Industry-University links and firms' resilience during the Great Recession: Evidence for Spanish firms.

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Abstract

This study analyses the extent to which industry-university links in innovation activities influence firms' performance at downturns. In doing so, we use a sample of Spanish manufacturing firms to estimate how those that collaborate with universities or acquire R&D from universities prior to the Great Recession out-performed, in terms of real sales growth, their counterparts, and even so in sectors that were severely hit by the crisis (as measured by export growth). Our results suggest that knowledge transfers from universities became more valuable at bad times. These results are robust to various specifications of the model. Furthermore, our findings suggest that vertical and horizontal product differentiation is a key mechanism for the greater resilience of firms with university links during the Great Recession.

Keywords: industry-university; financial crisis; resilience; innovation; product differentiation.

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1 Introduction

Similar to the Covid-19 pandemic, the Great Recession of the late 2000s rapidly spread around the world with the characteristics of a severe economic crisis. Between 2008 and 2010 the world GDP fell by an accumulated 6%, the unemployment rate raised by almost 2%, and the real trade flows collapsed by 11%[1]. Despite these severe slumps, some regions coped better than others with hardship during the Great Recession. From a macro perspective, literature emerged trying to understand why some areas react and recover better than others from the economic slowdown (Pizzuto, 2020; Brakman and Marrewijk, 2019)[2]. In the same vein, using firm-level data, a growing number of empirical works have looked at the determinants of firms' resilience during a sudden adverse shock (Alfaro and Chen, 2012; Aghion et al., 2021; Bertschek et al., 2019; Chodorow-Reich, 2014; Giroud and Mueller, 2017). One of these determinants is the firms' innovation potential (Gupta, 2020). However, even if universities play a central role in firms innovation performance (Bellucci and Pennacchio, 2016; García-Vega and Vicente-Chirivella, 2020; Vega-Jurado et al., 2017), to date the role that university-industry links might play upon firms' resilience has not been studied[3]. In this paper, we contribute to filling this gap by analyzing how these links impact firm resilience. Moreover, we study whether our results hold for the sectors that were hardest hit by the crisis. Finally, we also explore the possible mechanisms through which firms may accomplish this resilience.

To do so, we use a sample of Spanish manufacturing firms and estimate the differential effect of a negative demand shock on the performance of firms that either collaborate with universities in R&D activities or outsourced their R&D to universities[4]. The econometric model is based on a difference-in-difference approach, in which a firm's real sales growth depends on the firm's university links, and in particular in the firm-university relationships in the pre-recession period (i.e., in 2006), as well as its interaction with the demand shock. Our results suggest that knowledge transfers from universities make firms more resilient at bad times,

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[1] Between 2008 and 2010, four million persons lost their jobs within the European Monetary Union (ECB – European Central Bank 2012)

[2] See the 2010 special issue of the Cambridge Journal of Regions, Economy, and Society on The Resilient Region, the 2014 special issue of Raumforschung und Raumordnung on Regional Economic Resilience: Policy Experiences and Issues in Europe, or the 2016 special issue of Regional Studies on Resilience Revisited.

[3] Although resilience has been defined in multiple ways in the academic literature, we follow Pal et al. (2014) definition. Therefore, resilience is understood as the capability to be ready in time of crisis and to sustain superior organisational performance. Conz and Magnani (2020) offers an exhaustive survey of how resilience of firms has been defined in the business and management fields.

[4] Given that Spain was one of the countries that more intensively suffered the consequences of the Great Recession, we believe using Spanish data is a value added of our study. From 2008 to 2010 GDP fell by 3.6%, unemployment rate risen from 13,8 to 20,1% and public debt increased from 40% to 62%.

particularly in industries severely affected by the shock. We also find that the contribution of universities to firm resilience is particularly important for small and medium-sized firms. Finally, our results point that university-industry links increase firm resilience by increasing firm's investments in product differentiation. This increased in more product lines and higher quality allowed firms with university links to expand abroad too in a period where internal demand dramatically decreased.

We add to the literature the first evidence of the importance of university-industry links for improving firms' resilience. Moreover, we highlight the importance of these links among SMEs in a country where SMEs represent more than 90% of the total number of firms. Therefore, our results have important implications for the design of efficient innovation policies that can maximize not only firms' resilience, but also innovativeness.

The rest of the paper is organized as follows. In Section 2, we discuss the related literature. In Section 3, we describe the data, the main variables in the analysis, and present some descriptive statistics. Section 4 explains the estimation method. In Section 5, we present our results and some robustness. Finally, in Section 6, we discuss implications and conclude.

2 Literature review

Universities are acknowledged as crucial external partners that improve firms' innovation performance (González-Pernía et al., 2015; Mansfield, 1991; Veuglers and Cassiman, 2005). The channels through which universities may improve firms' innovativeness are manifold. For example, some innovations cannot be reached without a certain level of basic knowledge (Mansfield, 1991, 1995; Nelson, 1986; Partha and David, 1994). However, due to the public good feature of basic research, it is difficult to obtain it via private markets. Universities can provide this knowledge either through R&D collaboration agreements or by selling their R&D services[5]. Second, firms' engaging in cooperative R&D with universities may have multiple gains due to reductions in R&D costs, risk decentralization, promotion of shared resources, and attainment of complementary capabilities (Becker and Dietz, 2004; Caloghirou et al., 2021, Geroge et al., 2002, Schartinger et al., 2002). These gains may be critical in recessive periods, as firms face constraints in financial resources during downturns. Third, university-industry links decrease the amount of time needed between design and production since some of these agreements include activities such as development and prototyping. This enables firms to recover the development costs for a specific product quickly (Santoro and Gopalakrishnan,

[5] Crow and Bozeman (1998) carried out a study with more than 16,000 US university, industry and government laboratories. They found that 70% of university laboratories viewed basic research as a major mission.

2001). Finally, R&D investments usually involve large sunk costs that need to be paid upfront (Aw et al., 2011; Máñez et al., 2009) and require skilled personnel to implement the project[6]. Firms may prefer to outsource these investments rather than creating an R&D department, purchasing specific physical assets, and hiring a specialized workforce. That is, firms outsource R&D because of a lack of in-house capacity to carry out technological research (López-Martínez et al. 1994). The empirical evidence corroborates these arguments and has reached a wide consensus about the positive effects of university-industry interactions on firms' innovativeness (Añon Higón, 2016; 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). Consequently, companies establishing links with universities should be considered as firms with strong innovative potential. As pointed out by Gupta (2020), this innovative strength provides companies a larger knowledge base which allows them to suffer less during bad times. Hence, university-industry ties should increase firms' resilience during economic recessions.

The two main types of high-involvement relationships between universities and firms that can induce technology transfers are cooperation and R&D contracting (Perkmann and Walsh, 2007; Fontana et al., 2006; D'este and Patel, 2007). However, while the former has received much of the attention in empirical works (Yu and Lee, 2017; Szücs, 2018; Kafouros et al., 2015; Lööf and Broström, 2008; Grimaldi, 2002; Monjon and Waelbroeck, 2003), studies analyzing the impact of R&D contracting from universities are very scarce[7]. Nevertheless, given the differences between cooperation and contracting in innovation governance modes, knowledge transferred and costs, the effects of university-industry links upon firm innovativeness are likely to differ across the type of agreement adopted. On the one hand, contracting presents a very clear governance mode. Firms specify the services they need, and universities accomplish it under payment (Perkmann and Walsh, 2007). On the other hand, collaboration agreements imply sharing not only knowledge and resources, but also the decision-making process. This may conduct to longer-term projects, discouraging the formalization of the agreement. Moreover, while R&D collaboration embodies both tacit and

[6] Fifty per cent, or more, of expenditures on R&D are wages and salaries of highly skilled workers, and they generate some intangible assets which in the future will bring benefits to the company (Hall, 2002).
[7] Vega-Jurado et al. (2017), García-Vega and Vicente-Chirivella (2020) and Añón Higón (2016) are some of the few studies looking at contracting R&D.

codified knowledge (Lane and Lubatkin, 1998; Almeida et al., 2003)[8], R&D contracts only include codified knowledge and, therefore, it can be more limited than cooperation[9]. Another difference between contracting and collaborating is that R&D contracts are more focused on improving problem-solving capabilities. Given the high importance of problem-solving capabilities on firm innovativeness (Partha and David 1994; Antonelli 1999), this may lead to a higher impact of contracting versus collaborating. Besides, R&D contracting is more focused on internal core capabilities, which speed up the product development (Tsai and Wang, 2009). Finally, assuming that the knowledge transferred from R&D collaboration is more complex than from R&D contracting, to fully exploit it firms should maintain a minimal level of in-house technological capacity (Paoli and Prencipe, 1999; Veugelers, 1997) which could be problematic for SMEs. Due to information asymmetries (Leland and Pyle, 1977) and high adjustments and sunk costs (Arrow, 1962), R&D investments are very sensitive to liquidity constraints, which are more prevalent in SMEs (Ayyagari et al., 2011; Hall, 2002; Ughetto, 2008)[10]. In fact, Miotti and Sachwald (2003), Negassi (2004), and López (2008) find a positive relationship between firm size and the probability of R&D cooperation. On the contrary, evidence suggests that learning from R&D acquisitions is possible even without the adoption of in-house R&D (Lucena, 2011). We contribute to the literature by analyzing the differential effects of university-industry collaboration and university-industry outsource upon firm resilience. Besides, we explore whether firm size plays a role in this relationship.

