's start. Nonetheless, there is a strong and significant correlation (at 1% confidence level) between the share of firms that received Peiex treatment and the share of Peiex regional units at the state level.

Our analysis suggests that the decision of Peiex regional units' location is exogenous to changes on firms' organization based on

[27] More than 99.6% of the observations are from firms that did not change state over the period of analysis among treated and untreated firms. In the main results we keep these firms in the sample attributing to them the most common state over 2007–2010 period. The results are very similar if we exclude these firms from the sample.

Table 6
Correlations with number of Peiex's regional units.

Correlation with number of NOs					
	Peiex	Number exporters		Change layer	
	2007–2010	2007	2008	2007	2008
Corr	0.957	0.1786	0.1836	0.0451	0.1204
p-Value	0.000	0.3727	0.3592	0.8232	0.5498

Note: The columns show the correlations between number of Peiex regional units (NOs) and (1) number of treated firms (Peiex), (2) number of exporters in 2007, (3) number of exporters in 2008, (4) average change in the number of layers at state level in 2007, (5) average change in the number of layers at state level in 2007.

hierarchy of knowledge. Thus, we use this information to generate instrumental variables to capture this exogeneous shock at the firm-level. First, we used the inverse of geographic distance between the location of the firm and the closest Peiex regional unit (NO) interacting with a dummy indicating the presence of NOs in the state, as a first instrument (A) for estimating the probability of receiving Peiex assistance.[28] As a second instrument we use the number of Peiex regional units (NOs) in the state of firms' headquarters (B). The number of Peiex regional units by state (Number NO by State) was built based on the year of implementation (see Table 4) of Peiex regional units in the state of firms' headquarters. As a third instrument, we use a dummy identifying if there was a firm that received other Apex programs (excluding Peiex) in a previous year ($t-1$) by sector CNAE (5 digits) in each state, conditional on Peiex's existence (C). This instrument is justified because the Peiex program targets firms with some potential to become an exporter. For this purpose, it uses as a reference the information that is available related to those firms that receive other export promotion programs. Thus, we have taken into consideration the existence of treated firms in other export promotion programs in similar sectors and regions. To capture non-linearities we also used interaction between the instruments.

Table 7 presents the descriptive statistics of the variables used as instruments based on the post-treatment years (2009 and 2010). The inverse of the geographic distance to closest NO, as well as the number of NOs by state, are larger for treated firms. The share of firms in a sector-region in which firms received other Apex's support is slightly larger for untreated firms, while the interaction terms are substantially larger for the treated firms.

We used the following fixed effects instrumental variable (IV) specification with two-stage least square (2SLS) approach:

First stage

$$D_{isrt} = \alpha_i + \theta_{st} + \beta_1 Z_{srt} + \iota X_{isrt} + \zeta_{isrt}. \quad (2)$$

Second stage

$$Y_{isrt} = \lambda_i + \kappa_{st} + \tau \hat{D}_{isrt} + \gamma X_{isrt} + \epsilon_{isrt} \quad (3)$$

where D_{isrt} is the treatment status of firm i, in sector s, region r, at time t; Z_{srt} are the instruments for Peiex's treatment status (geographic proximity of Peiex' NOs (A), number of regional office units by state at time t (B), a dummy variable identifying if other firms received other Apex's support in the same sector and state at time $t-1$(C), and the interactions terms between A*B and B*C); $\hat{D}_{isrt}$ is the predicted D_{isrt} from the first stage; X_{it} are covariates used as control variables at the firm level (e.g. number of employees, employees' schooling, managers' characteristics — including previous experience in exporting firms, age of the firm, etc.); α_i and λ_i are the firm fixed effects; θ_{st} and κ_{st} are the sector-year fixed effects; ζ_{isrt} and ϵ_{isrt} are the error terms.

For the identification of Peiex's effect, we assumed that $\text{cov}(Z_{srt}, \epsilon_{isrt}) = 0$ and $\text{cov}(Z_{srt}, \zeta_{isrt}) = 0$.[29] Hence, we assumed that the geographic proximity to NOs or the total number of NOs in the state do not affect firms' organization except through the fact that it increases the likelihood of receiving the program. Moreover, firms' fixed effects (α_i and λ_i) control for time invariant firms' characteristics, including its geographic location, that could simultaneously affect the likelihood of receiving Peiex' regional units and changes on firms' organization. Even if some states are more likely to establish a Peiex regional unit for specific reasons that could be eventually correlated with firm performance, as long as these reasons are time invariant this would not affect our identification in the presence of firm or state fixed effects.[30]

Also, the fact that we are dealing with count data that might be correlated with previous years (hierarchy at t as function of hierarchy in $t-1$) demands additional cautions regarding non-linearity and dynamics.[31] We showed that firms' organization varies even after controlling for size (firms with the same number of workers have different number of layers).[32] Nonetheless, changes in hierarchy and size (measured by total number of workers) might be simultaneously determined which might result in $\text{cov}(X_{it}, \epsilon_{it}) \neq 0$. This might be a second source of endogeneity that may be an issue for identifying τ if $\text{cov}(X_{it}, D_{isrt}) \neq 0$.[33]

Regarding the count data properties of the dependent variable, we applied a logarithmic transformation of Y (number of layers) keeping the full number of knowledge-based hierarchy levels of the firm from 1 to 5. This transformation allowed us to estimate τ using a fixed-effect instrumental variable approach in order to control for time-invariant firms' characteristics. In order to check if the logarithmic transformation provides a reasonable approximation to deal with non-linearities, we compared them with an IV using a probit in the first stage and an ordered probit in the second stage.[34] For the second source of endogeneity we instrumented the regressors (X_{it}) that could be simultaneously determined with Y_{isrt} using their own variables with 2 lags.[35] The main assumption is that $(X_{it-2}, \epsilon_{it}) = 0$, once we controlled for firms' time-constant heterogeneity.

[28] The inverse of the geographic distance to NOs (invNOdist) is defined as invNOdist = {[1 / (NOdist + 1)] * PeiexNOdum }, where "NOdist" is the geographic distance in Kylometers (Km) between the municipality of the firm and the municipality of the closest NOs; PeiexNOdum is a dummy variable identifying the existence of PeiexNOdum in the state. Brazil has currently 5570 municipalities. If the firm is in the same municipality as the NO, NOdist equals zero and invNOdist takes the value equal 1. If the firm is in a state without NO, in principle this firm is not eligible and invNOdist takes the value equal 0. If the firm is in a state with NO, but not in another city, invNOdist takes the value of 1 / (NOdist + 1).

[29] This means that the instruments should be orthogonal to the error terms (ϵ_{isrt} and ζ_{isrt}) in the first and second stages.

[30] Also, there were no relevant changes in political power coming from elections at the state or federal levels over the 2007–2010 period in Brazil. The mandate of the president, state level government and congressmen elected in the general elections of 2006 went through the 2007–2010 period. Therefore, during the period of analysis there was no changes on key political positions such as president, state level government and congressmen at the state and federal levels.

[31] Observations in count data can take only non-negative integer values and these integers results from counting rather than ranking.

[32] We are interested in analyzing the impact of the program on firms' organization conditional on firms' size.

[33] Caliendo and Rossi-Hansberg 's (2012) theory implies that increases in the number of layers come with increases in the size of the firm.

[34] See Cameron and Trivedi (1998).

[35] The covariates include number of employees, average employee's wage, average years of employee's schooling, share of engineers and R&D workers, average experience of employees, management quality based on the wage's distribution for the top layers, new managers hired with former experience in exporting firms and number of subsidiaries.

Table 7
Descriptive statistics of the Instrumental variables (2009–2010).

Variables	*N*	Mean	sd	p10	p25	p50	p75	p90
Untreated (Peiex)								
(A) Inverse of the distance to NO	476,860	0.15	0.34	0.0	0.0	0.0	0.0	1.0
(B) Number NO by state	480,826	2.05	2.80	0.0	0.0	0.0	4.0	7.0
(C) lag(sector-region Apex)	480,826	0.62	0.49	0.0	0.0	1.0	1.0	1.0
Interaction term (A)*(B)	476,860	0.07	0.25	0.0	0.0	0.0	0.0	0.1
Interaction term (B)*(C)	480,826	1.20	2.42	0.0	0.0	0.0	0.0	6.0
Treated (Peiex)								
(A) Inverse of the distance to NO	6827	0.49	0.48	0.0	0.0	0.1	1.0	1.0
(B) Number NO by state	6831	5.01	2.40	1.0	3.0	6.0	7.0	8.0
(C) lag(sector-region Apex)	6831	0.68	0.46	0.0	0.0	1.0	1.0	1.0
Interaction term (A)*(B)	6827	0.34	0.46	0.0	0.0	0.0	1.0	1.0
Interaction term (B)*(C)	6831	3.58	3.12	0.0	0.0	3.0	7.0	8.0

Note: The descriptive of the variables used as instruments is based in a pooling data from 2009 to 2010, which is defined as a treatment period. Treatment status is defined as firms that did not receive any support from Peix's program (Untreated) and firms that did receive Peiex (Treated Peiex) over 2007–2010.

