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The effect of technology transfers from public research institutes and universities on firm innovativeness

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GEP

The Effect of Technology Transfers from Public Research Institutes and Universities on Firm Innovativeness

By María García-Vega and Óscar Vicente-Chirivella*

Abstract

Public research institutes and universities receive large amounts of public funds for the generation and transmission of knowledge. In this paper, we assess the differential impact of technology transfers from public research institutes versus technology transfers from universities on firm innovativeness. We use information of R&D acquisitions from a panel dataset of more than 10,000 Spanish firms from 2005 to 2014. Using matching and difference-in-difference estimators, we show that technology transfers from both organizations increase firm innovativeness. Our results suggest that the knowledge generated by public research institutes is particularly beneficial to firms with high levels of absorptive capacity. In contrast, the knowledge transferred by universities is relatively more beneficial to firms with low levels of absorptive capacities. Hence, public funds for public research institutes are especially important for the R&D intensive private sector. Therefore, the degree of absorptive capacities of the participating firms is important to design public programs that maximize the efficiency of public technology transfers.

Keywords: Public Research Institutes; Universities; Technology Transfers; Firm innovativeness.

JEL classification: L25, D22, L24, O31.

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1. Introduction

Public research institutes and universities are key organizations within a country's innovation policy, which is why they typically receive large amounts of public funds for the generation and transmission of knowledge.[1] The technology transfers from public research institutes and universities are potentially very important for the innovation of the private sector and consequently for economic growth. As Bozeman (2000) argued "universities and government laboratories make, industry takes" (p.633). To date, however there is scarce empirical evidence on the comparative importance of technology transfers from public research institutes and universities on firms' innovativeness. In this paper, we empirically assess this differential effect and study the role of absorptive capacities as a fundamental mechanism for differences in innovativeness.

The relative effect of the transmission of knowledge from public research institutes and universities on firms' innovativeness is not straightforward. The research produced by universities is often basic research and therefore more difficult to transfer and assimilate by private firms than the more applied knowledge produced by public research institutes.[2] Moreover, a distinct characteristic of universities is their teaching mission, which implies that some universities are less research intensive than specialized public research institutes (Dusdal et al., 2020). Consequently, the impact of the knowledge transfer from universities might be lower than from public research institutes. However, the teaching and pedagogical mission of universities can have some advantages for the transmission of knowledge to private firms. For example, the communication with universities might be more fluent than with public research institutes, in particular, when there are personal and professional links between former students

[1] For example, for the year 2017, German public research institutes received €13.5bn from R&D public national sources and German universities received €17.3bn; French public research institutes received €5.8bn from R&D public national sources and French universities received €10.2bn; US public research institutes obtained $53.9bn from R&D public national sources and US universities received $67.5bn. (Source: OECD Main Science and Technology Indicators).

[2] For instance, David and Metcalfe (2007) report that 80% of basic research is produced by universities in Europe.

and academics.[3] As a consequence, the transmission of tacit knowledge might be higher from universities than from public research institutes.

For our analysis, we use a panel dataset for more than 10,000 Spanish firms from 2005 to 2014. The dataset contains information on R&D acquisitions from public research institutes (different from universities) and universities. With this information, we construct three measures of technology transfers: R&D from public research institutes only (denoted as technology transfers from public research institutes only); R&D from universities only (denoted as technology transfers from universities only); and R&D from public research institutes and universities (denoted as technology transfers from both public research institutes and universities).[4]

Our empirical analysis is structured as follows. Firstly, we measure the impact of each type of technology transfer with respect to a control group of firms without technology transfers. To do so, we follow a matching procedure with multiple treatments as in Gerfin and Lechner (2002). For each type of technology transfer, we find a set of firms that have the same observable characteristics as the treated group but that did not receive the treatment. One contribution of our paper is to show the different determinants of obtaining technology transfers from public research institutes and universities. We find that firm size is particularly relevant to obtain transfers from universities, while the degree of globalization is key to obtain technology transfers from public research institutes. We calculate the average treatment effect using a difference-in-difference (DiD) estimator for each of the matched samples. In this way, we calculate the direct effect of technology transfers by provider on firm innovativeness.

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[3] For instance, Kunttu (2017) provides evidence of educational involvement in long-term university–industry relationships.

[4] Previous studies that consider R&D acquisitions as a measure of technology transfers are García-Vega and Vicente-Chirivella (2020), Medda et al. (2005) and Vega-Jurado et al. (2017), among others.

Our results reveal sizeable effects of technology transfers from public research institutes on firm innovativeness. For example, compared to firms without technology transfers, product innovation increased by 11%; process innovation by 5.4%; production processes increased by 8.0%, and the number of patents increased by 40.3%.

The effect of technology transfers from universities, using contractual R&D, on firms' innovativeness has been previously studied in the literature (for example, García-Vega and Vicente-Chirivella, 2020 and Medda et al., 2005), but we extend this research to study the role of firm absorptive capacities. Our results suggest that technology transfers from universities also increase firm innovativeness. For instance, compared to firms without technology transfers, product innovation increased by 12.7%; process innovation by 8.6%; and the number of patents by 61.1%. Companies that obtained technology transfers from both types of providers seem to have increased their innovativeness more than when they obtained technology transfers just from one provider, which suggests the existence of complementarities between knowledge transfers from public research institutes and universities.

Secondly, in order to measure the relative impact of technology transfers from public research institutes versus universities, we construct a matched sample of firms with technology transfers from public research institutes only and with technology transfers from universities only. We use a DiD estimator to calculate the average treatment effect of the differential effect. We do not find any significant difference at standard statistical levels on firm innovativeness between the matched sample of firms with technology transfers from public research institutes only and from universities only. This indicates that either there are no strong differences in the effectiveness of the technology transfers or that we cannot capture these effects with precision.

Thirdly, we further explore whether there can be heterogenous effects for the differential based on firm characteristics. In particular, we study whether the relative effect of technology transfers from public research institutes versus universities is moderated by the level of firm absorptive capacity, that is, the intensity of the internal R&D of the firm. We find that the effect of technology transfers from public research institutes on firm innovativeness is smaller than the effect of technology transfers from universities. However, as firm absorptive capacity increases, the differential effect becomes smaller. This suggest that firms with high levels of absorptive capacities benefit relatively more from technology transfers from public research institutes than from technology transfers from universities.

We add to the literature the first evidence of the importance of absorptive capacities for the relative effect of technology transfers from universities and public research institutes. Moreover, we highlight the importance of both public research institutes and universities as key organizations for the transmission of knowledge to the private sector. Therefore, our results have important implications for the design of efficient innovation policies that can maximize firms' innovativeness.

The rest of the paper is organized as follows. In Section 2, we provide the conceptual arguments and the empirical literature. In Section 3, we describe the data and the empirical methodology. In Section 4, we present our results. Finally, in Section 5, we discuss implications and conclude.

2. Conceptual arguments and related literature

The main purpose of our analysis is to assess the relative importance of knowledge transfers from public research institutions and universities on firm innovativeness. In this section, we provide the key conceptual arguments for the possible differences between technology transfers from the two organizations as well as the related literature.

2.1.Conceptual arguments

The starting point of our analysis is that universities and public research institutes share some common features, but there are also important differences in their mission and in their comparative advantages, which we explain below. Therefore, assessing the impact of technology transfers on firm innovation from public research institutes compared with technology transfers from universities is not straightforward.

The effectiveness in the transmission of knowledge from public research institutes or universities to the private sector might be higher for public research institutes than for universities because the research produced by public research institutes might be more applied and therefore easier to transmit than the research undertaken by universities. To study the national innovation system, Crow and Bozeman (1998) carried out a study with more than 16,000 US university, industry and government laboratories. These authors found that 23% of university laboratories viewed technology development as a major mission, while this percentage reached 51% in the case of government laboratories. Conversely, 70% of university laboratories viewed basic research as a major mission, compared to 42% of government laboratories. Bozeman (2000) argues that the two major comparative advantages of public research institutes in comparison with universities are: the highly interdisciplinary team research and their extremely expensive scientific equipment.