The last contribution of our study is related to the mechanisms behind the higher resilience of firms that carry out agreements with universities. As mentioned above, firms with strong innovative potential suffer less during slowdowns. Being innovative makes firms more capable to react to dramatic changes in the external environment because they can adjust their products to the new consumer needs faster than their non-innovative counterparts (Wang and Ahmed, 2007; Winter, 2003). Successful (high quality) product innovation allows firms to achieve a unique and differentiated product from competitors which increases firm performance (Kim et al., 2016; McNally et al., 2010). Furthermore, protecting these

[8] This double channel of knowledge makes the learning from collaboration more demanding, since requires that the firm have well-developed skills in transforming tacit in codified information that enables knowledge assimilation (Kale et al., 2002).

[9] Using Rosenberg's definition, tacit knowledge is understood as "the knowledge of techniques, methods and designs that work in certain ways and with certain consequences, even when one cannot explain exactly why." (Rosenberg, 1982, p.143),

[10] Smaller firms have less collateral to offer which raise the cost of external finance. Besides, they are usually younger than large firms, which hamper the access to external funds due to the lack of information that lenders have. Finally, large firms usually have larger internal funds.

innovations with a patent can ensure a certain market power that benefits the performance of these companies. Gupta (2020), using a sample of Spanish manufacturing firms, shows that the resilience of innovative firms operates through product differentiation and not through process innovation. Similar to her, we also explore the mechanism behind the higher resilience of firms collaborating/contracting with universities. Moreover, during a period of a dramatic drop in domestic demand, the development of a novel differentiated product could increase foreign demand pushing the firm to sell this good abroad (Hitt et al., 1997)[11]. Hence, expanding sales to new foreign markets could be also behind the lower impact on sales growth for firms with university links.

3 Data

The dataset used in this study is the Spanish Technological Innovation Panel (PITEC). It represents the contribution of Spain to the Europe-wide Community Innovation Survey (hereafter, CIS) and is the result of the collaboration between the Spanish National Statistics Institute and COTEC Foundation to provide data to the CIS[12]. Different from many European Community Innovation Surveys, the Spanish CIS is a panel data covering the period 2004-2014. The longitudinal dimension covers not only an entire business cycle but, of interest to us, also the years of the 2008 financial crisis. PITEC contains detailed firm-level information on several firm characteristics such as export status, number of employees, and turnover. Importantly to us, PITEC contains information on university-industry links[13]. The main interest of our analysis is to study the effect of technology transfers from universities upon firm resilience. Our measure of university technology transfers includes R&D services acquired from Spanish universities and R&D collaborations with Spanish universities by firms. In the dataset, the company reports its external R&D expenditures (a firm's purchases of R&D conducted by other entities) distinguishing between the type of providers. Firms also report whether they have cooperated in innovation activities with universities. Using this information, we construct the variable *university links*, which is a dummy variable that takes the value one

[11] Belke et al. (2014), using firm-level data for Spain, Portugal, Italy, France, Ireland and Greece, concludes that domestic demand is relevant for the dynamics of exports, especially for Spain, Portugal and Italy, and more significant during more extreme stages of the business cycle.
[12] See http://icono.fecyt.es/PITEC/Paginas/por_que.aspx for further details.
[13] PITEC contains information on both manufacturing and services companies. However, in this paper we concentrate on the sample of manufacturing firms. The underlying innovation processes can vary substantially between manufacturing and service firms (Hoffman et al., 1998) with limited scope and applicability of formal R&D in some services.

if a firm has expenditures in R&D services from Spanish universities, or if it has collaborated in innovation activities with universities, and zero otherwise. Measures similar to our measure of university links are used by García-Vega and Vicente-Chirivella (2020), Fudickar and Hottenrott (2019), Vega-Jurado et al. (2017), and Medda et al. (2005). Besides, in order to disentangle the different effects from outsourcing and collaboration, we define four mutually exclusive dummy variables i.e.: firms that collaborate and outsource (*Both*); firms that only collaborate (*Only collaborate*); firms that only outsource (*Only outsource*); and firms that neither outsource nor collaborate (*None*), which will be used as the reference category. Our final working sample is an unbalanced longitudinal panel of 6,578 firms based on 34,869 observations observed over the period 2004 to 2011. We work with two samples. Our baseline results are based on the sample covering the main years of the Great Recession (2007-2011); while for robustness tests we use the sample covering pre-recession and recession years (i.e., 2004-2011).

Similar to Aghion et al. (2021), Gupta (2020), Alfaro and Chen (201,2), and Alviarez et al. (2017) we use real sales growth as a dependent variable to proxy firm resilience. Therefore, a firm will be more resilient when it grows more (or shrank less) than other firms within its industry. Defining firm performance in terms of sales growth differences out any time-invariant unobservable firm characteristics affecting the level of sales of a firm (Gupta, 2020). When analyzing the mechanisms behind firms' resilience, we also use as dependent variables measures of innovation output at the firm level. In particular, we consider different measures of firm innovativeness in our baseline specifications: having product innovation, having a product innovation new to the market[14], and having patents.

3.1 Measuring the demand shock

Our baseline measure of the demand shock (*shock*) aims at measuring the severity of the 2008 Great Recession among Spanish manufacturing industries. Following Aghion et al. (2021) and Gupta (2020), we use export growth to proxy for the crisis intensity. More specifically, we use the percentage of exports decline at the industry level during the crisis as the baseline measure of the intensity of the demand shock. We assume that exports are driven by the demand of the

[14] See Mairesse and Mohnen (2005) for a detailed explanation of how CIS surveys are structured and the main innovation indicators in this type of survey.

world markets, and not by internal supply shocks, hence making the shock exogenous to firm performance (see Gupta, 2020). This assumption is supported by Behrens et al. (2013), who for Belgium, which is a small open economy like Spain, does not find support for supply-side explanations for the trade collapse during the Great Recession. Nevertheless, like robustness, we will relax this assumption by using an instrument for the decline in Spanish exports with US data.

The Spanish data of exports to the world is sourced from the UN COMTRADE database, which is an international database on bilateral imports and exports at five-digit product code (SITC 3). We aggregate the export data from COMTRADE from its five-digit product level (SITC 3) to two-digit NACE Revision 1, using the concordance table provided by WITS[15], and then we use the concordances between NACE Revision 1 and NACE Revision 2. As mentioned above, firms in PITEC are classified into industry groups according to the statistical classification of economic activities in the European Community, abbreviated as NACE Revision 2. For manufacturing, there are 23 unique industry groups classified in the PITEC with a one-to-one mapping to 2-digit NACE classification[16].

Given that the information on exports in UN COMTRADE is in nominal values, we proceed to deflate the nominal values by the Consumer Price Index (CPI) of Spain, sourced from INE. Thus, the percentage change of the exports is obtained as the two-year difference between a two-year rolling average of the real export value for each two-digit industry, as follows:

$$\Delta X_t = \left(\bar{x}_{t,t+1} - \bar{x}_{t-2,t-1}\right) \quad (1)$$

where$\bar{x}_{t,t+1}$is the logarithm of the average value of exports in *t* and *t*+1. In order to obtain the intensity of the Great Recession, we calculate the export growth of 2008. Specifically, the final shock can be defined as follows:

$$Shock = -(\Delta X_{2008}) \quad (2)$$

Thus, the higher the value of the shock, the higher will be the intensity of the shock in a specific industry. As recent studies by Bricongne et al. (2012) using French data and by Gupta (2020) with Spanish data showed, for most industries, except for leather and beverages, export

[15] https://wits.worldbank.org/product_concordance.html
[16] The "coke and refined petroleum products" industry is excluded from the analysis.

growth was below its trend during the recession. Metals and machinery, featured by trading intermediate goods, were among the most adversely affected sectors, while sectors trading mostly consumption goods like food, meat products, etc., were the least affected sectors.