4. Empirical results

4.1. Does Peiex assistance impact the organization of the firm?

In Section 2 we showed that the definition of layers is economically meaningful and brings important information about the dynamics of firms (see also Appendix A.2). A key objective of Peiex is promoting firms' reorganization to make them more competitive and more likely to export.[36] Therefore, to check if the program impacted the organization of the firm in terms of hierarchy of knowledge we analyzed its impact on the change of the number of layers. First, we carried an instrumental variable panel fixed effects estimation to control for time-constant heterogeneity among firms, allowing for $\text{cov}(\lambda_{isr}, \gamma X_{it}) \neq 0$. We instrumented treatment status D_{it} with Z's and $X_{it\text{-}2}$ as discussed in the previous section using the full sample for which observations are available.[37]

Table 8 shows the results for the instrumental variable panel fixed effects. We followed the general specification described in Eqs. (2) and (3). In order to test the sensitivity of the parameter for additional covariates we ran three different specifications with additional covariates $X_{it\text{-}2}$. The results for the first and second stages are presented in subsequent columns for each specification. In addition to controlling for time-invariant firms' heterogeneous characteristics, we also used sector-year fixed effects aiming to control for aggregated sectoral-year shocks (e.g. exchange rate, interest rate, tariff reduction).[38]

The Local Average Treatment Effect (LATE) of Peiex (τ) is positive and statistically significant at 5% for different specifications (Table 8), controlling for a large amount of covariates. The dependent variable was log-transformed. In order to interpret the coefficient, we can take the exponential of both sides of Eq. (3) and analyze the outcome conditional on Peiex status. Considering the estimations with all covariates (see column 3), the average impact is an increase of 11.5% in the predicted number of layers, based on $\tau = 0.109$.[39] Also, the variables "Manager exp $M_1 - M_3$" are positive and statistically significant in the second stage. This suggests that firms that hire managers with previous experience in other exporting firms are also more likely to change the way they organize knowledge.

Regarding the results of the first stage, the effect of the instrumental variables on the probability of getting Peiex is statistically significant at 1%. The key instruments (geographic proximity to NO and number of NOs by state, as well as their interactions) have positive signs. The closer to a Peiex regional unit and the larger the number of Peiex regional units in the state of the firm, the larger the probability of getting the assistance. A critical assumption in the identification is that these variables are orthogonal to the residuals in both stages.[40] In addition, we used as a covariate the log of the number of exporters at micro-region level.[41]

The third instrument aims to be a proxy for the fact that the program is targeting potential exporting firms that are interested in taking advantage of services for matching foreign buyers. For identifying this potential, Apex uses their own information on sectors for which these services have been provided. Peiex assistance is positively correlated with states that received NOs. Therefore, we should expect a positive sign for this variable in these states. This is what we get from the interaction term. For the instrument itself the answer is ambiguous because we are interacting with information at the sector level (CNAE 5 digits) for states where Peiex was not available and we are controlling for sector-year shocks (CNAE 2 digits). If there were sectors (at 5 digits) attended by Apex in the

[36] Caliendo and Rossi-Hansberg (2012) suggest that in a dynamic perspective more competitive firms add more layers, which allows them to reach lower levels of marginal cost.

[37] Results are consistent if we use a sample conditioned on firms that had not exported in 2007 and 2008.

[38] We do not include state-year fixed effects in our main estimation. When adding state-year fixed effects, our second instrument, which is the number of Peiex regional units (NOs) in the state of firms' headquarters, is dropped because of collinearity. The other instruments are still significant in the first stage, but the effects of Peiex's treatment are not statistically significant anymore. Our interpretation for these results is that there is not enough variation in our instruments between municipalities within state-year. In fact, the within state-level variation plays an important role in our identification strategy, given that the time difference in the distribution of NOs happened at the state level. Even if a firm A is relatively further away from the NO in a state that had a larger number of NOs than another firm B in a state with smaller number of NOs, it is reasonable the possibility that firm A will be more likely to be informed about the program. The geographic distance between the firm and the NO is a proxy that does not necessarily capture other barriers for the transmission of information, nor the non-linearity related to costs of distance, which can impact the probability to apply for the program. Results with state-year fixed effects are available in the online appendix. However, we should stress that when we use firms' fixed effects without IV, Peiex's treatment effect is significant even when controlling for both sector-year and state-year fixed effects.

[39] On average Peiex's treated firms have 2.7 different occupation categories based, which is equivalent to 1.7 layers of knowledge-based hierarchy.

[40] We showed in Section 3 that the null hypothesis that the correlation between number of NOs by state and average changes on firms' organization is different than zero in the period previous to the treatment is not rejected (see Table 6).

[41] This variable aims to control for potential exogenous shocks (e.g. external demand) that might impact exporters at the regional level and could affect production hierarchy of firms in the same region. However, we see that this variable is significant in the first stage, but not in the second stage.

Table 8
Instrumental variable fixed effects model. Dependent variable: number of layers.

Instrumental variable fixed effects estimator						
Dependent variable: Log(number of layers)						
	(1)		(2)		(3)	
Variables	1st	2nd	1st	2nd	1st	2nd
Peiex treatment		0.112***		0.112***		0.109***
		(0.040)		(0.040)		(0.038)
Other programs Apex	−0.072***	0.023***	−0.072***	0.023***	−0.072***	0.013**
	(0.014)	(0.006)	(0.014)	(0.006)	(0.014)	(0.005)
Firms' age	−0.000	0.010***	−0.000	0.010***	−0.000	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firms' age^2	0.000***	−0.000***	0.000***	−0.000***	0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log(number employees)$_{t-2}$	0.002***	0.018***	0.002***	0.018***	0.002***	0.013***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
log(wage)$_{t-2}$			0.001***		0.001***	0.001
			(0.000)		(0.000)	(0.001)
log(schooling)$_{t-2}$			−0.003**		−0.003**	−0.012***
			(0.001)		(0.001)	(0.003)
log(nbr exporters - region)			0.001		0.001	0.001
			(0.002)		(0.002)	(0.001)
Share(engineer and R&D)$_{t-2}$			0.001*		0.001*	0.013***
			(0.001)		(0.001)	(0.005)
Average experience $_{t-2}$			−0.000***		−0.000***	−0.004***
			(0.000)		(0.000)	(0.000)
Number of subsidiaries $_{t-2}$			0.001*		0.001*	0.005***
			(0.000)		(0.000)	(0.002)
Manager exp M_1					0.005	0.012***
					(0.003)	(0.005)
Manager exp M_2					−0.001	0.016***
					(0.005)	(0.004)
Manager exp M_3					−0.004*	0.020***
					(0.002)	(0.003)
Manager M_1 N-Q_4					0.000	0.181***
					(0.001)	(0.008)
Manager M_1 F-Q_4					−0.001	0.024***
					(0.001)	(0.007)
Manager M_2 N-Q_4					0.001	0.156***
					(0.002)	(0.013)
Manager M_2 F-Q_4					0.001	0.025**
					(0.001)	(0.010)
Manager M_3 N-Q_4					−0.001	0.253***
					(0.001)	(0.007)
Manager M_3 F-Q_4					0.001	0.003
					(0.001)	(0.006)
Instruments 1st *stage**						
(A) Inverse of the distance to NO	0.012***		0.012***		0.012***	
	(0.003)		(0.003)		(0.003)	
(B) Number NO by state	0.002***		0.002***		0.002***	
	(0.000)		(0.000)		(0.000)	
(C) lag(sector-region Apex)	−0.008***		−0.008***		−0.008***	
	(0.002)		(0.002)		(0.002)	
Interaction term (A)*(B)	0.024***		0.024***		0.024***	
	(0.007)		(0.007)		(0.007)	
Interaction term (B)*(C)	0.003***		0.003***		0.003***	
	(0.000)		(0.000)		(0.000)	
Additional manager's control*						
Managers Q_2-Q_3	No	No	No	No	Yes	Yes
Firms fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	778,565	778,565	778,497	778,497	778,497	778,497
Number of firms	219,578	219,578	219,562	219,562	219,562	219,562

Note: Standard errors clustered at the state-sector level in the first stage and at the firm level in the second stage are reported in parentheses. Managers are classified by occupations equivalent to CEOs and Directors (M1), Senior staff (M2) and Supervisors (M3). N and F refer to their nationalities, where N (Nationals) and F (Foreigners). Additional Manager's control (Managers Q_2–Q_3) refers to dummy variables for managers in the second and third quartile of wage distribution. The variables used as instruments are also significant in the first stage when the standard errors are clustered at the state level.

past that are more prevalent in states where Peiex is not available, once we are controlling for a more aggregate sector-year shock the coefficient's sign will depend on this interaction. We also tested for similar specifications keeping only two instruments (number of NOs by state and the lag of sectors(CNAE 5 digits) assisted in each state conditional on Peiex existence) and only one instrument (number

Table 9
Heterogeneous effect.