Another reason why technology transfers from public research institutes might induce more firm innovation than technology transfers from universities is that universities and public research institutes differ in their knowledge involvement with private industry. While the two primary missions of universities are research and teaching, one of the traditional goals of government laboratories is transferring the generated knowledge to the private sector, and to make knowledge available for the benefit of the nation (Spann et al., 1993). The direct contribution from university-industry links is only considered as the "third mission" of universities, which started in the late 80s (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 1998).[5]

An alternative possibility is that technology transfers from universities have a higher impact for the innovativeness of the private sector than the technology transfers from public research institutes, due to the special relationship between academics and their former students. In their study for US public organizations, Bozeman et al. (1999) highlight the importance of the value added of former students from universities. Researchers in private firms might keep personal and academic links with the faculty of the universities where they studied. Moreover, former post-docs might create startups that might require knowledge transfers (Siegel and Waldman, 2019). Usually, R&D contracts only involve the transfers of codified knowledge. However, the closer the relationship between researchers and employees in private firms and faculty scientists, the easier it would be for firms to obtain not only standard forms of codified knowledge, but also tacit knowledge (Lane and Lubatkin, 1998; Almeida et al., 2003). If this is the case, the impact on firms' innovativeness of R&D contracting from universities might be higher than when the knowledge is coming from public research institutes.

The differential effect of the technology transfers on firm innovativeness from public research institutes and universities might also depend on firms' absorptive capacities. As the innovation literature has recognized, to fully absorb and recombine the new knowledge, firms must possess sufficiently advanced internal R&D (Ceccagnoli et al., 2014; Cohen and Levinthal, 1990; Schweisfurth and Raasch, 2018) to develop new products or processes. This is particularly important for the case of acquisition of external public research, since public research rarely leads to readily usable product market innovations (Bloedon and Stokes, 1994; Min et al., 2020). Moreover, there might also be different cultural and informational barriers between the public sector and the private firms (Siegel et al., 2004). The knowledge coming

[5] University's third mission is related to the generation, application, use, exploitation and transfer of knowledge.

from public research institutes is likely to be less tacit than the knowledge coming from universities, given to the special links between academics and researchers at private firms. Therefore, firms that obtain technology transfers from public research institutes might need to invest more in the transformation of contextual into codified information for enabling knowledge assimilation than firms that obtain knowledge from universities. Given these arguments, having high absorptive capacities might be more relevant for the effectiveness of the technology transfers from public research institutes than technology transfers from universities.

2.2. Related literature

Studies analyzing the effects of public research on innovation performance can be clustered into three groups depending on the specific research agent: universities, public research institutes and a combination of universities and public research institutes. The first group of studies analyzes the effects of university-industry interactions on firms' innovativeness (Arvanitis et al., 2008; Bellucci and Pennacchio, 2016; Bishop et al., 2011; Cassiman et al., 2010; García-Vega and Vicente-Chirivella, 2020; Mansfield, 1991; Medda et al., 2006; Medda et al., 2005; Szücs, 2018, Un et al., 2010; Vega-Jurado et al., 2017; among others). In relative terms, this group of studies is the one that has received most of the attention in the academic literature. Mansfield (1991) is the first of a growing number of empirical works analysing the effects of academic research on firms' innovation performance. His results show that university research has an important positive effect on firm innovation, since one-tenth of the new products and processes commercialized during 1975-85 in seven manufacturing industries could not have been developed (without substantial delay) without recent academic research. Most recently, Bellucci and Pennacchio (2016) show that the quality of academic research increases the importance of knowledge transfers from universities to firms. The results from this literature suggest that there is a positive contribution of academic research to industrial innovation, but these effects are likely to be more important in the long-run than in the short-run (Medda et al., 2005). Our results are consistent with this literature and highlight the important contribution of universities to the transmission of knowledge to firms with medium and low absorptive capacities. These companies are likely to be small, young and local.[6] Therefore, universities play a central role for the innovation and economic growth of the local communities, but also for the potential growth of firms with initially internal research resources.

A second group of studies analyses the effectiveness of public research institutes on transferring knowledge (Adams et al., 2003; Chen et al., 2018; Jaffe et al., 1998; Jaffe and Lerner, 2001; Link et al., 2011). Differently from university technology transfer studies, the literature evaluating technology transfer from public research institutes is very small. One of the reasons is the lack of available data (Chen et al., 2018; Jaffe et al., 1998). The few studies that examinate the effects of public research institutes are mainly focused on case studies for US federal or national laboratories. These studies mostly analyse the effects of the Bayh-Dole and Stevenson-Wydler Technology Innovation Act of 1980, the Federal Technology Transfer Act of 1986 and the National Competitiveness Technology Transfer Act of 1989 on output measures of federal or national laboratories.[7,8] For example, Jaffe et al. (1998) studied how previous specified changes in the law affected NASA patents. These authors found that the NASA number and quality of patents increased during the 80s, which suggests that the new

[6] Small and young firms usually suffer from liquidity constraints that make difficult for them to cope with the high costs of investing in internal knowledge creation (Czarnitzki and Hottenrott, 2011; Hottenrott et al., 2016; Máñez et al., 2009). Furthermore, R&D investments involve some risks, and they are long-term investment. Therefore, small and young companies might be unable to commit resources to internal R&D.

[7] The Stevenson–Wydler Technology Innovation Act of 1980 made explicit the technology transfer responsibilities of U.S. Federal laboratories. The Federal Technology Transfer Act of 1986 facilitated technology transfer by permitting the laboratories to enter into Cooperative Research and Development Agreements (CRADAs) with public sector and private sector organizations. The National Competitiveness Technology Transfer Act of 1989 authorized Government-Owned, Contractor-Operated laboratories (GOCOs) to enter into CRADAs. See, Kerrigan and Brasco (2002).

[8] See Stevens (2004) and Schacht (2000) for an overview of the Bayh-Dole and Stevenson-Wydler Acts.

laws had a positive effect on NASA innovativeness. Jaffe and Lerner (2001) also found that the new laws had a positive effect on patenting for laboratories at the Department of Energy (DOE) and, also, that the patents per R&D dollar spent reached parity with research universities. Link et al. (2011) analysed patenting activity for two national laboratories: the Sandia National Laboratory and the National Institute of Standards and Technology. They conclude that the Stevenson–Wydler Act was not enough to increase patent applications of the examined national laboratories. However, the passage of the Federal Technology Transfer Act solved this problem by introducing financial incentives for scientist at federal laboratories to patent.

The recent studies that analyse the relationship between public research institutes and private sector innovativeness are scarce. Link et al. (2019) estimates the elasticity of R&D public investments on new firm applications for the US Environmental Protection Agency (EPA). They find that the elasticity is equal to 2, which indicates the importance of public agencies to generate new knowledge and potential technology transfers. Link et al. (2020) analyse for a sample of European firms the importance of public research institutes as a source of knowledge to generate innovations. They find a positive effect, which suggests that technology transfers from public research institutes have a positive effect on private sector innovation. Robin and Schubert (2013) find for a sample of French and German firms that cooperation with public research institutes seem to increase product innovation, however it does not increase process innovation.

Overall, there is a broad consensus from the previously described literature that allowing public research institutes to sign cooperation agreements with companies has generated knowledge complementarities that can be beneficial for the innovation of the private companies. In our study, we also find a strong positive effect of public research institutes on firm innovativeness. A difference with previous literature is that our main measure of technology transfers is contractual R&D, although we also present results for cooperation. Our results suggest that technology transfers from public research institutes increase both product and process firm innovation, however the effects on product innovation seem larger than for process innovation. This suggests that the knowledge transfers from public research institutes favour the demand size of the firm (Jaumandreu and Mairese, 2017), which is also related to our finding that an important determinant of obtaining technology transfers from public research institutes is being an exporter.