3.2 Instrumental variable

There are two sources of endogeneity concerns with the baseline measure of the *shock*. First, in case there was a supply-side shock that affects negatively the performance of firms with no university links relative to firms and sectors with strong university links, leading to a decline of exports in sectors with relatively low industry-university ties. This will imply that the link between firm performance and the interaction of the *Shock* with the university link will be endogenous. The second source of concern is that the knowledge transfer from universities may lead to an increase in exports in that industry. Thus, export growth at the industry level and sales growth of a firm could be affected by the same firm-specific shock. Nevertheless, this issue would cause a downward bias, and hence, the estimate of the interaction term in equation (4) would be a lower bound on the resilience of firms with university links. Nonetheless, to mitigate both concerns, we will use an instrumental variable approach.

The instrument we use is based on the data of the United States of America (see Gupta, 2020). We instrument the change of Spanish exports by the change of the US exports during the crisis period. An assumption we make is that the value of exports follows the demand of the world markets, and the export shock across industries was similar for Spain and the US. The findings by King and Rebelo (1999) and Bricongne et al. (2012) suggest that the sectoral impact of the recessions does not depend on a country but on the characteristics of an industry.

To be a valid instrument two conditions should be met. First, the US export decline is highly correlated with the Spanish export decline during the Great Recession. Second, we assume that the impact of the shock on firm-level performance in Spain is not correlated with the decline in US exports during the crisis period. That is to say, Spanish demand or supply-side factors do not affect US exports since Spain is not a large economy nor a large trading partner of the US. In any case, and to avoid any potential influence of trading with the US and fulfill the exogeneity condition of the instrument, we use the net exports value by subtracting exports to Spain from the total US exports to the World. Thus, we expect the decline in the US exports to be a valid instrument for the decline in Spanish exports during the crisis. Similarly, by the same way we obtained the Spanish shocks, we deflate the US exports nominal values by the CPI of the US. Further, the instrumented shock is measured with the function we defined in equation (2), but using instead US real exports.

3.3 Other control variables.

Informed by the literature, we also control for other firm-level characteristics which may influence firm growth. These are the firm's size (in logs); labor productivity (in logs), and a dummy that takes the value of 1 if the firm exports and 0 otherwise. Informed also by the literature, we also control for whether the firm invests in internal R&D (with a dummy that takes the value of 1 if the firm does R&D and 0 otherwise), as well as for the total (external and internal) R&D to sales ratio, that is, the total expenses of R&D over revenue. Moreover, we also control for the financial barriers that the firm faces, and by the foreign stake ownership. Finally, industry-year fixed effects are included in the specifications to account for other environmental factors that may influence a firm's performance. When requires, we will also control for unobserved firm-specific fixed effects.

3.4 Descriptive Statistics

Table 1 displays some descriptive statistics of the sample of manufacturing firms in PITEC over the period 2005 to 2010. The average (median) manufacturing firm has 154 (48) employees and €49 million (€7.9 million) in real sales. On average, firms' real sales dropped by 8.6 percent over the period 2005-2010. Besides, on average, only 14% of manufacturing firms hold some ties with universities (either in the form of innovation collaboration or contractual R&D). Finally, real exports at the sector level, on average, fell by 2 percent.

Figure 1 shows the different engagement across industries in terms of pre-crisis industry-university relationships. The sectors with the largest percentage of firms with university links (either in the form of collaboration in innovation with universities or/and contracting R&D from universities) are the basic pharmaceutical products, the air and spacecraft, the electrical, electronic, and optic, and the chemical and chemical products industries. On the other hand, firms in the furniture, other manufacturing, and the printing industries are the least engaged in university relationships. Additionally, figure 2 shows the share of firms by industry with university collaboration and those with R&D outsourcing contracts with universities in the pre-crisis period.

Our main result is illustrated in Figure 3, which shows the annualized average two-year growth rate in sales for all manufacturing firms included in the PITEC sample computed using data ending in the years 2011, 2010, and 2009 (hence, averaging across three different growth periods: 2011-2009, 2010–2008, and 2009–2007). These are all years involving the Great Recession[17]. The sample Figure 1 is subdivided into four categories of firms. First, we split firms according to whether they belong to an industry in which exports drop above (*High shock*) or below *(Low shock*) the average drop in exports in the main Great Recession years (the 2008 and 2009 average) compared to the latest pre-crisis years (2006 and 2007 average). Second, we split firms by whether they had or had not university links before the advent of the Great Recession, i.e., in the year 2006. As it can be observed, all firm's groups experienced a drop in average sales. Moreover, the decrease in sales is significantly larger for firms classified in industries experiencing a more severe export shock (compare the two bars on the right with the two on the left). The finding emerging from this figure is that holding university links was associated with better performance during the crisis, even within the group of firms experiencing a more severe shock (*High shock*). For firms facing a hard environment during the crisis, the decline in sales was significantly larger for those firms that did not have university links before the recession. All in all, firms with university links were more resilient to the crisis in terms of sales growth.

4 Empirical Model

This section examines econometrically the link between firms' sales growth during the crisis and firm-university links in innovation activities before the recession. More specifically, this study aims to estimate the differential effect of a negative demand shock on the performance of firms that either collaborate with universities in R&D activities or outsourced their R&D to universities. To do so, we use Aghion et al. (2021) framework, in which firm performance will be measured as firm real sales growth. The econometric model is based on a difference-in-difference approach, in which firm's real sales growth depends on the firm's university links, and, in particular, on the firm-university relationships in the pre-recession period (i.e., in 2006), as well as its interaction with the intensity of the demand shock, as follows:

[17] We just focus on the initial years of the Great Recession. The crisis in Spain persisted until 2013 due to the eurozone currency crisis and fiscal austerity policies. The results are robust to dropping the 2009–2011 period.

$$\Delta Y_{ijt} = Y_{ijt+1} - Y_{ijt-1} = \alpha Uni_{ij0} + \beta Uni_{ij0} * shock_j + \gamma x_{ij0} + \phi_{jt} + \varepsilon_{ij} \quad (3)$$

Where Y_{ijt} is the logarithm of real sales for firm i in industry j, measured from t - 1 to $t + 1$. Thus, the dependent variable, ΔY_{ijt}, reflects the change of real sales at the firm level over a two-year period. To obtain real sales, nominal values of sales are deflated by the industrial price index at 2-digit industry level taking 2010 as the reference year and sourced from INE. We focus on growth at t + 1 to give firms time to adapt to the unanticipated demand shock that takes place between t - 1 and t + 1. *Uni* is a dummy that takes the value 1 if a firm has university links (either in the form of collaboration in innovation with universities or/and contracting R&D from universities) before the year of the shock to guarantee that it is weakly exogenous to the shock (it is measured in the year 2006). We assume knowledge transfers from universities will affect firms positively. Additionally, the *shock* measures the severity of the 2008 Global Recession measured at two-digit Spanish manufacturing industries. The coefficient of main interest is β since it represents the difference in the adjustment during the crisis, i.e., it can be considered a measure of the differential effect of a severe negative demand shock on the performance of firms with university links relative to their counterparts. In equation (3), given the definition of the shock variable, β will be positive if firms with university links are more resilient (i.e., the drop in sales will be lower) when they are hit by a more severe shock.

Finally, the vector x represents a series of firm-level controls measured at pre-recession that play important roles in sales growth. The controls contain the firm's size (as the number of employees in logs), labor productivity (in logs), the export status, the firm's R&D status, and the total R&D intensity, the firm's financial barriers, and the foreign ownership status. Furthermore, ϕ_{jt} are industry-year fixed effects, such that β is identified from comparing firms within the same industry-year. Including these industry-year interactions imply that the direct effect of the *shock* (which is time-invariant) on sales growth gets absorbed by these fixed effects. Finally, ε is the standard errors that are clustered at the two-digit industry level.