Variable	Micro <10 workers		Small 10–39 workers		Medium 41–99 workers		Large ≥100 workers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Peiex	0.04	0.00	0.120**	0.096**	0.136**	0.191***	0.07	0.09
	(0.08)	(0.08)	(0.05)	(0.05)	(0.07)	(0.06)	(0.07)	(0.06)
log(number employees)$_{t-2}$	0.010***	0.007***	0.028***	0.020***	0.022***	0.012***	0.005**	−0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Covariates								
X1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
X2		Yes		Yes		Yes		Yes
Observations	412,582	412,550	177,429	177,429	43,739	43,739	30,787	30,787
Number of firms	114,704	114,700	45,866	45,866	11,195	11,195	7861	7861

Note: Results refer to the second stage. Standard errors clustered at the firm level in the second stage are reported in parentheses. Instrumental variables are statistically significant in the first stage with standard errors clustered at the state-sector level. The variables used as instruments are also significant in the first stage when the standard errors are clustered at the state level. The following additional controlling variables are included in the models: X1 (Other programs Apex, log of wage, log of schooling, dummy for multinational, share of engineers and R&D workers, lag of average experience, lag of additional plants), X2 (dummy Manager export M1–M3, TOP managers by nationality status M1–M3).

of NOs by state).[42] The impact is still positive and significant. The advantage of using additional instruments is that it allows us to test for overidentification restriction, which is part of the robustness check.

Our results are driven by firms that received assistance between 2009 and 2010. If we exclude firms that received assistance only in 2010 from the sample, Peiex's treatment is still significant and the magnitude of the coefficient is relatively similar ($\tau = 0.1$).[43] Overall, the program is fairly homogenous. It follows a diagnostic based on a standard evaluation across firms, and provides a certain amount of consulting hours that may span across different time period, but are similar in terms of intensity. On average, Peiex's treatment take between three to six months of follow up with firms, but the program did not have the specific information for each firm, over this period.[44]

4.1.1. Heterogeneous effects

We also test if there is evidence of heterogeneity of the program effects across different firms, according to their size based on number of employees. We distinguish firms in four groups, based on their average size between 2007 and 2008.[45] The first group is composed by firms with less than 10 employees (micro firms). The second group are firms between 10 and 39 employees (small firms). The third group are firms between 40 and 99 employees (medium), while the fourth group are firms with 100 or more employees (large). We run a specification that is similar to our baseline for four group of firms (micro, small, medium, and large). The predicted number of layers based hierarchy of knowledge increases with Peiex's support for small (by about 10.1%) and medium firms (by about 21.0%) The coefficients are similar to our baseline model for small firms, but slightly larger for medium firms (Table 9). However, we found no evidence of significant effect for a sub-sample of micro (less than 10 workers) or large (100+ workers) in pre-treatment years. These findings suggest that Peiex's effect was heterogeneous and more significant among small and medium firms in their initial condition.

[42] These results are available upon request.
[43] Most firms that received assistance in 2009 also appear in our data as receiving assistance in 2010.
[44] Some of the treated firms may have been treated only for a few weeks and that would not produce any sizable change in the organization. In this respect our estimates could be a lower bound.
[45] This period refers to two years before the implementation of the program.

4.2. Robustness check

A critical assumption in the identification is the exclusion restriction, which means that the instruments are orthogonal to the residuals in the first and second stages. While we cannot test this assumption directly, there are some standard robustness checks that provide additional support to the results. First, Table 10 shows the *F* statistic for joint significance of the instruments *Z* in the first stage. It is noticeable that we reject the null hypothesis that all excluded instruments are not significant at 1% significance. Stock-Yogo shows the critical value for the null hypothesis that the bias of 2SLS is less than a given fraction (e.g. 5%) of the bias of OLS. Based on the *F*-statistics of the first stage we can reject the null hypothesis at 5% of maximal IV relative bias.

Also, due to the fact that we used two variables and the interaction among them as instruments, we can test if at least one of the instruments is exogenous (see Hansen J test on Table 10). We do not reject the null hypothesis that all instruments are valid and conclude that the overidentifying restrictions are valid. In addition, we ran the specification using two instruments (number of NOs by state and the lag of sectors-region assisted in each state weighted by Peiex existence) with and without the interaction term between these variables and the null hypothesis is rejected.

Table 10
Overidentification test: Fixed effects instrumental variable.

Test	(1)	(2)	(3)
F test of excluded instruments:			
F-stat	53.95	54.43	54.48
Prob > *F*	0.00	0.00	0.00
Stock-Yogo weak ID test critical values:			
5% maximal IV relative bias	18.37	18.37	18.37
10% maximal IV relative bias	10.83	10.83	10.83
20% maximal IV relative bias	6.77	6.77	6.77
30% maximal IV relative bias	5.25	5.25	5.25
10% maximal IV size	26.87	26.87	26.87
15% maximal IV size	15.09	15.09	15.09
20% maximal IV size	10.98	10.98	10.98
25% maximal IV size	8.84	8.84	8.84
Hansen J statistic:			
Overidentification test of all instruments	4.73	4.31	6.57
Chi-sq(2) *p*-val	0.32	0.37	0.16

Note: Columns (1), (2) and (3) refer respectively to the three specifications used for the results presented on Table 8.

Our results using panel fixed effects IV with a log-transformation of the number of knowledge-based hierarchies is based on simplified linear assumptions. Yet, both the first and the second stages of the regression involve non-linear dependent variables (a dummy variable in the first stage and a count variable in the second stage). To address the non-linearity we ran similar specifications using a probit in the first stage and an ordered probit in the second stage. To make the estimation more comparable we use the first difference of the number of knowledge-based hierarchies in the second stage. The results are relatively similar to the ones obtained with logarithm transformation (Table 11), which suggests that the adopted procedure provides a good approximation of the non-linearity presented in the dependent count

Table 11
Instrumental variable fixed effects model. Dependent variable: number of layers.