The last strand of the literature studies the effects of technology transfers from universities and public research institutes without differentiating between the two providers. For example, Cohen et al. (2002), Fudickar and Hottenrott (2019) and Yu and Lee (2017) included universities, federal or national labs and other public research institutes in the same proxy. Cohen et al. (2002) found that large firms and start-ups benefit from collaborating with public organizations. Yu and Lee (2017) also found that collaboration with research organizations has a positive impact on innovation performance, especially for firms with a strong orientation toward exploration. Fudickar and Hottenrott (2019) investigated the impact of formal and informal interactions with publicly funded scientific research on the innovativeness of German start-ups. They found that firms engaged in these interactions were more likely to introduce new products and services to the market and that absorptive capacities played a fundamental moderating role for the effectiveness of the technological collaborations. In contrast to these studies, our paper distinguishes between the impact of knowledge transfers from public research institutes and universities. Moreover, we specifically analyse their determinants and their differential effects.

Our paper is most related to the literature that study differences between technology transfers from public research institutes and universities. Beise and Stahl (1999) was one of the first studies recognizing these differences. For a sample of German firms they find that, approximately, 40% of firms in their sample report that their innovations could not have been developed without the research from public laboratories and another 40% report that their innovation could not have been developed without the knowledge from universities.[9] Our major difference with respect to Beise and Stahl (1999) is that we use panel data, which allows us to address a potential reverse causation problem and we use a pecuniary measure of technology transfers, i.e., acquisitions of external R&D. Eom and Lee (2010) analysed in a sample of Korean firms for 2000 and 2001 the determinants of industry-university and industry-government research institutes (GRIs) cooperation and its impact on firms' performance. They found that cooperation with universities and cooperation with GRIs had a similar positive effect. However, once they controlled for endogeneity, this positive effect turned negative and became statistically insignificant at standard levels, which indicates the importance of selection. Differently from Eom and Lee (2010), we explore the effect of contractual technology transfers measured as R&D acquisitions on firm innovation and we use matching techniques to address the potential selection bias problem. Moreover, we specifically analyse differences between the effectiveness of technology transfers from universities or public research institutes and account for differences in absorptive capacities. Szücs (2018) investigated the effect of the EC's Seventh Framework Programme (FP7) that ran from 2007 to 2013 in the EU, which enhanced cooperation between universities, research centres (the majority of them public but not exclusively public) and private firms, on firm innovation.[10] The author found a positive effect of cooperation with universities for innovation and no effect of cooperation with research centres. In contrast to Szücs (2018), we compare technology transfers from *public* research institutions and universities using R&D acquisition data. A

[9] Beise and Stahl (1999) consider three publicly funded sources of knowledge: universities, polytechnics and other public laboratories.
[10] For the ranking of top 50 research organization that signed grant agreements with this program see European Commission (2013).

further novelty of our analysis is that we provide evidence for the role of absorptive capacity to explain the differential effects between technology transfers from PRIs and universities.

3. Data and methodology

3.1. The data

Our dataset comes from a yearly survey of Spanish firms (*Panel de Innovación Tecnológica, PITEC*) from 2005 to 2014. The Spanish National Institute of Statistics constructs this database on the basis of the annual responses to the Spanish Community Innovation Survey (CIS).[11] This is a unique dataset that includes representative samples of the universe of firms that are trying to innovate in Spain. The analysis is based on 143,653 firm-year observations in total, which accounts for an unbalanced panel of 10,254 companies.

The main interest of our analysis is to study the effect of technology transfers from public research centers on firm innovation as compared with the effect of technology transfers from universities. In the dataset, the company reports its *external R&D expenditures* (a firm's purchases of R&D conducted by other firms) distinguishing between type of providers.[12] In particular, the survey distinguishes between external R&D expenditures from public research institutes and from universities.[13] With that information, we construct the following dummy

[11]The PITEC survey is specifically designed to analyze R&D and other innovating activities following the recommendations of the OSLO Manual on performing innovation surveys (see OECD 2005). The survey is targeted at manufacturing and services companies whose main economic activity corresponds to sections C, D, and E of NACE 93, except non-industrial companies because of the imprecision of methodological marking in the international context by other branches of activity. Details on the survey and data access guidelines can be obtained at https://icono.fecyt.es/pitec/descarga-la-base-de-datos. The methodology about the construction of the dataset is available here: http://www.ine.es/prodyser/microdatos/metodologia_pitec.pdf.

[12] External R&D expenditures are defined as: "Acquisitions of R&D services through contracts, informal agreements, etc. Funds to finance other companies, research associations, etc, which do not directly imply purchases of R&D services are excluded". R&D services are defined as: "Creative work to increase the volume of knowledge and to create new or improved products and processes (including the development of software)". They specifically exclude licenses and royalties, which are a different question in the survey.

[13] In Spain, public research centers are different from universities. There are seven public research centers in Spain. The list of all the Spanish public research centers and detail information about the centers is available here: https://www.ciencia.gob.es/portal/site/MICINN/menuitem.7eeac5cd345b4f34f09dfd1001432ea0/?vgnextoid=a6cbc18d48530210VgnVCM1000001034e20aRCRD.

variables to measure the different types of technology transfers: *Only public research institutes*, which is a dummy variable that takes the value one if the firm reports acquiring R&D only from public research institutes; *only universities*, which refers to firms that purchase R&D services only from universities; and *both public research institutes and universities*, which corresponds to firms that acquire external R&D from both public research institutions and universities. Measures of technology transfers similar to our measure are used by García-Vega and Vicente-Chirivella (2020), Fudickar and Hottenrott (2019), Vega-Jurado et al. (2017) and Medda et al. (2005).

In Table 1, we present descriptive statistics. In column (1), we show the means for firms that obtain technology transfers only from public research institutes; in column (2), we present averages for firms with technology transfers only from universities; in column (3), we show means for companies that obtain technology transfers from both public research institutes and universities; and in column (4), we present averages for the rest of the firms in the sample, which we denote as *non-transfers*.

In Panel A, we show the volume of technology transfers by provider, measured in natural logarithms. In the sample, we observe that very few firms obtain technology transfers from public research centers. The percentage of firms that obtain technology transfers only from public research institutes is 0.82%, and the percentage of firms with technology transfers from both public research institutes and universities is 0.88%. These numbers compare with 5.84% of firms that obtain technology transfers only from universities. However, the average and the standard deviation of the volume of the R&D acquisitions is very similar between the different groups with technology transfers. These features suggest that even if more firms obtain knowledge transfers from universities than from public research institutes, the average amount of technology transfers per firm is very similar between the two providers, which indicates that the scale of the research projects is similar by provider.

The dataset also provides information about technological innovation output variables. Following Mairesse and Mohnen (2010), we consider the following measures: We construct two indicators for firms' product and process innovations. Both variables are dummy variables that take the value one if a firm reports having introduced new or significantly improved products or production processes, respectively, in the current or previous two years. The dataset provides disaggregated measures of process innovation. With that information, we construct dummy variables that take the value one if a firm reports having introduced new production, and new logistic processes, respectively, in the current or previous two years. Finally, we also consider the number of patents applied by the firm in the current or previous two years.

The mean values of the innovation output variables and other firms' characteristics are presented in panels B and C of Table 1 distinguishing by technological provider. Panel B reports sample means for technological innovation output variables, and panel C reports sample means for other key firms' characteristics.

The evidence in panel B suggests that there are very small significant differences between firms that obtain technology transfers only from public research institutes and firms that obtain technology transfers only from universities in terms of innovation outputs. For example, the average product innovation for firms with technology transfers from public research institutes only is equal to 0.74 (with std.=0.44) versus 0.75 (with std.=0.43) for firms with technology transfers from universities only. The only exception is the average number of patents that is larger for firms with technology transfers from universities only (equal to 1.48, with std.=8.62) than for firms with technology transfers from public research institutes only (equal to 0.97, with std.=2.91). Comparing columns (1) and (2) with column (3) reveals that firms with both types of technology transfers (column 3) significantly outperform firms with technology transfers from public research institutes only and firms with technology transfers from universities only. This is the case for all the different measures of innovation output and in particular for the number of patents. This suggests that there might be some complementarities between knowledge transfers from public research institutes and universities. Finally, firms without technology transfers are on average less likely to innovate than firms with any type of technology transfers.