First, we pool the data for three cross-sections (2008, 2009, and 2010) by measuring firm characteristics in 2006; i.e., prior to the recession. Thus, all firm characteristics, including the firm-university links are measured in 2006. We restrict the analysis up to the year 2011[18], since

[18] Given that the dependent variable measures the change of real sales at the firm level over a two-year period, data for the 2010 cross-sections covers the years 2009 (t-1) and 2011 (t+1).

we want to focus on the Great Recession, which in the case of Spain started in late 2008 and was followed by a Sovereign Debt Crisis.

5 Results

5.1 Baseline results

The first results of the baseline model described in equation (4) are presented in Table 2, which focuses on the relationship between ex-ante university links, the shock, and firm sales growth during the Great Recession. We assume that in the pre-Great Recession period, firms were in an initial equilibrium where they had decided their optimal level of relationship with universities (*Uni*) given their set of information, while the shock was largely unexpected. In column (1), we find that firms with university links perform better on average during the crisis (2008-2011). Firms with university links were associated with a significant 7% increase in real sales growth. Moreover, as we expected, the severity of the shock had a negative and significant impact on sales growth. A 1% increase in the intensity of the shock (*shock*) is associated with a significant 0.57 percentage point decrease in sales growth.

Comparing with column (1), in column (2), we introduce the interaction between the university link (*Uni*) and the measure of the crisis intensity, i.e., *shock*. The coefficient on the interaction term is positive and significant, which suggests that firms with university ties in an industry that experienced a more severe shock were more resilient and grew relatively more (or shrank less) than other firms with no university links in that industry. To be specific, an increase in the shock of 1 percent will lower the sales of a non-university related firm by 0.6 percentage points in that particular industry (i.e., if *Uni* = 0). Hence, the resilience of firms increases if firms are in a relationship with universities for their innovation activities. Moreover, in column 2, the coefficient for *Uni* is positive and significant, which implies that firms with university links grew differentially more (or shrank less) in the industries that had zero export growth (i.e., *shock* = 0).

In column (3), we use a series of control variables that have been suggested by previous literature to affect performance, including firm size, labor productivity, the R&D status, and the R&D intensity, the export status, the foreign origin, and the financial barriers faced by the firm, and we also include industry-year fixed effects. For ease of exposition, the coefficients of these controls are not shown but will be discussed. The linear shock is absorbed by the industry-time dummies, but the interaction term (*Uni # shock*) can still be identified. Even in this demanding specification, the coefficient on the interaction term (β) is positive and significant, with a coefficient of 0.23, which is consistent with the hypothesis that firms with knowledge transfers from universities were more resilient to the crisis, and they were even less damaged in sectors that were severely hit from the Great Recession compared with firms that did not have university links.

Finally, in column (4) we present the results using an instrumental variable approach, where the instrument used for crisis intensity using US data has been defined previously in section 3. The instrument is valid since the null for weak instruments is rejected. The first stage is valid since Kleibergen-Paap rk Wald F statistic takes the value of 66.8. The interaction term (β) stands as positive and significant, which is consistent with the results presented in previous columns and the coefficient is very similar to that in column 3. Thus, we fail to reject the null of the Durbin-Wu-Hausman test, that is to say, the coefficient with IV estimation and OLS are consistent, while the IV is not as efficient as the OLS estimation. Based on this, in what follows we will use the decline in export growth of Spain to measure the intensity of crisis across industries.

Regarding the rest of firm-level controls, although not reported, only the R&D status, the export status, the financial barriers, and the industry-year fixed effects appear to positively affect firm performance; while firm size, labor productivity, and foreignness, do not appear statistically significant after controlling for industry-year fixed effects.

The open innovation literature highlights the different effects of collaboration and contracting on innovation and a firm's performance (Cassiman et al., 2010). To see which mode of relationship with universities brings greater resilience to firms in times of crisis, we first look in columns (1) to (3) of Table 2.b to the effect of collaboration with universities and contracting R&D to universities (i.e., outsourcing) and their interaction with the shock. Results suggest that firms acquiring R&D from universities were more resilient. But, because firms may combine the two strategies and there may be complementarities between them, we require of a specification in which we can distinguish between four categories: firms that only acquire R&D to universities (but do not collaborate), firms that only collaborate, firms that both acquire R&D from universities and collaborate; and firms that neither collaborate nor outsource to universities, which will be the reference category. Results are presented in column (4) of Table 2.b. Overall, the results suggest that firms that outsource their R&D to universities (either with or without cooperating with universities) were more resilient in the recession, and even though in sectors severely affected by the demand shock. Firms that combined both strategies had a better performance during the recession than firms that only outsource. However, that is not the case for firms that opted for a strategy based exclusively on cooperation with universities, which did not see any difference in performance relative to firms that had no university links.

5.2. Placebo Test

A potential concern implicit in the results presented above is the fact that firms with university links might have better performance on average, and this performance could be independent of the business cycle. If that is the case, then, the results obtained above would be spurious. This might be the case if the measure of the shock is picking up some time-invariant industry characteristics such that firms with university relationships in sectors that face a severe demand crisis perform better even in non-recessionary periods. To address this concern, we estimate equation (3) for the period before recession years (i.e., 2005 and 2006). If the interaction term (*Uni # Shock*) turns out positive and significant in the years before the crisis, then it would indicate that firms with university links always perform better in sectors that were hit severely during the crisis, independently of the business cycle.

We use equation (3) and pool the data for two cross-sections, but now firm sales growth (i.e., the dependent variable), is measured over the non-recessionary period, i.e., 2004-2006 and 2005-2007, while university links, as well as the rest of controls (except the *shock*), are measured at the beginning of each growth period, i.e., in 2004 and 2005, respectively. Columns (1) and (2) of Table 3 present the results. Column (1) shows the relationship between having university links and firm-level growth in the pre-crisis period. The non-significant coefficient on the university link variable implies that firms with university links did not grow, on average, at a significantly higher rate in the pre-crisis period. Column (2), additionally, shows how this relationship varies with the severity of the crisis across sectors. A similar result to that in column (1) can be seen, that the coefficient on the university link variable is not significant. Moreover, the coefficient of the interaction term (*Uni # shock*) is insignificant. This implies that firms with university links did not perform significantly better in sectors that later on will experience a more severe shock during the recession. Therefore, the measurement of the crisis intensity we use is not picking up unobserved industry heterogeneity.

In column (3), we measure the crisis with a new dummy variable called *GFC* (Global Financial Crisis) and pool the years preceding the recession with the post-crisis years. Our goal here is to assess if firms using knowledge transfers from universities were especially resilient to the Great Recession. In other words, were firms with university links exclusively resilient to bad times? To study this, we pool the data for the period before the crisis and the crisis years, that is *t* goes from 2005 to 2010, and control for unobserved heterogeneity with a fixed effect specification. In a similar vein to Bertschek et al. (2019), we construct a dummy variable named *GFC*, which takes the value of one for the years of the crisis period, either 2008, 2009, or 2010. We use the same specification as in equation (3), but we add the GFC and its interactions with university links and the *shock*. Moreover, the university link variables and the rest of the firm's controls are measured at *t*-1, i.e., at the beginning of each growth period. The control variables are the same as in the preferred specification shown in column (3) of Table 2, and the specification controls also for the industry-year fixed effects and firm's fixed effects.

The result of this specification is presented in column (3) of Table 3. The coefficient on the interaction term between firms with university links and the Great Recession is significant and positive. In other words, when *GFC* = 1, firms with university relationships are associated with higher growth on average. This suggests that despite the insignificant difference in the pre-crisis growth rates of firms with and without university links, the relative growth rate of firms with university relationships increased during the crisis, and therefore, firms with university links were hit less severely exclusively during the crisis. Furthermore, the coefficient on the interaction term *Uni # GFC # Shock* is positive and significant (although at 10%), which implies that the effect of university knowledge transfers in industries in which the crisis was more intense is arising entirely from the Great Recession years. All in all, the results suggest that firms with university links are more resilient to bad shocks on average.

5.3 Robustness checks

In this section, we test whether our baseline results are robust to some changes in the specification. The changes in the baseline specification are as follows: the dependent variable in column (1) is the two-year difference in real sales growth but without trimming. The results of these robustness checks are presented in Table 4. Focusing on the coefficient of interest, the interaction term in column (1) is positive and significant, which is consistent with the hypothesis that firms with university links are more capable of disrupting the negative effects of a severe recession. In columns (2), in addition to the firm's controls used in the baseline specification, we control for other firm characteristics that may affect firm performance, such as the appropriability conditions and the log capital-labor ratio. A similar result with that in columns (1) is found.