Instrumental variable — ordered probit estimator						
Dependent variable: Changes in the number of layers						
	(1)		(2)		(3)	
Variables	1st	2nd	1st	2nd	1st	2nd
Peiex treatment		0.125***		0.141***		0.191***
		(0.041)		(0.039)		(0.036)
Firms' age	−0.004*	−0.007***	0	−0.005***	−0.001	−0.003***
	(0.002)	0.000	(0.002)	0.000	(0.002)	0.000
Firms' age^2	0.000	0.000***	0.000	0.000***	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log(number employees)$_{t-2}$	0.139***	−0.035***	0.143***	−0.041***	0.147***	−0.084***
	(0.005)	(0.001)	(0.006)	(0.001)	(0.006)	(0.001)
log(wage)$_{t-2}$			−0.066***	0	−0.036**	−0.102***
			(0.012)	(0.003)	(0.014)	(0.003)
log(schooling)$_{t-2}$			0.111***	−0.117***	0.136***	−0.195***
			(0.041)	(0.006)	(0.042)	(0.007)
log(nbr exporters — region)			−0.077***	0.005***	−0.076***	−0.002**
			(0.006)	(0.001)	(0.006)	(0.001)
Manager exp M_1			0.175	0.223***	0.199	0.125***
			(0.131)	(0.036)	(0.132)	(0.036)
Manager exp M_2			0.05	0.131***	0.115	0.063*
			(0.125)	(0.035)	(0.127)	(0.035)
Manager exp M_3			−0.022	0.182***	−0.028	0.036
			(0.099)	(0.024)	(0.099)	(0.024)
Share(engineer and R&D)$_{t-2}$			0.069***	0.011	0.081***	−0.036**
			(0.018)	(0.012)	(0.021)	(0.017)
Average experience $_{t-2}$			−0.010***	−0.006***	−0.010***	−0.006***
			(0.001)	(0.001)	(0.001)	(0.001)
Number of subsidiaries $_{t-2}$			−0.005	0.004***	−0.001	0.000
			(0.008)	(0.001)	(0.006)	(0.001)
Manager M_1 N-Q_4					−0.217	0.055*
					(0.182)	(0.029)
Manager M_1 F-Q_4						0.060***
						(0.021)
Manager M_2 N-Q_4					−0.713*	0.242***
					(0.385)	(0.035)
Manager M_2 F-Q_4						0.139***
						(0.033)
Manager M_3 N-Q_4					−0.101	0.259***
					(0.192)	(0.029)
Manager M_3 F-Q_4					−0.045	0.057***
					(0.393)	(0.022)
Instruments 1st *stage**						
(A) Inverse of the distance to NO	0.465***		0.500***		0.497***	
	(0.028)		(0.028)		(0.028)	
(B) Number NO by state	0.111***		0.142***		0.144***	
	(0.035)		(0.035)		(0.035)	
(C) lag(sector-region Apex)	0.116***		0.121***		0.121***	
	(0.004)		(0.004)		(0.004)	
Interaction term (A)*(B)	−0.251***		−0.164***		−0.165***	
	(0.026)		(0.028)		(0.028)	
Interaction term (B)*(C)	0.026***		0.017***		0.016***	
	(0.005)		(0.005)		(0.005)	
*Additional manager's control**						
Managers Q_2-Q_3	No	No	No	No	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	633,431	633,431	633,369	633,369	633,369	633,369
Number of firms	252,904	252,904	252,878	252,878	252,878	252,878

Note: Standard errors clustered at the state-sector level in the first stage and at the firm level in the second stage are reported in parentheses. Managers are classified by occupations equivalent to CEOs and Directors (M1), Senior staff (M2) and Supervisors (M3). N and F refer to their nationalities, where N (Nationals) and F (Foreigners). Additional Manager's control (Managers Q_2–Q_3) refers to dummy variables for managers in the second and third quartile of wage distribution. The number of observations is smaller because the first year is dropped from the regression when we take the first difference using the same sample used to estimate results in Table 8.

variable. Yet, this estimation imposes further constraints. We control for sector and year fixed effects separately and kept the variables in level, in order to reach convergence of the model.

We also ran a Poisson panel fixed effects and a linear panel fixed effect estimators using similar specifications,[46] identifying Peiex's treatment effect under DID assumptions, without IV. We controlled for regional year (state-year dummies) shocks that play an important role in the IV identification strategy. Results are qualitatively similar if we use panel fixed-effects or Poisson panel fixed-effects estimations. The estimation confirms that Peiex' assisted-firms had changed their organization, adding additional layers (this difference is significant at 1%), after controlling for time-constant heterogeneity and a large set of firms' covariates, including proxies for quality of management. In both cases (Poisson fixed effects and Panel fixed effects), Peiex's coefficients are still positive and significant, though the magnitude is smaller than the LATE from the IV.[47]

4.3. Peiex and hierarchy of knowledge: what does this means for firms' performance?

The hierarchy based on knowledge measures different levels of competencies of workers limited to 4 layers. Hence, this is not about increasing the number of directors or manager positions itself; neither are we assuming that the more managers, the better. Instead, increasing the number of layers in this case means that a firm is incorporating workers with different levels of competency and specialized knowledge in solving different problems at the firm. For example, if a firm already has 3 layers and decides to hire more workers at the same layers we assume that there is no change in the way firms organize their knowledge of production, even if these new workers have managers' positions. Thus, we capture one type of organization, but one which matters for performance.

We found evidence that Peiex has an effect on firms' organization based on hierarchy of knowledge (see Section 4.1). This means that the program increases the propensity of a treated-firm adding workers with level of knowledge not previously available in its structure. The majority of firms already have producer workers. Hence, by increasing the number of layers they are adding workers in new occupations that require additional and specialized knowledge. Apart from the fact that these workers have more average years of schooling (see Appendix A.2), the concept of occupation does not take into consideration only the education background of the worker, but also her activity at the firm.[48] Therefore, the layers of hierarchy measure specialization of knowledge at the firm (see Caliendo et al., 2015b).

Fig. 2 shows that for the same amount of employees there are firms with different number of layers. There are almost the same number of firms with 0 or 4 layers of management based on knowledge among those firms between 19 and 20 employees (approximately log of 3) (see Table 17 in Appendix A.2). Nonetheless, on average those firms with larger number of layers of knowledge are more likely to be exporters. Fig. 3 plots the propensity to export against the number of employees according to number of layers for firms with less than 150 workers.[49] It is noticeable that the propensity to export is larger for firms with more layers based on knowledge given the same amount of workers.[50]

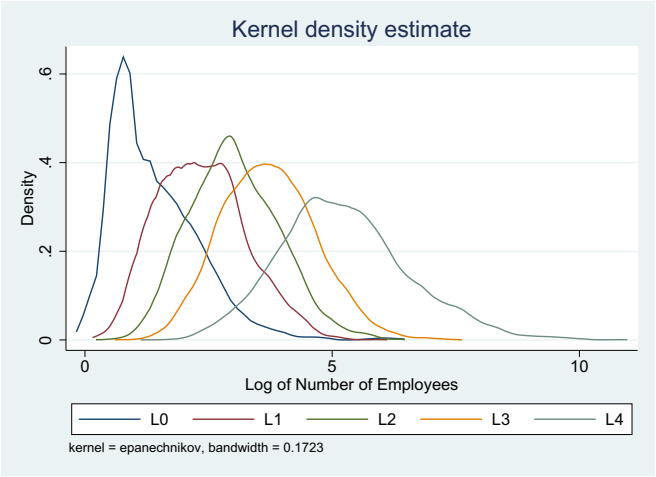

Fig. 2. Kernel density estimate of number of employees by number of layers. Note: L0 refers to the distribution of the number of workers across firms without hierarchy of knowledge. Usually those firms have only employees with occupations classified as blue collars. L1 refers to the distribution of the number of workers across firms with one layer of hierarchy of knowledge. Those are firms that have employees in two different occupations according to the classification in Table 1 (e.g. blue collars and technicians). L2, L3 and L4 refer to the distribution of the number of workers across firms with 2, 3, and 4 layers of hierarchy of knowledge. Those are firms that have employees in 3, 4, and 5 different occupations according to the classification in Table 1.

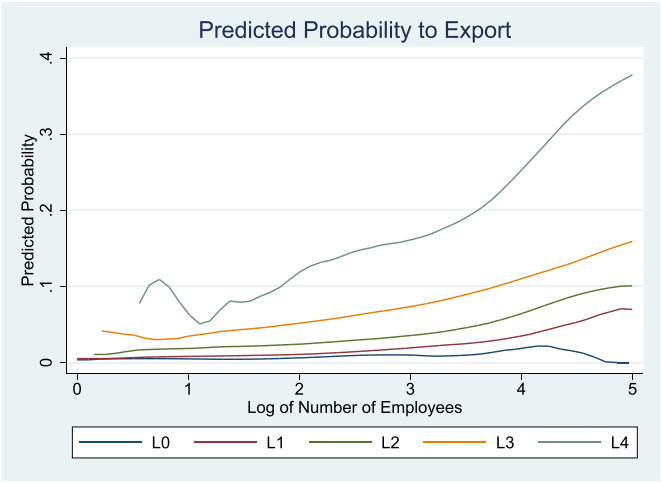

Fig. 3. Export propensity plotted against number of employees according to number of layers of management. Note: L0 refers to the propensity to export according to total number of workers for firms without hierarchy of knowledge. Usually those firms have only employees with occupations classified as blue collars. L1 refers to the propensity to export according to total number of workers for firms with one layer of hierarchy of knowledge. Those are firms that have employees in two different occupations according to the classification in Table 1 (e.g. blue collars and technicians). L2, L3 and L4 refer to the to the propensity to export according to total number of workers for firms with 2, 3, and 4 layers of hierarchy of knowledge. Those are firms that have employees in 3, 4, and 5 different occupations according to the classification in Table 1.