In Panel C, we report averages for the following firm characteristics: the natural logarithm of total innovation investment; physical investment, which is measured as the natural logarithm of physical investments per employee; a dummy variable that takes the value one if the firm is an exporter; labor productivity, which is measured as the natural logarithm of sales per employee; the natural logarithm of the number of employees; and the natural logarithm of internal R&D. The sample means in panel C are consistent with the patterns observed in panel B. Firms with technology transfers from public research institutes only and from universities only are very similar in all different firm observable characteristics of Panel C. Firms with both types of technology transfers are larger, invest relatively more in innovation activities and are more productive than firms with only one type of provider. On average, firms without technology transfers invest less in total and internal R&D, are smaller, less productive and less likely to be exporters than firms with technology transfers.

Table 2 presents the percentage of firms by sectors differentiating by type of technology transfer. In columns (1) to (3), we show the ratio between the number of firms with technology transfers over the total number of firms in a given sector. In column (4) we present the total number of firms in a given sector. Firms with technology transfers from public research institutes only and with technology transfers from both public research institutes and universities are concentrated in the agriculture and the pharmaceutical sector. Firms with technology transfers from universities only are mainly in the pharmaceutical, R&D services and agricultural sectors. This reflects the importance of the technology transfers for both the pharmaceutical and the agricultural sectors, and it suggests the importance of the special relationship between high-tech services and universities.

3.2. The empirical methodology

In order to examine the relative effect of public research institutes and universities on firm innovation, we follow a matching procedure with multiple treatments as in Gerfin and Lechner (2002). This methodology consists of two steps.[14]

In the first step, we define three groups of treated firms (denoted by *s=Only Public Research Institutes, Only Universities, Both Public Research Institutes & Universities*) and two control groups (denoted by *l=Non-transfer, Only Universities*), which will be explained in detail below. For each case, we find a set of firms in the control group that have the same observable characteristics as the treated group before obtaining technology transfers but that did not receive the treatment. The matching procedure is conducted using a nearest neighbor matching based on the propensity score of receiving a certain treatment.[15] In the empirical implementation, we include a set of observable pre-treatment characteristics that we describe in detail in the following section. In the second step, we calculate the average treatment effect on the treated using a DiD estimator for each of the matched samples.

We construct four matched samples ($m = 1, \dots, 4$), for different combinations of treatments and control groups. In Table 3, we show how we define the four matched samples. In the first matched sample (case 1), we consider as treatment *firms with technology transfers from public research institutes only* and as control group firms without technology transfers (denoted as *non-transfers*). The second matched sample (case 2) includes as treatment *firms*

[14] A similar methodology has also been used for innovation topics by García-Vega and Huergo (2019), Huergo and Moreno (2017), Czarnitzki and Lopes-Bento (2014), and Czarnitzki et al. (2007) among others.
[15] For each treated firm, we search for a firm in the counterfactual group that had the same probability of receiving the treatment but did not receive the treatment.

with technology transfers from universities only. The control group is *non-transfers*. The third matched sample (case 3) has as treatment *firms with both technology transfers from public research institutes and universities* and as a control group *non-transfers*. Finally, the fourth matched sample includes as treatment *firms with technology transfers from public research institutes only* and as control *firms with technology transfers from universities only*. In cases 1 and 2, we measure the direct effect of public research institutes and universities on firm innovation, respectively. In case 3, we measure the combined effect of public research institutes and universities with respect to firms without technology transfers. Case 4 is the main focus of our analysis. In case 4, we measure the relative effect of technology transfers from public research institutes versus technology transfers from universities on firm innovativeness.

We implement the DiD estimators for each of the four different matched samples explained above using the following specification:

$$Y_{it+1} = \alpha + \beta^s Technology\ Transfer_{it}^s + \varepsilon_{it} \quad (1)$$

where Y_{it+1} represents innovation output; $Technology\ Transfer_{it}^s$ is a dummy variable that takes the value one if a firm has obtained technology transfers from provider *s* at time *t*. The coefficient β^s is the DiD estimate of the average treatment effect. Note that our key identifying assumption is that control and treated groups are observationally equivalent before the treatment.

4. Results

4.1. The characteristics of firms with technology transfers from Public Research Institutes and/or from Universities

Before studying the effects of technology transfers from public research institutes and from universities on firm innovation, we first present the estimates of the probability models that we use to obtain the propensity scores for our matching procedure. This also allows us to further explore the determinants to obtain technology transfers through different providers. For each of the four samples that we described in the previous section, we estimate probit models where we regress a dummy variable indicator of whether a firm receives the treatment during the sample period on firm characteristics that we explain below. Formally,

$$Treated_{it} = \begin{cases} 1 \text{ if } \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} > 0 \\ 0 \text{ if } \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} \leq 0. \end{cases} \quad (2)$$

In equation (2), $Treated_{it}$ is a dummy variable that takes the value one if the firm receives the treatment. The vector X_{it-1} reflects pre-treatment firm characteristics that influence the treatment, d_t denotes time dummies and ε_{it} is the error term, which we assume is normally distributed with variance σ_{ε}^2. We include as pre-treatment characteristics the following variables: number of employees, which accounts for firm economies of scale, labor productivity, average physical investment and being an exporter. In order to take advantage of the panel structure of our dataset and to control for common pre-trends of the dependent variables, we also add pre-treatment outcome variables in the matching procedure (see, for example, Guadalupe et al., 2012; Lechner, 2015; Stiebale, 2016, García-Huergo, 2019, among others). In particular, we include the lagged values of the dummies for product and process innovation. We also add geographic, industry and year dummies. In the robustness checks presented in the Appendix, we use alternative dependent variables for the matching procedure. In all regressions, we use cluster-robust standard errors. The results are reported in Table 4, where each of the columns corresponds to the different cases defined in Table 3.

In column (1), we show the determinants of firms that obtain technology transfers from public research institutes only versus firms without transfers (non-transfers). Before obtaining technology transfers from public research institutes, firms are more innovative and with higher physical investment than firms without technology transfers. They are also more likely to be exporters than firms without technology transfers. The coefficient for number of employees is positive although not significant at standard statistical levels. These results suggest that a firm's globalization and its capital intensity are important determinants to obtain technology transfers from public research institutes.

In column (2), we present results for the determinants of firms that obtain technology transfers from universities only as compared with firms without technology transfers. The results are similar to those in column (1) with one exception: the estimated coefficient for number of employees is positive and highly significant. This suggests that economies of scale play a more important role for the decision to obtain technology transfers from universities as compared to the decision to obtain technology transfers from public research institutes.

In column (3), we show the determinants of the firms that obtain technology transfers from public research institutes and universities versus firms that do not obtain technology transfers. Before the transfer, firms with both types of technology transfers are more innovative, larger, more productive, more capital intensive and more likely to be exporters than firms without technology transfers. This reflects a strong selection into the decision to obtain technology transfers from both public research institutes and universities.

In column (4), we compare determinants of technology transfers from public research institutes only and from universities only. Here, we find some interesting empirical regularities. The estimated coefficients for process innovation, size, labor productivity and physical investment are negative although only process innovation and size are significant at standard statistical levels. This suggests that firms that obtain technology transfers from public research institutes are less likely to have process innovation; they are smaller; and they tend to have lower labor productivity and areless capital intensive than firms that obtain technology transfers from universities, although the last two effects are imprecisely estimated. In contrast, firms that obtain technology transfers from public research institutes are more likely to be exporters and they also tend to have more product innovations than firms that obtain technology transfers from universities.

