Asymmetries in export and R&D adoption sequence and the impact of the crisis

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Abstract

Exports and R&D strategies, when jointly adopted generate important synergies, however little is known about their adoption sequence. This paper aims to shed more light on whether they are adopted simultaneously or sequentially and, in the latter case, on the direction of their adoption sequence. Our empirical evidence is based on 6512 manufacturing firms drawn from the Spanish Technological Innovation Panel from 2004 to 2013, a period covering an entire business cycle as well as the crisis. By using both a probabilistic and a performance based approach, we find that sequential adoption is more frequent than simultaneous adoption and the adoption sequence is not symmetric. While the 2008 crisis has increased the export propensity of all firms, the likelihood of joint adoption has increased more for firms already performing R&D than for those companies already exporting reinforcing the asymmetry in the adoption strategy with important industrial policy implications.

JEL Classification: F10, L10, L60, O30.

Keywords: export, R&D, sequential adoption, simultaneous adoption, asymmetry, crisis.

1. ***INTRODUCTION***

Both internationalization and innovative activities (R&D) are strategies that could improve firms' performance and, therefore, economic growth. If jointly adopted, R&D and export strategies should allow firms to successfully compete in international markets (Becker and Egger, 2013; Roper and Love, 2002) and a positive association between R&D and internationalization has indeed been found in the literature, suggesting the presence of clear benefits from their joint adoption (Golovko and Valentini, 2011; Aw et al., 2007; Peters et al., 2015). However, despite their importance, very little is known about their adoption dynamics. Both export and R&D activities involve high start-up costs and also fixed costs (Aw et al., 2011). Typical of any strategies, sunk costs[1], learning effects and likely decreasing marginal performance associated with diseconomies of scope from simultaneous adoption, would make it rational for any strategies to be adopted at different points in time rather than simultaneously (Battisti et al., 2015; Astebro et al., 2016). Hence, *sequential* adoption is often more likely than *simultaneous* adoption. However, while most of the existing studies are based on the observation of joint adoption of two strategies (see for example Cassiman and Veugelers 2006; Miravete and Pernias 2006; Kretschmer et al., 2012) our knowledge of their adoption sequence is still very limited. Battisti et al. (2015) is one of the first papers that tests and empirically distinguishes sequential from simultaneous adoption. Using a probability approach, they define "*simultaneous adoption when the likelihood of the simultaneous adoption of two innovations is greater than the likelihood of adopting each of them in isolation and… sequential adoption when a prior adoption decision of one innovation leads to a posterior increase in the likelihood of the adoption of the other innovation*" (Astebro et al., 2016, p.3). They also demonstrated that in the presence of sequential adoption, the adoption order matters and should be taken into account. That is, when sequential adoption between export and R&D is evaluated, it is important to keep in mind that it is not the same adding R&D when the firm was already exporting as adding exporting when the firm was already performing R&D. This also suggests that any study of R&D (Export) strategy adoption in isolation could be highly misleading if the Export (R&D) strategy decision was ignored. The initial adoption of any one strategy might make the adoption of the other strategy more likely and often more profitable than in its absence.

[1] Das et al. (2007) estimate average sunk costs for foreign market entry of more than 400,000 US$ for Colombian industries.

To fill this gap in the understanding of the R&D and Export adoption dynamics, we first follow the *probability approach* to the study of sequential adoption strategies proposed by Battisti et al. (2015), we then extend it to the traditional *profitability approach* based upon the investigation of the gains derived from the various adoption strategies.

The probability approach relies on transition probabilities and discrete choice models for dynamic panel data to identify the direction of the adoption decision. While these models can handle both simultaneous and sequential adoption, we use the Mundlak (1978) approach to correct for unobserved heterogeneity. Further to using probability models, we use a *profitability approach* based on the growth regressions via the panel-corrected standard error model to assess the expected gains associated with the various adoption strategies.