These findings are supported by Cruz (2014), who shows that non-exporting firms that received export promotion assistance, including Peiex, are more likely to become exporters. Also, Table 12 shows the relationship between the transition of exporting status and organization.[51] Firms are divided in three groups: non-exporters (firms that did not export at periods t and $t+1$); new exporters (firms that did not export at period t but become an exporter at period $t+1$) and continuing exporters (firms that continuously exported from $t-2$

[46] The Poisson estimation takes into consideration the non-linearity of the dependent count variable. This method was made popular by Hausman et al. (1984).

[47] Results are available under request.

[48] A firm can hire workers with higher level of education in occupations that do require lower level of knowledge.

[49] More than 98% of firms that received Peiex's support in 2009 and 2010 had less than 150 employees.

[50] Peiex can impact firm performance directly, not only via changes in the hierarchy of knowledge. Managers may learn useful work practices and start applying them even if they retain their job title.

[51] The dynamic year by year from 2007 to 2010 is relatively similar.

Table 12
Distribution of layers at $t+1$ conditional on layers at t (by year).

	Number of layers	Year 2009–2010 (year $t+1$)					Firms (2009)	
		0	1	2	3	4	Number	Share*
Non-exporting firms								
	0	**81.66**	15.75	2.23	0.32	0.05	80,628	35.42
Year t	1	12.59	**73.64**	12.06	1.53	0.18	77,335	33.97
(2010)	2	2.81	16.67	**67.74**	11.59	1.19	41,815	18.37
	3	1.17	3.46	18.42	**65.70**	11.26	18,960	8.33
	4	0.63	0.77	3.46	16.80	**78.34**	8904	3.91
Firms	Number	77,027	77,341	43,250	20,239	9785	227,642	–
(2010)	Share*	33.84	33.97	19.00	8.89	4.30	–	100.00
New exporters firms								
	0	**57.24**	28.97	9.66	1.38	2.76	145	8.02
Year t	1	4.61	**70.72**	17.76	5.26	1.64	304	16.80
(2010)	2	1.30	6.74	**68.91**	17.88	5.18	386	21.34
	3	–	0.50	13.03	**67.17**	19.30	399	22.06
	4	–	–	0.70	7.30	**91.83**	575	31.79
Firms	Number	102	286	390	397	634	1809	–
(2010)	Share*	5.64	15.81	21.56	21.95	35.05	–	100.00
Continuing exporters								
	0	**75.21**	17.36	3.31	2.48	1.65	121	1.90
Year t	1	9.28	**73.65**	13.77	2.10	1.20	334	5.24
(2010)	2	0.87	10.14	**69.13**	16.67	3.19	690	10.82
	3	0.56	1.21	8.22	**70.84**	19.16	1,070	16.78
	4	0.12	0.10	0.34	3.46	**95.99**	4163	65.27
Firms	Number	139	354	629	1027	4229	6378	–
(2010)	Share*	2.18	5.55	9.86	16.10	66.31	–	100.00

to $t+1$). The rows show the number of layers at period t and the columns show the number of layers the same firms have at period $t+1$. The main diagonal shows the share of firms that kept the same number of layers.

When analyzing non-exporting firms, almost 70% of them have no more than one layer of hierarchy. Among them, the majority (82% of those firms without layers and 74% of those with one layer) did not change the number of layers. Also, among those firms with between 1 and 3 layers the share of firms that increase the number of layers is always smaller than the share of firms that decrease them. It is noticeable that the scenario for new exporters is different. Among them, the share of firms that add an additional layer is always larger than those ones that decrease it if we take into consideration firms that had between 1 and 3 layers in t.[52] Moreover, approximately 91% of the firms with 4 layers in t_0 kept this organization design after switching from non-exporting to exporting status. Hence, firms that become exporters are more likely to change their organization and add new layers.

Regarding continuing exporters, the share of firms that add new layers is much larger than firms that reduce them, which is similar to new exporters. Also, the majority of the firms have already 3 or 4 layers and among the former, almost 95% keep the same structure. Therefore, the structure of exporting firms is composed of more layers than non-exporting firms and new exporters are more likely to add layers of managers than non-exporting firms.[53] Fig. 5 in Appendix A.2 shows the dynamic of firms that become exporters regarding their average wage and hours hired.[54]

[52] Having between 1 and 3 layers is a condition that allows firms to add or subtract at least one layer.

[53] What is interesting in these findings is that depending on adding layers or not, new exporters react differently in terms of how they distribute production knowledge within the firm when they expand and this can be observed by the average wage in different layers.

[54] Overall, we find that the prediction of Caliendo and Rossi-Hansberg (2012) theory holds in most of the cases when the transition of the same firms that become exporters and add additional layers in the same year is compared. This suggests that on average the same firms that switch export status (from non-exporting to exporting) and add one layer usually pay lower wages for workers at previously existing layers.

4.4. Expansion, reorganization and wage inequality

Another relationship between the firms' organization and competitiveness is related to within-firm wage inequality and hours hired among production workers. According to Caliendo and Rossi-Hansberg (2012), a reorganization of the firm by adding additional layers of knowledge-based hierarchy would lead to a decrease in the average wage in layers previously existent, even though the average wage for the whole firm may increase. Because the new top layers of management have an average wage that is higher than the previous layer and the average wage for producer workers decreases, we would expect the ratio of average wage in the top layer divided by the average wage in L0 to increase for those firms that receive Peiex's support.

We ran similar specifications with panel fixed effects for log of wage's inequality between the top and bottom layers. Table 13 shows the results (first three columns). Overall, we observed Peiex treatment is associated with an increasing in wage inequality between layers and its coefficient is statistically significant at 5%. Also, the theoretical reference predicts that the number of hours on previously existing layers, more specifically for the production workers, would increase. Table 13 shows that the coefficients are positive and significant at 1% confidence (last three columns). These results are consistent with the theory that firms reorganize their knowledge on production by adding new occupations with relatively higher wages, used here as a proxy of more knowledge, which allows them to keep relatively lower marginal cost of production, while expanding the number of hours hired of production workers.

5. Conclusion

This paper evaluates the impact of the Peiex program, a consulting service on management and production practices provided by Apex-Brasil aimed at improving the competitiveness of small and medium firms. We found a positive impact of Peiex on firms' organization. Based on the IV identification strategy, firms that received the program increased by approximately 11.5%, on average, the predicted number of layers of knowledge-based hierarchy. We find that our results are driven by increasing the number of layers

Table 13
Dependent variables: Log(Inequality between the top and the bottom layer) and Log(Hours hired in L0) — Panel fixed effects.

	Log inequality			Log hours L0		
Variable	Model1	Model2	Model3*	Model1	Model2	Model3*
Peiex	0.021***	0.021***	0.017***	0.141***	0.136***	0.133***
	(0.007)	(0.007)	(0.006)	(0.011)	(0.011)	(0.011)
Apex(other programs)	0.020**	0.019**	0.015**	0.076***	0.069***	0.067***
	(0.008)	(0.008)	(0.008)	(0.015)	(0.014)	(0.014)
Firms' age	0.005**	0.005**	0.003	0.032***	0.034***	0.032***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)
Firms' age^2	−0.000***	−0.000***	−0.000***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log(number employees)$_{t-2}$	0.013***	0.013***	0.010***	0.022***	0.018***	0.017***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
log(wage)$_{t-2}$		−0.000	−0.000		0.007**	0.007**
		(0.001)	(0.001)		(0.003)	(0.003)
log(schooling)$_{t-2}$		0.002	0.002		−0.008	−0.008
		(0.003)	(0.003)		(0.008)	(0.008)
log(nbr exporters sector-region)		−0.002	−0.002		−0.006	−0.006
		(0.002)	(0.002)		(0.004)	(0.004)
Share(engineer and R&D)$_{t-2}$		0.020***	0.017***		0.015	0.011
		(0.006)	(0.006)		(0.009)	(0.009)
Average experience $_{t-2}$		−0.001***	−0.001***		−0.013***	−0.013***
		(0.000)	(0.000)		(0.000)	(0.000)
Number of subsidiaries $_{t-2}$		0.005**	0.003		0.072***	0.071***
		(0.002)	(0.002)		(0.008)	(0.008)
Manager exp M_1			0.052***			0.057***
			(0.012)			(0.019)
Manager exp M_2			0.003			0.075***
			(0.012)			(0.021)
Manager exp M_3			0.001			0.055***
			(0.008)			(0.012)
Manager M_1 N-Q_4			0.202***			−0.089***
			(0.017)			(0.025)
Manager M_1 F-Q_4			0.070***			0.046
			(0.019)			(0.036)
Manager M_2 N-Q_4			−0.015			−0.214***
			(0.028)			(0.047)
Manager M_2 F-Q_4			−0.032			0.106**
			(0.025)			(0.052)
Manager M_3 N-Q_4			0.059***			−0.065**
			(0.017)			(0.025)
Manager M_3 F-Q_4			0.027			0.105**
			(0.021)			(0.044)
*Additional manager's control**						
Managers N-Q_2-N-Q_3	No	No	Yes	No	No	Yes
Managers F-Q_2-F-Q_3	No	No	Yes	No	No	Yes
Fixed effect						
Firms	Yes	Yes	Yes	Yes	Yes	Yes
Sector-Year	Yes	Yes	Yes	Yes	Yes	Yes
Region (State)-Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	812,319	812,243	812,243	818,162	818,090	818,090
Number of firms	267,102	267,077	267,077	266,436	266,411	266,411