Based on the results from equation (2), we pair each treated firm with the closest untreated firm by caliper matching with replacement.[16] The matching procedure works well for all the different cases. In Table A1 in the Appendix, we report balancing tests and number of observations after matching. For all the different cases, after matching, the covariates no longer explain the probability of participation into the treatment well. The LR-Chi2 statistic does not exceed the critical value at the 5% significance level. Moreover, the Pseudo-R2 after matching is very small or close to zero in most cases. Consequently, after matching, the covariates do not seem to have any explanatory power to predict the treatment status. This suggests that our matching specification generates well-balanced samples, which implies that control and treatment groups are equivalent in their overall observable characteristics before treatment for the different cases.

4.2. The effect of technology transfers from public research institutes and/or from universities on firm innovativeness

In Table 5, we present the results of estimating equation (1) for the four matched sample of firms. In Panel A, we show results for firms with technology transfers from public research institutes only and non-transfers. In Panel B, we show results for firms with technology transfers from universities only and non-transfers. In Panel C, we present the results for firms with both technological transfers from public research institutes and universities. In Panel D, the matched sample includes firms with technology transfers from public research institutes only and universities only. The results in panels A, B and C measure the direct effect of technology transfers by provider on firm innovativeness. The results in panel D indicate the

[16] Matching is carried out with STATA command PSMATCH2 by Leuven and Sianesi (2003).

relative impact of technology transfers from public research institutes as compared with the effect of technology transfers from universities. In the table, we distinguish between the following innovation outputs: product innovation (column 1), process innovation (column 2), new production process (column 3), new logistic process (column 4), and number of patents (column 5).

The results from Panel A suggests that technology transfers from public research institutes strongly increase firm innovativeness. For example, product innovation increases by 11%, process innovation by 5.4%, production processes increase by 8.0%, and the number of patents increases by 40.3%. The findings from Panel B indicate that technology transfers from universities also increase firm innovativeness. The estimated coefficients are slightly higher than those in Panel A. For instance, product innovation increases by 12.7%; process innovation by 8.6%; and the number of patents by 61.1%.

Comparing the estimated coefficients in Panels A and B with those in Panel C for firms with both types of technology transfers, the results indicate that both types of technology transfers increase firm innovation for all the different types of innovation outputs, with the exception of new logistic processes. These findings suggest that combining both types of technology transfers raise innovativeness more than when firms obtain knowledge from only one source. This might be indicative of knowledge complementarities or additionalities between technology transfers from public research institutes and universities, particularly for patenting activities.

Focusing on Panel D, where we compare the relative effect of technology transfer from public research institutes versus universities, we find that the estimated coefficients are all negative (except for new logistic processes). This seems to suggest that technology transfers from public research institutes increase firm innovativeness less than technology transfers from universities. However, the estimated coefficients are not significant at standard statistical levels for any of the different innovation outputs. Given that the standard errors are high, the effects are not estimated with precision. This could indicate that there is large heterogeneity in the sample, which we explore in the following section.

4.3. The role of absorptive capacities

In this section, we study the role of absorptive capacities on the relative effect of technology transfers from public research institutes and from universities. We expect that firm absorptive capacity plays a moderating role for the effectiveness of the technology transfers from public research institutes. In order to assess the role of absorptive capacities, we analyze the interaction between technology transfers from public research institutes and absorptive capacities as in the following equation:

$$Y_{it+1} = \alpha + \theta^s Technology\ Transfer_{it}^s \times Absorptive\ Capacity_{it} +$$
$$+\beta^s Technology\ Transfer_{it}^s + \gamma Absorptive\ Capacity_{it} + \epsilon_{it} \quad (3)$$

We estimate equation (3) for the matched sample of firms with technology transfers from public research institutes only and for firms with technology transfers from universities only (case 4). We construct two measures of firm absorptive capacity that are standard in the literature (Crescenzi and Gagliardi, 2018). The first variable is the natural logarithm of the ratio of internal R&D over number of employees and the second variable is the natural logarithm of the ratio of R&D employment over number of employees.[17] We interact the absorptive capacity variable with technology transfers.

In Table 6, we present results for the estimation of equation (3) using the two alternative measures of absorptive capacity in Panels A and B respectively. In columns (1) to (4) in both

[17] We also conduct robustness checks, not presented in the paper, with the natural logarithm of internal R&D over sales and the main findings are unchanged.

Panels, the table shows a negative coefficient for the effect of public research institutes only and a positive effect for the interaction term. This suggests that the effect of technology transfers from public research institutes on firm innovativeness is smaller than the effect of technology transfers from universities. However, as firm absorptive capacity increases the differential effect becomes smaller.

As for the magnitude of these estimations, for example for column (2) of Panel A, the threshold level of absorptive capacity such that the effect of technology transfers from public research institutes on process innovation equals zero is equal to 12.64. The average absorptive capacity in the sample is equal to 11.79 and the median is equal to 12.66. This suggest that for the average firm the effect of technology transfers from universities on process innovation is larger than the effect of technology transfers from public research institutes. However, for the median firm the relationship is reversed. In particular, firms with high levels of absorptive capacities benefit relatively more from technology transfers from public research institutes than from technology transfers from universities.

The estimated coefficients on column (5) for patents require special attention. In both Panels, we find that the estimated coefficient for public research institutes is positive and the interaction term negative, which is the opposite of what we found in columns (1) to (4). This suggests that technology transfers from public research institutes might have a larger positive effect on patents than technology transfers from universities and this effect is mediated by the firm's absorptive capacity. However, given that the estimated coefficients are not significant at standard statistical levels, this evidence is just suggestive.

4.4. Robustness checks

We perform the following robustness checks to our main specification results that we present in the Appendix. In these robustness checks, we first control for longer pre-existing trends, and secondly, we study the effect of cooperation with public research institutes and universities as an alternative measure of technology transfers.

As a first robustness check, we control for longer pre-existing trends. We modify our matching procedure in order to include two years of pre-treatment data in order to assure that the treatment and the control group share statistically similar characteristics one and two years before the technology transfers. We present balancing tests for the matching procedure in Table A1 and the results are presented in Tables A2 and A3. The results in Table A2 are very similar to these in Table 5, although they are estimated with less precision given the smaller number of observations. We find that having technology transfers from public research institutes only, from universities only, and from both increases firm innovation. We do not find any significant effect at standard statistical levels when we compare technology transfers from public research institutes only and from universities only. The results in Table A3, when we show the interaction with firm's absorptive capacities, are consistent with Table 6. The effects of technology transfers from public research institutes on innovation seem smaller than the effects of technology transfers from universities, but they are moderated by the degree of firm's absorptive capacities.

As a second robustness check, we explore the effect of cooperation with public research institutes and universities. In the survey, companies report whether they have cooperated for technologically innovative activities in the current and previous two years with different partners. The survey further distinguishes, among other things, between public research institutes and universities. With this information, we construct dummy variables that take the value one if a firm has cooperated with public research institutes only, with universities only and with both public research institutes and universities. The percentage are a bit higher than in the case of external R&D expenditures although the relative proportions are similar. In the sample, 1.14% of firms cooperate with public research institutes only; 7.35% cooperate with universities only; and 0.56% cooperate with both. We replicate our analysis and present the new balancing test in Table A5 and the results in Tables A6 and A7. The results from Table A6 corroborate previous findings. Interestingly, many of the estimated coefficients are of similar magnitude than the estimated coefficients in Tables 5 and 6. In Table A6, we find that firms that cooperate with public research institutes only, with universities only and with both increase their innovation. We do not find any significant effect at standard statistical levels when we compare firms that cooperate with public research institutes and firms that cooperate with universities. In Table A7, we explore the moderating effect of absorptive capacities. We find that cooperation with universities increases firm innovation more than cooperation with public research institutes, but a firm's absorptive capacity reduces this difference.

To conclude, the analysis in this section suggests that, after controlling for an alternative measure of technology transfers and longer pre-treatment trends, there is evidence that technology transfers from public research agents increase innovation. On average, technology transfers from universities increase firm innovation more than technology transfers from public research institutes, although this differential effect declines with a firm's absorptive capacity.