Our evidence is based on a Spanish panel data for the period 2004-2013, containing information on the R&D and export strategy of around 6,500 manufacturing firms observed over a nine year period leading to almost 47,000 observations. The sample is drawn from the *Spanish Technological Innovation Panel* (PITEC, hereafter). PITEC represents the Spanish contribution to the Europe-wide Community Innovation Survey. Differently from the vast majority of other European Countries, the Spanish CIS is a long longitudinal unbalanced panel dataset enabling us to carry out the analysis of the adoption timing and the adoption sequence of the various strategies while controlling for internal and external environmental factors. Interestingly to us, our sample includes the years of a whole business cycle as well as the 2008 financial and economic crisis, allowing us to explore the sensitivity of the adoption sequence not only to internal conditions but also to external shocks and changes in the external environment.

Overall our findings contribute to the understanding of the synergies between internationalization and R&D strategies with important implications for public policy.

The rest of the paper is organized as follows. Section 2 summarises the related literature and introduces the main hypotheses. In Section 3, the data and some preliminary evidence of the firms' adoption strategies are detailed. Section 4 is devoted to the methodology and the variables used in the study. Section 5 presents and discussed the results. Finally, Section 6 concludes.

2. *RELATED LITERATURE AND MAIN HYPOTHESES*

Export and R&D activities are regarded as strategies that may reinforce one another and empirical evidence corroborates the positive association between them (Hallward-Dreimeier et al., 2002; Baldwin and Gu, 2003; Iacovone and Javorcik, 2012). On the one hand, investment in R&D increases the propensity to export (Aw et al., 2011; Becker and Egger, 2013; Roper and Love, 2002) as the introduction of a successful innovation may boost productivity growth (Gu and Tang, 2004; Parisi et al., 2006; Rochina-Barrachina et al., 2010; Máñez et al., 2009), and this improvement in productivity allows firms to enter into international markets (Greenaway and Kneller, 2007; Wagner, 2007). Similarly, and independent of the increase in productivity, the development of a novel (or better quality) product could increase foreign demand pushing the firm to internationalize by selling this good abroad (Hitt et al., 1997). On the other hand, international trade allows firms to get in touch with new technologies, processes or techniques not available in their home markets, expanding firms' capabilities (Álvarez and Robertson, 2004). This new knowledge promotes firms' learning and, thus, positively contribute to the performance of the R&D investments.[2] Moreover, the larger market for exporters comparing with home-based firms allows international firms to spread out the costs associated with R&D investment, and therefore make R&D investment more profitable (Lileeva and Trefler, 2010; Bustos, 2011). Within this literature, Bustos (2011), Aw et al. (2008), Atkeson and Burstein (2010) or Costantini and Melitz (2007) are some of the studies showing the positive impact of exports on R&D. In particular, Bustos (2011) predicts that during periods of liberalization of trade, (both new and the oldest) exporting firms improve their technology faster than those that do not export. In the same vein, Atkeson and Burstein (2010) and Constantini and Melitz (2007) argue that trade liberalization can increase the amount of R&D performed.

Golovko and Valentini (2011), Aw et al. (2007) and Peters et al. (2015) explicitly analyse the complementarities between these two strategies.[3] Golovko and Valentini (2011) define complementarity as in Milgrom and Roberts (1990). That is, adding an activity while the other activity is already being performed has a higher incremental effect on performance than adding the same activity in isolation. They conclude that firms that invest in both activities

[2] This new knowledge acquired by the firm because of its export activity has been labelled "learning-by-exporting" and it has been widely studied in the applied industrial organization research. See for example Golovko and Valentini (2014), Love et al. (2014) or Álvarez and Robertson (2004).

[3] Contrary to the studies analysing the synergies between internal and external innovation activities (Battisti and Iona, 2014; Berchicci, 2013; Hagedoorn and Wang, 2012; Schmiedeberg, 2008; Veugelers and Cassiman, 1999) the synergies between export and R&D have received little attention.