Note: Note: Standard errors clustered at the firm level are reported in parentheses. We exclude outliers (equivalent to 1% of extreme values). Managers are classified by occupations equivalent to CEOs and Directors (M1), Senior staff (M2) and Supervisors (M3). N and F refer to their nationalities, where N (Nationals) and F (Foreigners). Additional Manager's control (Managers Q_3–Q_1) refers to dummy variables for managers in the second and third quartile of wage distribution. Sector (CNAE 2 digits). Log Inequality refers to the ratio of the average real wage at the top hierarchy (Ln) and production workers (L0). Log hours L0 refers to the log of total hours hired of production workers. Results refer to the full sample. Similar results is obtained if firms that exported in pre-treatment years (2007 or 2008) are excluded.

of knowledge-based hierarchy for small and medium firms, defined as firms between 10 and less than 100 employees two consecutive years before the program started.

In addition, we find that Peiex firms have expanded the hours hired of production workers, the reorganization of those firms is associated with an increase in the likelihood of being an exporter and a rise in wage inequality between layers of hierarchy based on knowledge. Understand whether firms promote lower-level workers or hire new ones when changing the organization of knowledge is an important avenue for future research.

Appendix A

A.1. Peiex-treated firms and methodology

Peiex was launched in late 2008/2009. The program was motivated by the fact that some small and medium firms interested in exporting were not prepared to take full advantage of other export promotion services provided by Apex. Peiex program works as an extensionism for manufacturing firms, following the methodology presented in Fig. 4.

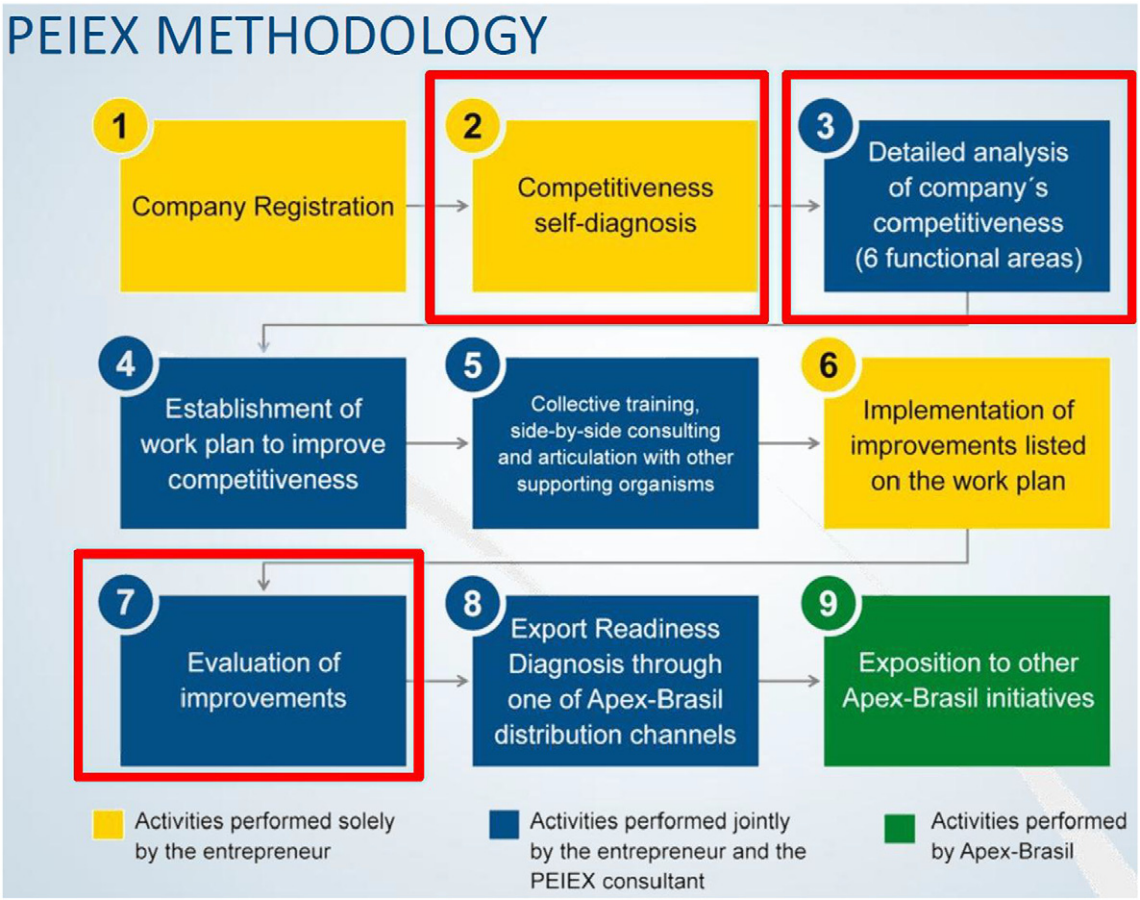

Fig. 4. Peiex methodology.
Source: Replicated from Borges (2010).

Table 14 shows the total number of firms, the number of exporters and the number of Peiex-treated firms by year. Most firms that received assistance in 2009 also appear in our data as receiving assistance in 2010. Yet, the program is fairly homogenous in terms of intensity. The program follows a diagnostic based on a standard evaluation across firms, and provides a certain amount of consulting hours that may span across different time period, but are similar in terms of intensity. On average, Peiex's treatment take between three to six months of follow up with firms, but the program did not have the specific information for each firm, over this period.

Table 14
Number of manufacturing firms by year (2007–2010).

Year	Number of firms	Exporters	(Share)	Peiex	(Share)
2007	226,188	12,191	5.4	–	–
2008	231,583	11,965	5.2	–	–
2009	239,931	11,626	4.8	2410	1.0
2010	246,674	11,362	4.6	3517	1.4

Note: This is the total number of firms per year that respected the condition of existence for at least three years, including year t — reported in this table, $t-1$, and $t-2$. We excluded 2205 firms' observations for which the number of hierarchy of knowledge is missing due to missing information on occupations.

A key element of Peiex is decentralization, given that the program requires presencial interactions between consultants and firms. The regional units (NOs) are implemented through agreements with local institutions (e.g. universities, research foundations, and technological parks). Before setting up the center, Peiex program establish a partnership with a local institution. Most of the contracts with local institutions, for NOs operating until 2010, were signed up in 2008 and firms started to received treatment in 2009. To account for the time to be organized we give 6 months of gap from the moment of Peiex's program sign the agreement to establish an NO and the time it is operating.

The program considered the initial years of 2009 and 2010 as a pilot. For this reason, they started the implementation of NOs in few states where previous studies, commissioned by Apex Brasil, suggested potential for exporters. Yet, they strategically left out few of these states, including São Paulo, which is the state with the largest amount of firms and almost 50% of exporting firms in Brazil, where they already had a large concentration of firms receiving other Apex' support.