4.5. The effect of technology transfers from public research institutes and/or from universities on other firm's characteristics

The previous sections show a positive effect of technology transfers from public research institutes on firm's innovation and the moderating role of absorptive capacities. In this section, we consider other firm level characteristics that can also been influenced by technology transfers.

In Table 7, we present the differential effect of technology transfers from public research institutes and universities on sales (columns 1 and 4), employment (columns 2 and 5) and labor productivity (columns 3 and 6). We consider the two alternative measures of absorptive capacities previously described. In all the different columns, the estimated coefficient for technology transfers from public research institutes is negative and the interaction term with absorptive capacity is positive. For sales and labor productivity, these effects are significant at standard statistical levels. The results suggest that firms that obtain technology transfers from universities increase their sales and their labor productivity more than firms that obtain their technology transfers from universities. However, this effect declines with firm's absorptive capacities.

5. Summary and concluding remarks

Some of the main technological innovations of the last century have emerged thanks to the fundamental role of the public sector in the production and transmission of knowledge (Link et al., 2020; Mazzucato, 2011). In this paper, we studied the effect of technology transfers on firm innovativeness from two main organizations that receive large amounts of public funds: public research institutes and universities. For this purpose, we applied propensity score matching techniques and DiD estimators to a sample of more than 10,000 Spanish firms for the period 2005-2014. Our results suggest that, technology transfers from both organizations increased firm innovativeness, highlighting the relevance of public funds for promoting private innovation activities. We also find that for a firm with an average level of absorptive capacity, technology transfers from universities increased firm innovativeness more than technology transfers from public research institutes. Finally, our results also indicate that firms' absorptive capacities played a moderating role for the effectiveness of technology transfers from public research institutes. Specifically, we find that as absorptive capacity increased above the mean, the positive impact of technology transfer from public research institutes on firm innovativeness was larger than the effect of technology transfers from universities.

All in all, our empirical analysis suggests that economic policies that encourage, facilitate and fund research projects between firms and publicly funded research centres are very beneficial for the innovativeness of the private sector. However, our results suggest that the efficiency of these policies depends on the internal knowledge capabilities of firms. Our results show that firms with high levels of absorptive capacity benefitted relatively more from technology transfers from public research institutes than from universities. In our view, this is valuable information for the design of innovation policies. From the point of view of generating a high level of firm innovation, it would be advisable that research funded projects between public research institutes and private firms are targeted to firms with medium and high absorptive capacities. Our results suggest that publicly funded projects from universities are better suited for firms with low levels of absorptive capacities. Moreover, innovation policies that encourage firms' absorptive capacities might be key to fully exploit the efficiency of the technology transfers from public research institutes.

Our study provides relevant insights for the design of efficient innovation policies. However, we would like to point out some caveats and limitations of our study that we believe merit future research. First, there is some heterogeneity across universities and public research institutes in terms of their research intensity and management. Therefore, it is important to explore this variability to understand the specific characteristics of the organizations that lead to an increase in firm innovativeness. Second, "science parks" (special areas devoted to scientific and development research) are another important agent within the national and regional R&D system. The impact of science parks on firm innovation is beyond the scope of our study, but we think that is an interesting channel for technology transfers, because the potential knowledge spillovers due to agglomeration effects. Finally, our measure of technology transfers is R&D industry contracts and cooperation. However, public research institutes and universities might have other ways of transferring knowledge such as licensing technologies or through spin-offs. The analysis of the effects of other types of technology transfers between public research institutes and universities and the private sector is an important avenue for future research.

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TABLES

Table 1: Means of main variables

	Technology transfers from			Non-transfers
	Only public research inst.	Only Universities	Both public research inst. & Universities	
	(1)	**(2)**	**(3)**	**(4)**
Panel A: Volume of R&D technology transfers:				
Public Research Institutes (in logs.)	10.29	0.00	10.65	0.00
	(1.70)	(0.00)	(1.86)	(0.00)
Universities (in logs.)	0.00	10.36	10.84	0.00
	(0.00)	(1.44)	(1.69)	(0.00)
Panel B: Technological innovation output variables:				
Product innovation (0/1)	0.74	0.75	0.79	0.45
	(0.44)	(0.43)	(0.41)	(0.50)
Process innovation (0/1)	0.69	0.71	0.76	0.47
	(0.46)	(0.45)	(0.43)	(0.50)
New production (0/1)	0.55	0.55	0.61	0.32
	(0.50)	(0.50)	(0.49)	(0.47)
New logistic (0/1)	0.20	0.17	0.25	0.10
	(0.40)	(0.38)	(0.43)	(0.30)
Number of patents	0.97	1.48	7.06	0.35
	(2.91)	(8.62)	(33.42)	(4.31)
Panel C: Other firm characteristics:				
Innovation investment (in logs.)	13.17	13.31	14.53	6.71
	(1.81)	(1.61)	(1.65)	(6.21)
Physical investment (in logs.)	7.41	7.51	8.33	5.28
	(3.22)	(3.05)	(2.56)	(4.03)
Exporter (0/1)	0.80	0.76	0.80	0.59
	(0.40)	(0.43)	(0.40)	(0.49)
Labor productivity (in logs.)	11.98	11.83	12.23	11.66
	(1.04)	(1.19)	(1.25)	(1.14)
Number of employees (in logs.)	4.32	4.36	5.26	4.12
	(1.56)	(1.57)	(1.65)	(1.65)
Internal R&D expenditures (in logs.)	11.86	12.23	13.72	5.38
	(3.94)	(3.47)	(2.70)	(6.12)
No. Observations	842	5,993	905	94,808

Notes: Standard deviations in parentheses. The symbol (0/1) means dummy variable. The variables *Public Research Institutes (Universities) is the natural logarithm of the external R&D expenditures plus one coming from public research institutes (Universities). Product innovation, Process innovation, New production process*, and *New logistic process* are all indicators that equal one if the firm reports innovations of each type during the periods t to t-2. *Number of patents* is the number of applied patents. *Innovation investment* and *Physical investment* are, respectively, the natural logarithms of a firm's total innovation expenditures or physical investment over its number of employees; *Exporter* is a dummy variables that take the value one if the firm is an exporter; *Labor productivity* is the natural logarithm of sales over number of employees; *Employees* is the natural logarithm of the number of employees. *Internal R&D expenditures* is the natural logarithms of spending on internal R&D activities.

Table 2: Number of observations and percentages by sector of activity

	Percentage of firms with respect to the number of observations in the sector			Number of observations
	Only public research inst.	Only Universities	Both public research inst. & Universities	
Sectors	(1)	(2)	(3)	(4)
Agriculture	4.7%	11.3%	3.2%	1,365
Mining and extractive industries	0.5%	7.1%	1.7%	5,870
Food and tobacco	1.2%	7.0%	1.6%	6,991
Textiles, printing and wood	0.6%	2.1%	0.3%	9,525
Chemicals	1.4%	9.3%	1.8%	5,418
Pharmaceuticals	4.7%	24.7%	9.6%	1,476
Manufacturing of non-metallic products	0.8%	3.8%	0.7%	6,394
Manufacturing of basic metals	0.7%	5.1%	0.5%	9,485
Manufacturing of electrical and optimal equipment	0.8%	7.9%	0.5%	9,979
Manufacturing of transport equipment	0.9%	4.8%	0.6%	3,185
Wholesale and retail trade	0.6%	2.7%	0.4%	8,199
Transport, storage and communication	0.3%	4.3%	0.2%	7,482
Final intermediation	0.2%	0.7%	0.0%	2,017
Real estate, renting and business activities	0.4%	5.3%	0.4%	7,257
R&D services, software and technical analysis	1.3%	12.6%	1.5%	8,288
Other services	0.2%	2.4%	0.2%	8,604
Total number of observations	842	5,993	905	94,808

Table 3: Cases of treatments and control groups

Case	Actual status (treatment)	Counterfactual (control)
1	Only Public Research Institutes	Non-transfers
2	Only Universities	Non-transfers
3	Both Public Research Institutes & Univ.	Non-transfers
4	Only Public Research Institutes & Univ.	Only Universities

Table 4: Characteristics of firms that obtain technology transfers from Public Research Institutes and/or Universities. Probit models.