The results discussed so far suggest the existence of a positive relationship between sales growth and university links during the crisis, and even so in the industries most affected by the Great Recession. In columns (3) and (4) we test whether this also holds for other measures of firm performance, as employment growth (column (3)) and labor productivity growth (column (4). The results for employment growth are similar to those for sales growth, while for productivity growth the interaction term turns not significant. But still, we observe that in the recession period, firms with university links cut down on layoffs and enjoyed higher productivity growth compared to firms with no-university links. The effect of university links on employment growth was positive too in those industries severely affected by the Great Recession.

5.4 Mechanisms: product diversification & market expansion

Our findings above show that the outperformance of firms with university links arise entirely from the Great Recession years, which suggests that industry-university links become even more valuable in downturns. Here, we try to gain further insights into the mechanisms that allowed firms with university links to be more resilient during the Great Recession. While the opportunity cost theory states that firms have greater incentives to innovate in downturns (Geroski and Walter, 1995), the cash-flow effect will suggest otherwise (Shleifer, 1986). However, industry-university links compensate for the constraints in financial resources during the recession. Hence, we would expect that knowledge flows from universities become more valuable for firms when they are hit by a negative shock, and hence, their propensity to innovate increases in downturns. Therefore, we aim first at showing evidence on whether university links could impact differently firm's innovation propensity during the pre-crisis and the crisis period. If this holds, it could help explain why firms with university links were hit less severely concerning sales growth during the Great Recession.

Thus, we estimate the following equation:

$$I_{it} = \beta_0 Uni_{it-1} + \beta_1 Uni_{t-1} * shock_j + \beta_2 GFC * shock_j + \beta_3 Uni_{t-1} * GFC + \beta_4 Uni_{t-1} * GFC * shock_j + \gamma x_{it-1} + \phi_{jt} + \varepsilon_{ij} \quad (4)$$

Where I_{it} represents the firm's innovation decision in period t. Considering these variables are not in growth rates, the period of analysis, t, is set from 2005 to 2010. As innovation outcomes, we look at the decision to product innovate, introduce new products to the market and fill patent(s). Our interest here lies in the estimates of the β_3 and β_4 coefficients. If knowledge transfers from universities become more valuable during the recession to enhance the innovation propensity, and more so in sectors severely affected, we should expect these coefficients to be positive and significant.

The results are presented in Table 5, where we pool the data for the pre-recession and crisis years. The dependent variable in columns (1) is a categorical variable for whether a firm has introduced a product innovation. The dependent variable in columns (2) and (3) is a categorical variable for whether the firm has introduced a product innovation that is new to the market, and for whether the firm has filed a patent in period t. All columns control for firms' characteristics that previous literature has shown to affect the innovation propensity. Hence, we control for firm's size, R&D status, total R&D intensity, financial obstacles, government funding, export status, foreign ownership, start-up status, and group ownership dated at t-1, as well as industry-year fixed effects. While in the previous sections we use OLS, or FE, given that the dependent variable was continuous, here the dependent variables are binary, therefore, to overcome the potential inconsistency issue, we present the estimates of a Probit specification.

Thus, results in columns (1) to (3) show that firms with university links are, independently of the business cycle, more likely to deliver product innovation, product innovations new to the market, and more likely to patent too. These results are in line with previous findings in the literature (Añon Higón, 2016; Arvanitis et al., 2008; Bellucci and Pennacchio, 2016; Bishop et al., 2011; Cassiman et al., 2010; García-Vega and Vicente-Chirivella, 2020, among others). Another interesting result emerges, which implies that in a period of crisis, firms in sectors severely hit by the recession were relatively more likely to innovate in a way to escape from a negative shock. However, this behavior seems common to all firms, independently of whether they have or not university links. Hence, it seems that the outperformance of firms with university links during the Great Recessions is not explained by a change in their propensity to innovate during this period.

An alternative explanation may be that knowledge transfers from universities become more valuable during the recession by allowing firms to expand to foreign markets. Hence, in column (4) we estimate the same specification but the dependent variable is instead the export status[19]. Results here show that firms with university links are, independently of the business cycle, more likely to export. Moreover, during the Great Recession, firms in more affected sectors were relatively more likely to sell abroad in a way to escape from the negative shock. Therefore, it seems that the outperformance of firms with university links during the Great Recessions is not explained either by the change in their propensity to sell abroad during this period.

Looking at the scarce literature on the relationship between business cycles and innovation, Geroski and Walters (1995) claim that the potential counter-cyclicality of innovation is driven by product differentiation, as opposed to incremental improvements in existing products. Furthermore, according to the literature on strategic diversification (Ansoff, 1958), firms facing a demand shock could engage in product differentiation to explore new markets or niches where demand might be growing and to diversify their product portfolio (Berchicci et al, 2014). Hence, a mechanism to explore is that related to a change in the innovation strategy towards (horizontal and vertical) product differentiation in the Recession, an idea also put forward by Gupta (2020). The argument is that knowledge transfers from universities may help firms to upgrade the quality of their products or to bring higher quality products to the market in downturns. Increased product differentiation leads to higher switching costs and a more inelastic demand, which in bad times may alleviate the decline in demand (Klemperer, 1995)[20]. The problem with the above results is that the general innovation measures used (i.e., product innovation) do not clearly distinguish between new (high quality) products and incremental improvements to existing products.

To address this issue, we make use of other questions present in the survey that may be more related to product differentiation and estimate equation (4) with these new dependent variables. Particularly, we use the number of patents filed and questions that deal with innovation objectives. Firms are asked to indicate the degree of importance of specific innovation goals: i) increase of product lines; ii) quality improvements; iii) increase in market share and expansion to new markets. We infer that if firms give high or medium priority to these

[19] In this specification, we control for firm's size, R&D status, total R&D intensity, financial obstacles, government funding, foreign ownership, start-up status, group ownership and innovation status dated at *t*-1, as well as industry-year fixed effects.
[20] There is, however, the alternative hypothesis, which states that when a recession hits, customers become more price elastic and less willing to pay for quality (Field and Pagoulatos, 1997).

innovation goals during downturns, they are more likely to come up with (horizontal or vertical) differentiated product innovations. Results are presented in Table 6. Our interest here lies in the estimates of the β_3 and β_4 coefficients. If knowledge transfers from universities become more valuable during the recession to enhance product differentiation, and more so in sectors more intensively affected, we should expect these coefficients to be positive and significant.

The results in Table 6 confirm our hypothesis. Firms with university links were more likely to horizontally and vertically differentiate their products during the financial crisis (i.e., the coefficient on *University links # GFC* is positive and significant). Thus, during the Great Recession firms with university links filled a higher number of patents, and were more likely to increase product lines, improve product quality and expand to new markets. Moreover, firms with university links in sectors severely affected by the crisis (*University links # GFC # shock)* increased the number of patents and were more likely to improve product quality, which as a result, enhanced their resilience during the Great Recession.

5.5. Differences in firm size

In this section, we aim to see whether firm heterogeneity influences the results obtained previously. Particularly, we focus on whether firm size matters. In this regard, we classify firms into two categories: large firms (i.e., firms with 200 or more employees), and small and medium-sized enterprises (SMEs, i.e., firms with less than 200 employees). We argue that the benefits of knowledge transfers through industry-university links may be greater for SMEs than for larger firms.

To analyze the role played by size we estimate equation 3 for both large-sized firms and SMEs, respectively. The results are displayed in Table 7. Columns (1) and (3) show the results of SMEs while columns (2) and (4) do so for large firms. Data are pooled for growth over 2007-2009 to 2009-2011 in columns (1) and (2), and 2004-2006 to 2009-2011 in columns (3) and (4). Panel A reports the results without considering the different modes of industry-university relationship, while Panel B distinguishes between collaboration with universities and contracting R&D to universities.

It is interesting to find that for SMEs, having university links played a significant role in the event of a crisis, and more so in industries adversely hit by the Great Recession. Thus, the interaction term for SMEs in both columns (1) and (3) is positive and significant. Results in column (3) reveal that this was exclusive of the crisis period. On the contrary, for large firms, we obtain that university relationships cannot make large firms more resilient, either in those industries severely hit by the shock or in the general event of a recession.