Firms can show interest for the program by phone or email, but to register to the program they need to visit the NO or receive a visit of a Peiex's extensionist. The second, is the most common approach and is strongly affected by proximity with Peiex's NOs. Peiex's extensionists also interact with local institutions, including municipal government and local industry associations to promote the program. Peiex's extensionists also contact firms that could fit the profile of potential beneficiaries based on information obtained through Internet and local municipal authorities. Overall, the NOs follow a rule to prioritize firms that are no further than 100 km away from their office in the same state. The municipality is the most disaggregated geographic unit for which there is an interaction with Peiex's offices and local institutions. For example, Peiex team would promote their activities in partnership through local business associations and municipality authorities. Therefore, being in a state of NOs and geographically near to them substantially increases the probability of these firms to learn, apply and receive Peiex. If a firm is from another state, despite the potential proximity to the NO, a special

requirement needs to be forwarded to Peiex's coordination office, in Brasília for clearance. This procedure is very unusual.[55]

A.2. A proxy for firms' organization

The proxy for firms' organization based on hierarchy of knowledge was build in the spirit of Garicano (2000) and Caliendo and Rossi-Hansberg (2012) theoretical frameworks. In Caliendo and Rossi-Hansberg (2012), heterogeneity on productivity and other firms' outcome results from the way firms organize their knowledge given the level of demand for their products (economies of scale), which is randomly drawn by an entrepreneur. The production function requires labor and knowledge. Employees can act as production workers (layers $l = 0$) or managers (layers $l \geq 1$). While workers use their unit of time to generate production possibility and solve standard problems for which they are trained, managers use their time on solving exceptional problems that require greater knowledge. Adding an additional layer of knowledge-based hierarchy (layers $\partial l > 0$) results in an additional fixed cost, which allows firms to economize in the knowledge acquisition of their employees, who generate production possibility and determine the marginal cost. This allows firms to reach lower average costs conditional on a sufficiently large scale of production. This section provides additional descriptive statistics for the variable "layers" based on hierarchy of knowledge, which is used as proxy for firms' organization. To begin with, we analyzed the distribution of wages of workers among the classification we followed in order to check if this criteria matches differences on wages between and within layers.[56]

The key criteria to define the hierarchies based on the current structure is defined by the level of competency required by the task, the share of higher educated workers (with college or graduation degree), and wages. The level of skills and competency is defined by the Brazilian Ministry of Labor, adapting the International Standard Classification of Occupation (ISCCO 88) towards the reality of labor market in Brazil. We use occupation at 1 digit to define the structure of knowledge in the firm, which is based on 10 occupations. The first major group (CG1) refers to Senior officials, CEOs and Managers. The concept of skill level is not applied in the case of CG1 because skills for executing tasks and duties of occupations belonging to this major group vary to such an extent that it would be impossible to link them with any of the four broad skill levels category. Yet, this group has the highest average in the Brazilian data. The second group (CG2) comprises occupations whose core activities require for their performance high level professional knowledge and experience in the physical, biological, social and human sciences. These are tasks that require the largest level of skills (4) and this group comprises the largest share of workers with college or graduate degree.The third group (CG3) comprises occupations whose principal activities require for their performance, technical knowledge and experience of one or more disciplines of the physical and biological sciences or of the social and human sciences. These are tasks that require the second-highest level of skills (3) and this group comprises the second-largest share of workers with college or graduate degree.

We keep these three-top levels of hierarchy in our structure of occupation as their original definition. For the other groups (CGs 4, 5, 7, 8, and 9), the skill level (or level of competency) determined by the MTE-IBGE when evaluating the complexity of these tasks are similar (2). In this case, we use the purpose of activity and level of education to define the groups. The fourth and the fifth groups (CG4 and CG5) refer to services: clerks and other service workers. Because our empirical analysis is focusing on "manufacturing firms" these are workers that are not directly involved with production. Also, these groups comprise the fourth- and the fifth-largest share of workers with college or graduate degree. The other groups (CG7, CG8, and CG9) refer to direct production and Maintenance. The large majority of workers in these groups are concentrated in CG7 and CG8, which are directly defined as "production workers." The difference between these groups is based on discrete manufacturing (CG7) or process manufacturing (CG8), while CG9 refers to operators of industrial installations and maintenance of machines and equipment. Also, CG9 is defined as skill level 1 in the ISCO 88.

Table 15
Schooling level by layers (2007–2010).

Classes	No degree	Prim.	Second.	Higher Ed.	Postgrad	Total
Year=2007						
CEOs, Directors	7.47	13.16	35.33	43.28	0.76	161,874.08
Senior staff/manager	2.71	4.14	18.72	73.60	0.83	180,500.75
Supervisors	7.32	15.91	61.68	14.98	0.11	509,858.67
Clerks	15.63	25.36	51.29	7.67	0.05	1,023,941.92
Blue collars	28.84	33.92	36.30	0.92	0.01	4,632,421.92
Total	23.82	29.82	40.13	6.15	0.07	6,508,597.33
Year=2008						
CEOs, Directors	6.84	12.36	35.92	43.94	0.93	173,567.83
Senior staff/manager	2.62	3.96	19.50	72.92	1.00	198,000.33
Supervisors	6.57	14.74	62.85	15.69	0.15	553,906.00
Clerks	14.73	24.52	52.86	7.83	0.07	1,117,624.00
Blue collars	26.58	32.89	39.55	0.96	0.02	4,945,734.00
Total	21.93	28.78	42.87	6.33	0.09	6,988,832.17
Year=2009						
CEOs, Directors	6.55	11.73	36.54	44.07	1.12	177,990.67
Senior staff/manager	2.41	3.50	19.44	73.54	1.11	203,053.33
Supervisors	5.95	13.78	63.41	16.70	0.16	556,933.83
Clerks	13.97	23.34	54.35	8.26	0.08	1,123,999.00
Blue collars	25.15	32.11	41.70	1.02	0.02	4,751,836.25
Total	20.57	27.78	44.76	6.78	0.10	6,813,813.08
Year=2010						
CEOs, Directors	6.12	11.06	37.66	43.96	1.20	190,899.92
Senior staff/manager	2.21	2.87	16.77	77.00	1.14	228,782.08
Supervisors	5.53	12.98	64.28	17.03	0.18	601,766.08
Clerks	13.08	22.47	55.93	8.44	0.08	1,214,824.92
Blue collars	23.44	30.99	44.45	1.10	0.02	5,154,415.00
Total	19.17	26.74	46.92	7.06	0.11	7,390,688.00

Table 15 shows the level of schooling according to different layers. The first layer includes Self-employed entrepreneurs, CEOs, Directors and Managers, which results in more heterogeneity in terms of demanded skills. For the other layers there is a clear correlation between the level of competency and schooling degree.[57] For example, if we compare two extreme cases it is noticeable that the share of employees with higher education is the majority among senior staff (78% in 2010) while almost 55% of blue collars had not completed the secondary degree in 2010.[58]

[55] Among the firms that received Peiex treatment between 2009 and 2010 in our sample, only 11 outlier firms do not have the headquarter in states with NOs. Among these firms, only 1 firm increased the number of layers between 2008 and 2009–2010, 2 firms decreased the number of layers, and the other 8 firms continued with the same number of layers. Moreover, 8 of these 11 firms had subsidiaries that could potentially being in a Peiex's eligible state. Results are similar if we exclude these outlier firms from the regressions.

[56] We do not analyze if firms change the number of layers by promoting lower-level workers or hire new ones, but this is an interesting question related to this literature to be addressed.

[57] We also can control for years of experience.

[58] When we compare these variables (see Table 15) over time the increase of the share of workers with more schooling from 2007 to 2010 is remarkable. The number of blue collar employees increased from 4.63 to about 5.15 million and the share of them with secondary or higher schooling jumped from 37% to 45%. These changes are even more significant if we compare them, starting from 2006, when there were 4.36 million blue collar workers and only 34% with secondary schooling.

Table 16
Distribution of hours hired and wage by occupation (2007–2010).

Year	Hours hired					Average salaries				
	H1	H2	H3	H4	H5	H1	H2	H3	H4	H5
Y=2007										
Mean	16,035	11,964	14,734	11,237	36,398	30.0	14.1	8.3	5.2	4.7
sd	53,564	91,035	98,359	68,389	344,292	28.8	12.6	7.6	4.4	4.3
p50	5808	2288	2112	3344	7920	19.6	10.7	6.6	4.1	3.9
N (Firms)	13,738	33,715	74,780	149,845	226,188					
Y=2008										
Mean	15,962	12,300	15,158	11,768	38,193	29.7	14.1	8.5	5.3	4.8
sd	56,041	95,912	102,357	74,269	372,805	28.4	12.7	8.4	4.6	4.4
p50	5632	2288	2112	3344	8272	19.3	10.7	6.7	4.2	4.0
N (Firms)	15,146	36,335	79,079	155,900	231,583					
Y=2009										
Mean	15,636	12,092	14,724	11,525	35,471	29.8	14.4	8.6	5.5	5.0
sd	53,979	92,830	104,055	87,481	363,963	28.3	14.1	7.5	4.7	3.8
p50	5456	2192	2112	3344	7920	19.4	11.0	6.9	4.4	4.2
N (Firms)	15,786	37,763	82,371	161,444	239,931					
Y=2010										
Mean	15,696	12,190	15,003	11,779	37,105	29.4	14.3	8.8	5.7	5.1
sd	55,676	94,518	110,519	86,904	381,569	27.8	12.8	8.0	4.5	4.1
p50	5456	2288	2112	3344	7920	19.4	11.1	7.1	4.6	4.4
N (Firms)	16,756	40,038	86,558	167,664	246,674					

Table 17
Number of firms by different layer in a narrow interval of firms' size difference (2007–2010).