	Case 1	Case 2	Case 3	Case 4
Dependent variable:	**Only Public Research Institutes**	**Only Universities**	**Both Public Research Inst. and Universities**	**Only Public Research Institutes**
	(1)	**(2)**	**(3)**	**(4)**
Product innovation$_{t-1}$	0.0047***	0.0285***	0.0031***	0.0160*
	(0.001)	(0.001)	(0.000)	(0.009)
Process innovation$_{t-1}$	0.0015***	0.0193***	0.0012***	-0.0215**
	(0.000)	(0.001)	(0.000)	(0.010)
Number of employees (in logs.)$_{t-1}$	0.0001	0.0033***	0.0013***	-0.0080***
	(0.000)	(0.000)	(0.000)	(0.003)
Labor productivity (in logs.)$_{t-1}$	-0.0001	0.0005	0.0003**	-0.0023
	(0.000)	(0.001)	(0.000)	(0.004)
Physical investment (in logs.)$_{t-1}$	0.0006***	0.0043***	0.0005***	-0.0004
	(0.000)	(0.000)	(0.000)	(0.001)
Exporter$_{t-1}$	0.0034***	0.0158***	0.0007**	0.0208**
	(0.001)	(0.001)	(0.000)	(0.010)
No. Observations	90,380	95,328	90,453	6,570
Sample:	*Only Public Research Institutes and non-transfers*	*Only Universities and non-transfers*	*Both Public Research Institutes and non-transfers*	*Only Public Research Inst. and only Univ.*

Note: All regressions include 14 industry dummies, three geographical dummies and year dummies. Explanation of variables in Table 1. The explanation of the treatment and control groups for each case is in Table 2. We report marginal effects at sample means. Estimated standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table 5: The effect of technology transfers from Public Research Institutes and Universities on innovation

	Dependent variable:				
	Product Innovation	Process Innovation	New production process	New logistic process	Patents
	(1)	(2)	(3)	(4)	(5)
	Panel A: Only Public Research Institutes vs. Non-transfers				
Only Public Research Inst. (0/1)	0.110***	0.054*	0.080**	0.054**	0.403**
	(0.031)	(0.032)	(0.034)	(0.026)	(0.169)
No. Observations	1,202	1,202	1,202	1,202	1,202
	Panel B: Only Universities vs. Non-transfers				
Only Universities (0/1)	0.127***	0.086***	0.079***	0.022**	0.611**
	(0.014)	(0.014)	(0.015)	(0.011)	(0.254)
No. Observations	7,571	7,571	7,571	7,571	7,571
	Panel C: Both Public Research Institutes and Universities vs. Non-transfers				
Both Public Research Inst. & Univ. (0/1)	0.123***	0.090***	0.084**	0.020	4.392**
	(0.033)	(0.035)	(0.039)	(0.031)	(2.047)
No. Observations	1,166	1,166	1,166	1,166	1,166
	Panel D: Only Public Research Institutes vs. Only Universities				
Only Public Research Inst. (0/1)	-0.002	-0.015	-0.007	0.037	-0.626
	(0.032)	(0.033)	(0.036)	(0.028)	(0.465)
No. Observations	1,101	1,101	1,101	1,101	1,101

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The symbol (0/1) means dummy variable. All regressions include year dummies. The sample in Panel A corresponds to case 1 and it includes firms with technology transfers from public research institutes only and firms without technology transfers (non-transfers). The sample in Panel B corresponds to case 2 and it includes firms with technology transfers from universities only and firms without technology transfers (non-transfers). The sample in Panel C corresponds to case 3 and it includes firms with technology transfers from both public research institutes and universities and firms without technology transfers (non-transfers). The sample in Panel D corresponds to case 4 and it includes firms with technology transfers from public research institutes only and firms with technology transfers from universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 6: The effect of technology transfers from only Public Research Institutes on innovation as compared to technology transfers from only Universities by absorptive capacity

	Dependent variable:				
	Product Innovation (1)	**Process Innovation (2)**	**New production process (3)**	**New logistic process (4)**	**Patents (5)**
Panel A: Absorptive capacity defined as internal R&D/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity A	0.008	0.017**	0.015**	0.015**	-0.185
	(0.009)	(0.007)	(0.007)	(0.006)	(0.129)
Only Public Research Institutes (0/1)	-0.092	-0.216**	-0.180**	-0.137*	1.602
	(0.111)	(0.094)	(0.090)	(0.070)	(1.165)
No. Observations	1,101	1,101	1,101	1,101	1,101
Panel B: Absorptive capacity defined as R&D employment/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity B	0.017	0.038**	0.034**	0.034**	-0.554
	(0.019)	(0.017)	(0.017)	(0.016)	(0.373)
Only Public Research Institutes (0/1)	-0.032	-0.086*	-0.071	-0.026	0.451
	(0.052)	(0.047)	(0.046)	(0.035)	(0.387)
No. Observations	1,101	1,101	1,101	1,101	1,101

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. Only Public Research Institutes is a dummy variable. The symbol (0/1) is a dummy variable. All regressions include year dummies. The sample in Panel A and B corresponds to case 4 and it includes firms with technology transfers from public research institutes only and firms with technology transfers from universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 7: The effect of technology transfers from only Public Research Institutes on other firm variables as compared to technology transfers from only Universities by absorptive capacity

	Dependent variable:					
	Sales	**Employment**	**Labor productivity**	**Sales**	**Employment**	**Labor productivity**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Only Public Research Inst. (0/1) x Absorptive capacity A	0.102***	0.046	0.052***			
	(0.038)	(0.028)	(0.016)			
Only Public Research Inst. (0/1) x Absorptive capacity B				0.230**	0.094	0.137***
				(0.098)	(0.079)	(0.038)
Only Public Research Institutes (0/1)	-1.033**	-0.442	-0.597***	-0.278	-0.088	-0.240**
	(0.456)	(0.344)	(0.198)	(0.237)	(0.189)	(0.106)
No. Observations	1,099	1,101	1,101	1,099	1,101	1,101

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. Only Public Research Institutes is a dummy variable. The symbol (0/1) is a dummy variable. All regressions include year dummies. The sample corresponds to case 4 and it includes firms with technology transfers from public research institutes only and firms with technology transfers from universities only. Absorptive capacity A is internal R&D/total employment (in logs.) and absorptive capacity B is R&D employment over total employment (in logs.). Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

APPENDIX

Table A1: Balancing tests and number of observations after matching corresponding to Tables5 to 8

			Balancing tests			Number of observations		
Case	**Treatment**	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Total**	**Treated**	**Control**
1	Only Public Research Institutes	Non-transfers	0.014	23.22	0.565	1,202	603	599
2	Only Universities	Non-transfers	0.002	19.55	0.770	7,571	3,862	3,709
3	Both Public Research Inst. & Univ.	Non-transfers	0.011	18.96	0.754	1,166	590	576
4	Only Public Research Inst. & Univ.	Only Universities	0.012	19.32	0.735	1,101	565	536

Notes: LR Chi2 reports the test on overall significance of the Probit model after the matching. Observations for total, treated and control samples are obtained after applying the matching procedure.

Table A2: Balancing tests and number of observations after matching corresponding to Table A3 and A4 for longer pre-treatment trends

			Balancing tests			Number of observations		
Case	**Treatment**	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Total**	**Treated**	**Control**
1	Only Public Research Institutes	Non-transfers	0.008	10.62	1.000	929	466	463
2	Only Universities	Non-transfers	0.002	18.78	0.945	6,145	3,130	3,015
3	Both Public Research Inst. & Univ.	Non-transfers	0.016	22.82	0.785	961	482	479
4	Only Public Research Inst. & Univ.	Only Universities	0.014	18.49	0.934	858	432	426

Notes: LR Chi2 reports the test on overall significance of the Probit model after the matching. Observations for total, treated and control samples are obtained after applying the matching procedure.