What type of industry-university links brings higher gains in resilience? For SMEs, results shown in Panel B of Table 7 reveal that R&D outsourcing (either as an exclusive strategy or in combination with collaboration) makes firms more resilient in the event of a crisis, even more in sectors severely affected by the shock. For large firms, results show that only the strategy that combines collaboration with contracting R&D to universities brings resilience rewards, which are higher for firms in sectors severely affected by the shock.

6. Conclusions

The main goal of the present study was to determine whether industry-university links enhance firms' performance in an economic downturn. Shocks like the Great Recession or the current COVID-19 pandemic bring high uncertainty as well as resource constraints. Under this turbulent environment, it is difficult to predict whether firms will pursue links with universities to innovate and whether firms with active university relationships will be more resilient. On the one hand, companies establishing links with universities should be considered as firms with strong innovative potential, which should allow them to suffer less during bad times. Moreover, firms actively engaged in collaboration with universities may display greater organizational flexibility, which may be key in downturns when firms need to adapt their products to find potential new markets. Furthermore, the firms engaged in open innovation strategies with universities may have multiple gains due to R&D costs reduction, shared resources, risk decentralization, and attainment of complementary capabilities. These gains may be critical in recessive periods, as firms, particularly SMEs, face constraints in financial resources during downturns. Hence, our aim lies in assessing the role that university-industry links might play upon firms' resilience in the wake of a severe demand shock.

Hence, to empirically analyze the role of industry-university links in the event of a global economic downturn we use firm-level data from the PITEC survey, which collects information on innovation activities of Spanish firms. We focus on manufacturing firms and we exploit the negative shock of the 2008 financial crisis which reduced demand across sectors in heterogeneous ways. Following a similar difference-in-difference approach to Aghion et al. (2021), we find that firms with university links were hit less hard and, therefore they were more resilient during the main years of the Great Recession. This is true whether we use export shocks which vary at the industry level or a more general definition of the Global Financial Recession. Moreover, the results also indicate that firms with university links had better performance than their counterparts even in sectors severely hit by the shock. Moreover, our results show that product differentiation is a key mechanism explaining the resilience of firms with university links. In this regard, knowledge transfers from universities help firms invest more in product differentiation in order to upgrade the quality of their products or/and to bring higher quality products to the market in downturns.

This research has important policy implications for managers and policy makers. Our results show that regardless of the economic cycle, firms' establishing links with universities always have a positive impact on sales, employment, and labor productivity growth. Besides, these companies are more likely to introduce a product innovation, a patent, and selling abroad. Hence, policy makers should promote these partnerships irrespectively of the cycle. Firms' managers have also the duty of finding cooperation agreements or outsourcing relationships that best fit the company. Although most of the studies looking at the effects of university-industry links have used collaboration to identify the ties, our results suggest that in downturns the positive effects are coming from R&D outsourcing rather than from R&D collaboration. Consequently, policies aimed to help firms to set up links with universities should take into account this finding. A possible explanation for this result is that firms do not possess enough absorptive capacity to fully exploit collaboration agreements with universities. Aligned with this argument, we find that the positive effects of university links hold for SMEs but not for large firms.

Regarding the crisis years, we find that university links are especially important for dealing with hardship during the Great Recession. Firms with university ties in an industry that experienced a more severe shock grew relatively more (or shrank less) than other firms with no university links in that industry. Again, R&D outsourcing is the channel through which this higher resilience is achieved, and SMEs are the firms enjoying the improvements. Finally, our results indicate that firms with university links were more resilient during the crisis because, during a period of a dramatic drop in domestic demand, they were able to horizontally and vertically differentiate their products and, therefore, allow them to expand their markets abroad. That means that facilitating university-industry links could have a very desirable side effect pushing firms to internationalize. All in all, this study highlights the important role that universities may play not only during stable macroeconomic periods but especially during bad times.

Although this study provides relevant insights, we acknowledge some limitations. First, the results are obtained based on data from a single country. It would be interesting to extend the analysis to other countries. Second, we focused on high-involvement relationships between universities and firms that can induce technology transfers (cooperation and contracting), however knowledge transfer from universities can also be achieved from patenting and licensing, company spin-offs from academic research, consulting, etc. It would be desirable to check whether results hold when other ways of technology transfer are considered. These are interesting avenues for future research.

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Table 1: Summary statistics (2005-2010)

Variable	Mean	Median	sd
Sales growth (2 years difference)	-.086	-.041	.445
Sales levels (€ *thousands*)	49032	7887	222626
Employment	154	48	431
University ties (%)	.14	0	.347
Exports (change in sector exports in 2008/2009 relative to 2006/2007)	-.022	-.0002	.159

Source: PITEC

Figure 1: Share of firms with University links in 2006, by industry.

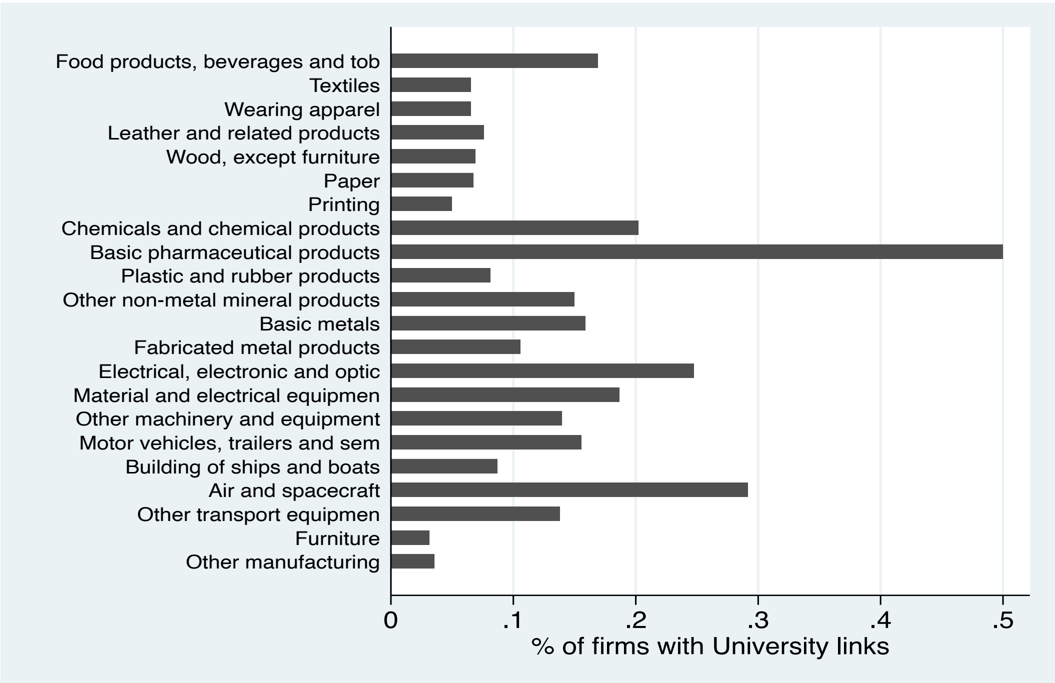


Figure 2: Share of firms with University collaboration and outsourcing contracts in 2006, by industry.