Layers	$9 \geq L \geq 10$		$19 \geq L \geq 20$		$99 \geq L \geq 101$		$150 \geq L \geq 450$	
	Obs	(%)	Obs	(%)	Obs	(%)	Obs	(%)
0	4181	14.66	561	5.83	5	0.62	37	0.21
1	12,968	45.48	2874	29.85	38	4.73	111	0.64
2	8539	29.95	3705	38.49	109	13.57	659	3.78
3	2491	8.74	1983	20.60	253	31.51	2576	14.79
4	336	1.18	504	5.24	398	49.56	14,031	80.57
Total	28,515	100	9627	100	803	100	17,414	100

Table 16 shows the distribution of average hourly wage and total amount of hours hired over by level of hierarchy and year, as well as how many firms in .[59] Firstly, the distribution is ranked, the higher the level of competency in the position the higher the average wage.[60] Secondly, wages are heterogeneous not only between layers, but also within them. The higher the position, the larger the within variation. The difference on the mean wage between the CEO's, Directors and Managers category to blue collars is more than 6 times.

Moreover, it is important to highlight that even after controlling for total number of employees (or hours hired), firms have different organization in terms of knowledge-based hierarchy. Although it is clear that the number of layers is positively correlated with firms' size (in terms of number of employees), there is a lot of heterogeneity regarding how firms organize knowledge in their production when they expand, even conditioned to firms' size. Table 17 shows that even in a narrow interval regarding number of employees (e.g. common thresholds for differentiating firms by size) firms differ significantly in terms of organization of knowledge. For example, the first two columns present the frequency of firms of size between 9 and 10 employees in 2010.[61] The majority of them have 1 or 2 layers of management, but there are firms in all layers. The same thing is observed among firms between 19 and 20 employees, 99 and 101 or 150 and 450. In addition, this heterogeneity also happens within sector.

[59] The distribution is relatively similar to the other years in the data.
[60] This is consistent with previous findings, see Caliendo et al. (2015b).
[61] Results are very similar for the other years in the sample.

Table 18
Number of firms' observations by exporting and treatment status and share of firms by number of employees (2007–2010).

Layers	Number of observations	Column share (%)	Share on total number of firms			
			≤500	≤100	≤20	≤10
Full sample						
0	309,523	32.78	99.96	99.93	98.59	93.99
1	312,065	33.04	99.99	99.85	90.99	72.69
2	174,937	18.52	99.99	98.84	71.72	41.46
3	86,425	9.15	99.86	92.92	40.83	15.54
4	61,426	6.50	89.33	54.57	9.56	2.20
Total	944,376	100.00	99.28	96.11	80.03	64.07
Exporters						
0	1981	4.20	99.80	99.34	95.41	86.37
1	4493	9.53	99.99	99.35	78.72	53.37
2	7086	15.03	99.94	95.68	53.50	25.50
3	9198	19.51	99.28	82.95	25.40	7.39
4	24,386	51.73	79.18	34.06	3.56	0.55
Total	47,144	100.00	89.07	61.83	26.35	14.28
Peiex						
0	950	16.03	99.79	99.79	98.53	91.47
1	1867	31.50	99.99	99.68	85.75	62.13
2	1438	24.26	99.99	98.96	68.22	35.74
3	978	16.50	99.80	92.94	40.49	12.07
4	694	11.71	95.10	64.27	11.38	3.31
Total	5927	100.00	99.36	94.26	67.37	45.28

Note: We excluded 2205 firms' observations for which the number of hierarchy of knowledge is missing due to missing information on occupations.

Table 18 shows the distribution of firms by number of employees and layers. The large majority of firms in manufacturing have less than 100 employees and are non-exporters.[62] Also, there is more heterogeneity regarding how firms organize knowledge among the smaller ones. If we take firms with more than 500 employees, the large majority will have more than 3 layers of management and many of them will be among the exporters.

[62] Indeed, the share of exporting firms in manufacturing (between 2007 and 2010) was only about 5% and the share of firms with less than 100 employees was about 96%.

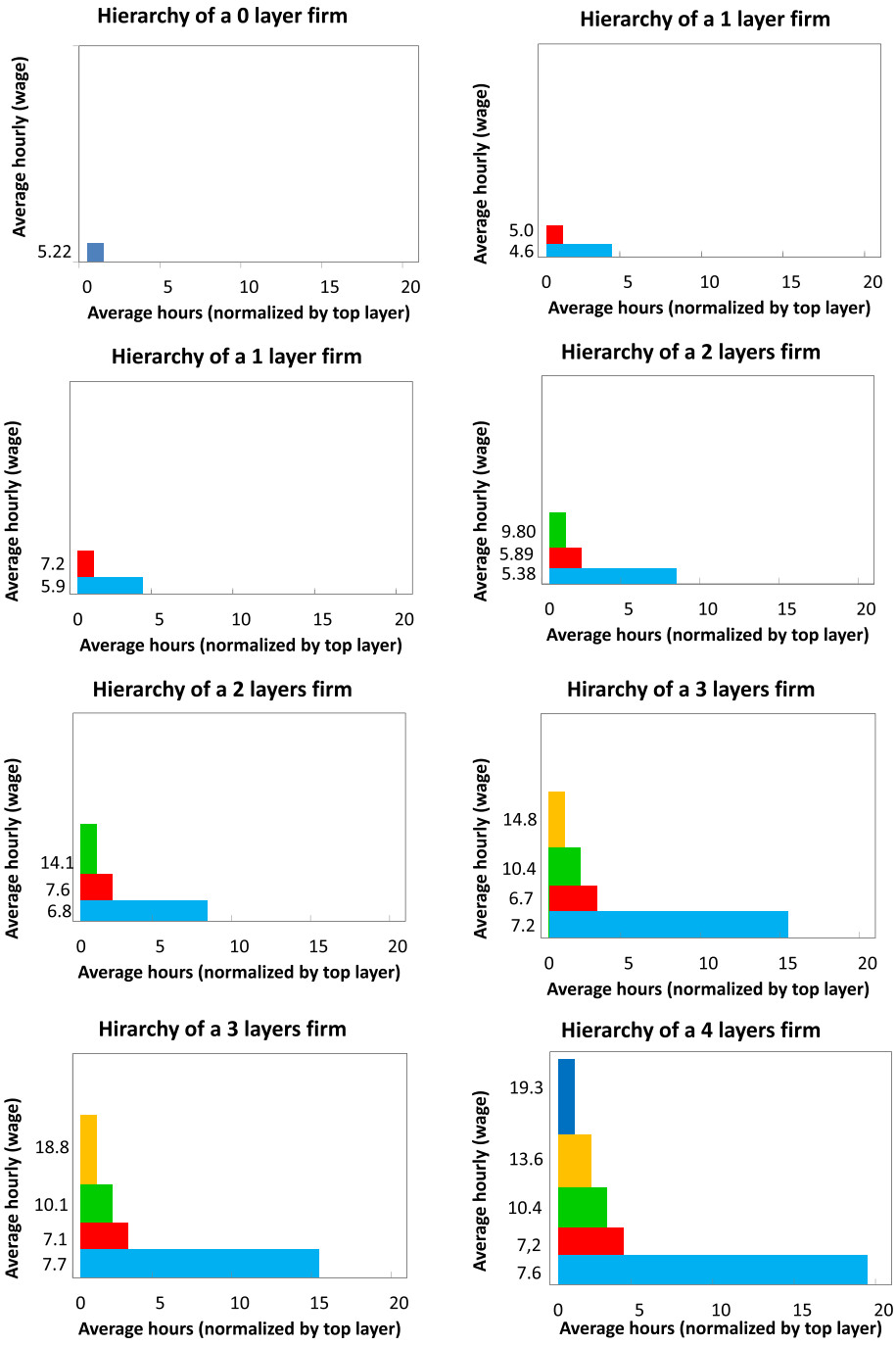

Fig. 5. Hierarchies of new exporting firms' transition from $t-1$ to t (2007–2010). Note: Average hourly wage in R$ of 2010. New exporting firms defined as firms that have exported at period t, but have not exported at periods $t-1$ and $t-2$.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jinteco.2017.12.001.

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