Table A3: The effect of technology transfers from Public Research Institutes and Universities on innovation controlling for longer pre-trends

	Dependent variable:				
	Product Innovation	Process Innovation	New production process	New logistic process	Patents
	(1)	(2)	(3)	(4)	(5)
	Panel A: Only Public Research Institutes vs. Non-transfers				
Only Public Research Inst. (0/1)	0.127***	0.052	0.062	0.057*	0.564***
	(0.036)	(0.036)	(0.039)	(0.029)	(0.205)
No. Observations	929	929	929	929	929
	Panel B: Only Universities vs. Non-transfers				
Only Universities (0/1)	0.096***	0.095***	0.082***	0.024**	0.422**
	(0.015)	(0.015)	(0.016)	(0.012)	(0.202)
No. Observations	6,145	6,145	6,145	6,145	6,145
	Panel C: Both Public Research Inst. and Universities vs. Non-transfers				
Both Public Research Inst. & Univ. (0/1)	0.124***	0.076*	0.070	0.002	4.113
	(0.037)	(0.039)	(0.043)	(0.035)	(2.831)
No. Observations	961	961	961	961	961
	Panel D: Only Public Research Inst. vs. Only Universities				
Only Public Research Inst. (0/1)	0.037	0.013	0.020	0.035	-0.077
	(0.035)	(0.036)	(0.039)	(0.032)	(0.466)
No. Observations	858	858	858	858	858

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The matched samples has been constructed using two years of lagged independent variables. The symbol (0/1) means dummy variable. All regressions include year dummies. The sample in Panel A corresponds to case 1 and it includes firms with technology transfers from public research institutes only and firms without technology transfers (non-transfers). The sample in Panel B corresponds to case 2 and it includes firms with technology transfers from universities only and firms without technology transfers (non-transfers). The sample in Panel C corresponds to case 3 and it includes firms with technology transfers from both public research institutes and universities and firms without technology transfers (non-transfers). The sample in Panel D corresponds to case 4 and it includes firms with technology transfers from public research institutes only and firms with technology transfers from universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table A4: The effect of technology transfers from only Public Research Institutes on innovation as compared to technology transfers from only Universities by absorptive capacity controlling for longer pre-trends

	Dependent variable:				
	Product Innovation (1)	**Process Innovation (2)**	**New production process (3)**	**New logistic process (4)**	**Patents (5)**
Panel A: Absorptive capacity defined as internal R&D/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity A	0.010	0.015*	0.005	0.012**	-0.035
	(0.009)	(0.008)	(0.008)	(0.006)	(0.120)
Only Public Research Institutes (0/1)	-0.090	-0.177*	-0.051	-0.115*	0.187
	(0.123)	(0.104)	(0.106)	(0.066)	(0.857)
No. Observations	858	858	858	858	858
Panel B: Absorptive capacity defined as R&D employment/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity B	0.020	0.032*	0.014	0.018	-0.101
	(0.021)	(0.018)	(0.019)	(0.014)	(0.335)
Only Public Research Institutes (0/1)	-0.012	-0.063	-0.020	-0.011	-0.029
	(0.058)	(0.052)	(0.053)	(0.036)	(0.216)
No. Observations	858	858	858	858	858

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The matched samples has been constructed using two years of lagged independent variables. Only Public Research Institutes is a dummy variable. The symbol (0/1) is a dummy variable. All regressions include year dummies. The sample in Panel A and B corresponds to case 4 and it includes firms with technology transfers from public research institutes only and firms with technology transfers from universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table A5: Balancing tests and number of observations after matching corresponding to Table A6 and A7

			Balancing tests			Number of observations		
Case	**Treatment**	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Total**	**Treated**	**Control**
1	Only Public Research Institutes	Non-transfers	0.004	15.27	0.935	3,007	1,526	1,481
2	Only Universities	Non-transfers	0.001	17.45	0.865	7,885	4,033	3,852
3	Both Public Research Inst. & Univ.	Non-transfers	0.003	23.28	0.561	4,745	2,417	2,328
4	Only Public Research Inst. & Univ.	Only Universities	0.002	9.66	0.997	2,200	1,123	1,077

Notes: LR Chi2 reports the test on overall significance of the Probit model after the matching. Observations for total, treated and control samples are obtained after applying the matching procedure.

Table A6: The effect of cooperation with Public Research Institutes and Universities on innovation

	Dependent variable:				
	Product Innovation	**Process Innovation**	**New production process**	**New logistic process**	**Patents**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Panel A: Only Public Research Institutes vs. Non-transfers				
Only Public Research Inst. (0/1)	0.116***	0.082***	0.081***	0.032*	0.820***
	(0.022)	(0.022)	(0.023)	(0.016)	(0.255)
No. Observations	3,007	3,007	3,007	3,007	3,007
	Panel B: Only Universities vs. Non-transfers				
Only Universities (0/1)	0.125***	0.097***	0.095***	0.031***	0.527**
	(0.014)	(0.014)	(0.015)	(0.010)	(0.235)
No. Observations	7,885	7,885	7,885	7,885	7,885
	Panel C: Both Public Research Inst. and Universities vs. Non-transfers				
Both Public Research Inst. & Univ. (0/1)	0.170***	0.131***	0.149***	0.069***	2.548***
	(0.017)	(0.018)	(0.019)	(0.016)	(0.689)
No. Observations	4,745	4,745	4,745	4,745	4,745
	Panel D: Only Public Research Inst. vs. Only Universities				
Only Public Research Inst. (0/1)	-0.002	0.006	0.030	-0.000	-0.340
	(0.025)	(0.026)	(0.028)	(0.020)	(0.842)
No. Observations	2,200	2,200	2,200	2,200	2,200

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The main independent variables have been constructed using cooperation instead of R&D external expenditure. All regressions include year dummies. The sample in Panel A includes firms with cooperation with public research institutes only and firms without cooperation with public research institutes or universities. The sample in Panel B includes firms with cooperation with universities only and firms without cooperation with public research institutes or universities. The sample in Panel C includes firms with cooperation with both public research institutes and universities and firms without cooperation with public research institutes and universities. The sample in Panel D corresponds includes firms with cooperation with public research institutes only and firms with cooperation with universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table A7: The effect of cooperation with only Public Research Institutes on innovation as compared to cooperation with only Universities by absorptive capacity

	Dependent variable:				
	Product Innovation (1)	**Process Innovation (2)**	**New production process (3)**	**New logistic process (4)**	**Patents (5)**
Panel A: Absorptive capacity defined as internal R&D/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity A	0.004	0.017***	0.010*	0.001	-0.133
	(0.006)	(0.006)	(0.006)	(0.004)	(0.142)
Only Public Research Institutes (0/1)	-0.034	-0.240***	-0.182**	-0.026	0.736
	(0.079)	(0.076)	(0.071)	(0.047)	(1.091)
No. Observations	1,221	1,221	1,221	1,221	1,221
Panel B: Absorptive capacity defined as R&D employment/total employment (in logs.)					
Only Public Research Inst. (0/1) x Absorptive capacity B	-0.001	0.042***	0.021	0.008	-0.487
	(0.014)	(0.015)	(0.015)	(0.013)	(0.456)
Only Public Research Institutes (0/1)	0.012	-0.119***	-0.103**	-0.029	0.101
	(0.041)	(0.040)	(0.040)	(0.028)	(0.388)
No. Observations	1,221	1,221	1,221	1,221	1,221

Note: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The main independent variables have been constructed using cooperation instead of R&D external expenditure. All regressions include year dummies. Only Public Research Institutes is a dummy variable. The symbol (0/1) is a dummy variable. All regressions include year dummies. The sample in Panel A and B corresponds to firms with cooperation with public research institutes only and firms with cooperation with universities only. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.