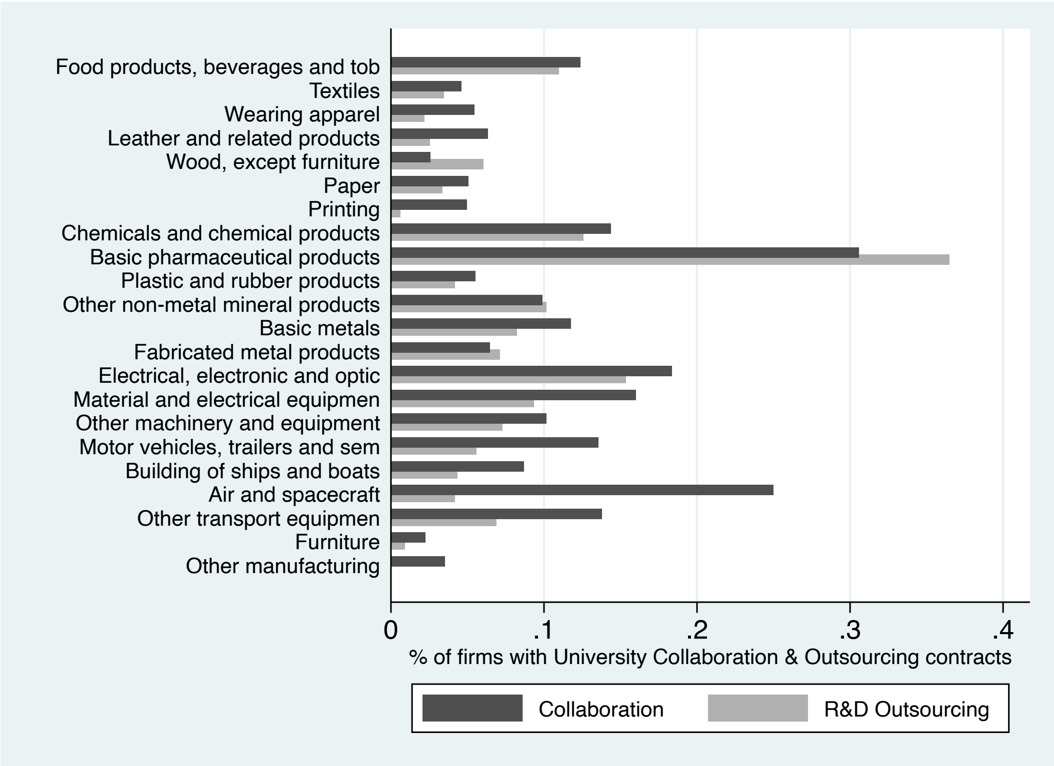
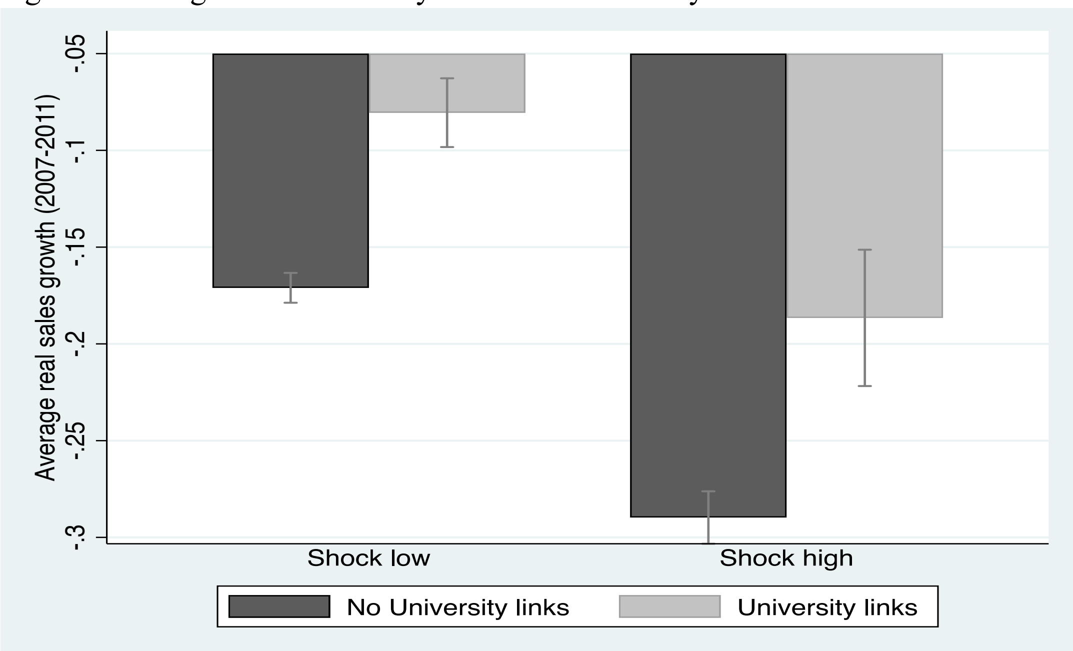


Figure 3: Changes in real sales by shock and university links



Note: The bars plot average firm-level change in the log of real sales over 2007-2009, 2008-2010 and 2009-2011, with the 95 percent confidence bands reported. "Shock low" is whether the firm belongs to an industry in which the drop in the average level of export in 2008 and 2009 (the main Great Recession years) compared to the average level in 2006 and 2007 (the pre-recession years) is below the average shock. Shock high represents then those industries more severely affected by the crisis. Firms are split whether they have university-ties (collaborate with universities in innovation or acquire R&D from universities) in the pre-recession period (2006).

Table 2a. University links and sales growth during the crisis (2007-2011): baseline results

	Dependent variable: Sales growth (Two-year difference)			
	OLS	OLS	OLS	IV
	(1)	(2)	(3)	(4)
University links$_{2006}$	0.067***	0.064***	0.052***	0.052***
	(0.011)	(0.011)	(0.015)	(0.014)
Shock	-0.566***	-0.603***		
	(0.103)	(0.104)		
University links$_{2006}$ # Shock		0.224***	0.221**	0.233**
		(0.080)	(0.084)	(0.094)
Industry FE	Yes	Yes		
Industry-year FE			Yes	Yes
Firm controls			Yes	Yes
Weak instruments (F-stat)				66.8
Observations	15,148	15,148	15,148	15,148
R^2	0.052	0.052	0.162	0.162

Note: The dependent variable is firm real sales growth measured from t–1 to t + 1. Data are pooled for growth over 2007-2009, 2008-2010, and 2009-2011. Growth is winsorized at 1% on both tails. University links is measured at 2006 for the three cross-sections respectively. *Shock* is the export growth measured as the percentage change from 2006-07 to 2008-09 at the industry level. Columns (3) and (4) control for labor productivity, firm size, export status, inhouse R&D status, total R&D to sales ratio, and firm's financial barriers prior to the Great Recession in the year 2006. Standard errors are clustered at the industry level and reported in parentheses. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 2.b. University collaborations and R&D contracted to universities and sales growth during the crisis (2007-2011)

	Dependent variable: Sales growth (Two-year difference)			
	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
Collaborate$_{2006}$	0.030	0.033*	0.029	
	(0.018)	(0.019)	(0.018)	
Outsource$_{2006}$	0.047***	0.046***	0.049***	
	(0.009)	(0.009)	(0.013)	
Collaborate$_{2006}$ # shock	0.179		0.233**	
	(0.124)		(0.099)	
Outsource$_{2006}$ # shock	0.134	0.229***		
	(0.112)	(0.073)		
Only Collaborate$_{2006}$				0.035
				(0.023)
Only Outsource$_{2006}$				0.054***
				(0.014)
Both$_{2006}$				0.073***
				(0.021)
Only Collaborate$_{2006}$ # shock				0.188
				(0.179)
Only Outsource$_{2006}$ # shock				0.156**
				(0.066)
Both$_{2006}$ # shock				0.304**
				(0.119)

Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	15,148	15,148	15,148	15,148
R^2	0.163	0.162	0.162	0.163

Note: The dependent variable is firm real sales growth measured from t–1 to t + 1. Data are pooled for growth over 2007-2009, 2008-2010, and 2009-2011. Growth is winsorized at 1% on both tails. Collaboration and Outsourcing is measured in 2006 for the three cross-sections respectively. *Shock* is the export growth measured as the percentage change from 2006-07 to 2008-09 at the industry level. Columns (3) and (4) control for labor productivity, firm size, export status, internal R&D status, R&D to sales ratio, and firm's financial barriers prior to the Great Recession in the year 2006. Standard errors are clustered at the industry level and reported in parentheses. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 3. Placebo Analysis

	Dependent variable: Sales growth (Two-year difference)			
	2004-2007		2004-2011	
	OLS	OLS	FE	FE
	(1)	(2)	(3)	(4)
University links$_{t-1}$	0.019	0.023	-0.021*	-0.017
	(0.015)	(0.015)	(0.012)	(0.011)
University links$_{t-1}$ # Shock		-0.160		-0.144
		(0.123)		(0.097)
University links$_{t-1}$# GFC			0.050***	0.045***
			(0.014)	(0.014)
GFC # Shock				-0.231
				(2.681)
University links$_{t-1}$ # GFC # Shock				0.226*
				(0.121)
Firm FE	No	No	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	10,530	10,530	31,254	31,254
R^2	0.476	0.476	0.468	0.468

Note: The dependent variable is firm real sales growth measured from *t*–1 to t + 1. Growth is winsorized at 1% on both tails. In columns (1) and (2), data is pooled for growth over 2004-2006 and 2005-2007; while in columns (3) and (4) data is pooled for pre- and post-crisis periods (2004-2006, 2005-2007, 2006-2008, 2008-2010, 2009-2011. The *University links* variable is measured at *t*-1. *Shock* is the export growth measured as the percentage change from 2006-07 to 2008-09the at the industry level. *GFC* is a dummy equal to 1 for *t* equal to 2008, 2009, and 2010. All columns control for labor productivity, firm size, export status, internal R&D status, R&D to sales ratio, and firm's financial barriers in *t*-1. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 4. Robustness: University links and Resilience during the crisis (2007-2011)

	Sales growth (without trimming)	With more firm controls	Employment growth	Labor Productivity growth
	(1)	(2)	(3)	(4)
University $links_{2006}$	0.055***	0.052***	0.016*	0.033**
	(0.017)	(0.015)	(0.009)	(0.015)
University $links_{2006}$# shock	0.291***	0.221**	0.151**	0.031
	(0.099)	(0.084)	(0.053)	(0.050)
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls in 2006	Yes	Yes	Yes	Yes
Observations	15,148	15,148	15,148	15,148
R2	0.128	0.162	0.063	0.113

Notes: The dependent variable in columns (1) and (2) is it is the two-year difference in real sales growth from t−1 to t+1. The dependent variable in column (3) is the difference in the log of employment from t−1 to t+1, while that in column (4) is the difference in the log of employment from t−1 to t+1. Growth is winsorized at 1% on both tails, except for the results in column (1). Data are pooled for growth over 2007-2009, 2008-2010, and 2009-2011. *University links* is measured at the pre-recession period 2006. *Shock* is the export growth measured as the percentage change from 2006-07 to 2008-09 at the industry level. Firm controls include labor productivity (excluded in (4)), firm size (excluded in (3)), export status, R&D status, R&D to sales ratio, and firm's financial barriers. Column (2) additionally controls for the log of the capital-labor ratio and the appropriability conditions. Standard errors are clustered at the industry level and reported in parentheses. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 5. Innovation, Sales abroad, and University links

	2005-2010			
Dep. Variable:	product innovation	new product innovation for the market	Patents	Sales abroad
	Probit	Probit	Probit	Probit
	(1)	(2)	(3)	(4)
University links	0.167***	0.357***	0.238***	0.158***
	(0.048)	(0.056)	(0.031)	(0.044)
University links # Shock	0.139	-0.130	-0.097	-0.021
	(0.245)	(0.282)	(0.169)	(0.260)
University links # GFC	0.068	0.038	-0.047	0.075
	(0.047)	(0.070)	(0.042)	(0.046)
GFC # Shock	15.946***	16.353***	6.703***	1.886*
	(0.746)	(0.965)	(0.545)	(1.000)
University links# GFC # Shock	0.184	0.392	0.036	0.055
	(0.212)	(0.433)	(0.118)	(0.219)
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	33,024	32,983	20,385	33,024

Note: The dependent variable in column (1) is a categorical variable for whether a firm has introduced a product innovation. The dependent variable in columns (2) is a categorical variable for whether the firm has introduced a product innovation that is new to the market. The dependent variable in columns (3) is a categorical variable for whether the firm has patented. The dependent variable in columns (4) is a categorical variable for whether the firm has sold abroad. In columns (1) to (4) data is pooled for the period 2005-2010 is pooled. All columns control for labor productivity, firm's size, R&D status, total R&D intensity, financial obstacles, government funding, export status, foreign ownership, and group ownership dated period t-1 and industry-year fixed effects. Standard errors are clustered at the industry level and reported in parentheses. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 6. Product differentiation and university links

	2005-2010			
Dep. Variable:	Number of patents	Increase product lines	Quality improvement	New markets
	Negative binomial	Probit	Probit	Probit
	(1)	(2)	(3)	(4)
University links	0.693***	0.087*	0.106**	0.062
	(0.081)	(0.052)	(0.046)	(0.050)
University links # Shock	-0.875***	0.355	-0.462***	0.246
	(0.303)	(0.279)	(0.151)	(0.189)
GFC # Shock	0.287**	0.089*	0.158***	0.256***
	(0.125)	(0.048)	(0.061)	(0.041)
University links # GFC	37.615***	1.721***	2.147***	13.841***
	(1.379)	(0.444)	(0.396)	(0.514)
University links# GFC # Shock	1.150**	-0.069	0.409*	0.314
	(0.507)	(0.263)	(0.224)	(0.314)
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	33,024	33,024	33,024	33,024

Note: The dependent variable in column (1) is the number of patents. The dependent variable in columns (2) is a categorical variable for whether the firm ranks very or quite important the objective of increasing the number of product lines. The dependent variable in columns (3) is a categorical variable for whether the firm ranks very or quite important the objective of quality improvement. The dependent variable in columns (4) is a categorical variable for whether the firm ranks very or quite important the objective of market expansion through innovation. In columns (1) to (4) data is pooled for the period 2005-2010 is pooled. The firm's controls include (dated at period t-1): firm's size, R&D status, total R&D intensity, financial obstacles, government funding, export status, foreign ownership, group ownership, and whether the firm is a start-up. All columns control also for industry-year fixed effects. Standard errors are clustered at the industry level and reported in parentheses. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 7. Firm size and University links
Panel A:

	Dependent variable: Sales growth (Two-year difference)			
	2007-2011 (OLS)		2004-2011 (FE)	
	SMEs	Large	SMEs	Large
	(1)	(2)	(3)	(4)
University links$_{2006}$	0.057***	0.047		
	(0.014)	(0.030)		
University links$_{2006}$ # shock	0.343***	-0.029		
	(0.056)	(0.160)		
University links$_{t-1}$			-0.013	-0.037*
			(0.014)	(0.020)
University links$_{t-1}$# shock			-0.113	-0.139
			(0.105)	(0.140)
GFC# shock			1.401	-2.054
			(3.320)	(4.777)
University links$_{t-1}$# GFC			0.049***	0.027
			(0.018)	(0.023)
University links$_{t-1}$# GFC# shock			0.260*	0.128
			(0.145)	(0.175)
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	12,349	2,806	25,085	6,169
R2	0.155	0.251	0.459	0.574

Panel B:

	SMEs	Large	SMEs	Large
	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Only Collaborate	0.041	0.031	-0.013	-0.021
	(0.026)	(0.035)	(0.021)	(0.028)
Only Outsource	0.058***	0.054	-0.003	-0.033
	(0.014)	(0.042)	(0.019)	(0.031)
Both	0.076***	0.067*	-0.017	-0.056**
	(0.020)	(0.037)	(0.020)	(0.028)
Only Collaborate # shock	0.311*	-0.257	-0.133	-0.227
	(0.152)	(0.216)	(0.153)	(0.198)

Only Outsource # shock	0.250***	0.127	0.102	-0.033
	(0.073)	(0.131)	(0.154)	(0.233)
Both # shock	0.441***	0.106	-0.291**	-0.097
	(0.143)	(0.164)	(0.122)	(0.180)
Only Collaborate # GFC			0.008	-0.020
			(0.028)	(0.033)
Only Outsource # GFC			0.067**	0.050
			(0.027)	(0.039)
Both # GFC			0.094***	0.069**
			(0.027)	(0.033)
Collaborate # GFC # shock			0.249	0.224
			(0.205)	(0.255)
Outsource # GFC # shock			0.112	-0.074
			(0.214)	(0.314)
Both # GFC # shock			0.384*	0.246
			(0.208)	(0.214)
Industry-year FE	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	12,349	2,799	25,085	6,169
R2	0.155	0.252	0.460	0.575

Note: The dependent variable is firm real sales growth measured from *t*–1 to t + 1. Growth is winsorized at 1% on both tails. In columns (1) and (2), data is pooled for growth over 2004-2006 and 2005-2007; while in columns (3) and (4) data is pooled for pre- and post-crisis periods (2004-2006, 2005-2007, 2006-2008, 2008-2010, 2009-2011. The *University links* variable is measured at 2006 in the OLS specification and at *t*-1 in the panel FE specification (Column 3 to 4). *Shock* is the export growth measured as the percentage change from 2006-07 to 2008-09the at industry level. *GFC* is a dummy equal to 1 for *t* equal to 2008, 2009, and 2010. All columns control for labor productivity, firm size, export status, internal R&D status, R&D to sales ratio, and firm's financial barriers in either 2006 or *t*-1. Significance level: * p<0.1, ** p<0.05, *** p<0.01.