(joint adoption) are characterized by higher growth rates than those that do only one or none of them, and that the performance from any one activity increases as the level of the other increases. Aw et al. (2007) and Peters et al. (2015) study the effects of different combinations of export and innovation across the productivity improvements. Aw et al. (2007) find a positive relationship between exports and future productivity. They also find that exporters that also invest in R&D, have higher future productivity than firms that only export. Finally, Peters et al. (2015), for a sample of five high-tech German industries, concluded that exporting firms have a higher payoff from R&D investment, invest in R&D more frequently than firms that only sell in the domestic market, and, subsequently, have higher rates of productivity growth. That means that expenditures on R&D facilitate a firm's ability to benefit from exporting. Overall, the literature consistently indicates that when analysing the probability of exporting or performing R&D a virtuous circle is associated with their joint adoption. Therefore, we argue that the two strategies cannot be treated in isolation as this could lead to biased conclusions and also to overestimating the impact of individual adoption. When the probability of carrying out R&D is analysed, export status should be taken into account and vice versa for exports. However, the majority of studies tend to focus on the evidence based on joint adoption and/or on only one adoption sequence, e.g. R&D first and export second, lacking clarity on whether the most frequently observed adoption sequence is simultaneous or sequential. Battisti et al. (2015) and Astebro et al. (2016) have argued that strategies are generally more likely to be adopted sequentially rather than simultaneously[4]. Hence, we formulate the following hypothesis:

HYPOTHESIS 1. Export and R&D strategies are more likely to be adopted sequentially -from R&D/Export to both- rather than simultaneously -from none to both *(sequential versus simultaneous adoption).*

The literature has argued in favour of both Export firms being highly likely to engage also in R&D and also for R&D firms being highly likely to also engage in exports but has never looked at any asymmetries in the direction of the adoption sequence. Hence, we formulate the following hypothesis:

[4] They argue, although they do not directly test, that this can be due to a number of reasons such as diseconomies of scope, managerial and organisational complexity, convex adjustment costs, high sunk costs associated to investment in human capital, internal reorganisation and infrastructure (see Battisti et al., 2015 and Astebro et al., 2016).

HYPOTHESIS 2. The direction of *sequential adoption* ie. whether R&D is adopted first and export second or export first and R&D second - matters and it is not necessarily symmetric.

We have no preferred explanation concerning the adoption sequence. The literature has argued both ways. Hence, we leave it to the empirics to determine the most likely adoption sequence.

Lastly, the 2008 financial crisis has caused a major shock across developed and developing economies and we acknowledge this can have affected both exports and R&D adoption decisions via a number of channels (Máñez et al.,2014; Bricongne et al., 2012; Chor and Manova, 2012), although with different intensity. Exports may be motivated not only by firm internal conditions and the opportunity to gain access to global market demand for own products, but it might also be the result of domestic crisis and a reduction in domestic demand (Greenaway and Kneller, 2007). Hence, sales in international markets may act as a substitute for sales in a national internal market. Belke et al. (2014) have recently corroborated this idea. Using firm-level data for Spain, Portugal, Italy, France, Ireland and Greece, they conclude 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.

Secondly, uncertainty of outcome (Brealey et al.,1977) as well as asymmetric information and reluctance to full disclosure (Bhattacharya and Ritter, 1983) associated with new projects and hence new strategies can make it difficult for prospective funders to calculate the probability of success and future profits, hence creating moral hazard and adverse selection problems (Jensen and Meckling, 1976; Stiglitz and Weiss 1981). Investment in new R&D strategies can generate a large number of intangible assets and higher sunk costs that cannot be used as collateral to the lender (Lev, 2000)[5]. The 2008 financial and economic crisis is likely to have exacerbated those factors. Campello, et al. (2010) surveyed 1,050 Chief Financial Officers in the U.S, Europe and Asia to evaluate the effects of the crisis on the corporate spending plans. They conclude that due to the credit tightening constrained firms planned deeper cuts in R&D spending. Similarly, Aghion et al. (2010) for a sample of 21 OECD countries argues that tighter credit constraints contribute to a more pro-cyclical share of long-term investment. As later demonstrated by Aghion et al. (2012), López-García et al. (2013) and Beneito et al. (2015) when firms are credit constrained the counter-cyclicality of R&D is reversed. Beneito et al. (2015) and López García et al. (2013) found that firms' R&D spending is countercyclical for Spanish firms. They aslo found that credit constraints may reverse this counter-cyclicality.

[5] 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).

Garicano and Steinwender (2014) indeed corroborated that shocks can reduce the value of long-term investments, relative to short-term ones and that firms are willing to give up some future expected payoffs in order to increase the probability of surviving another day. This translated to our concern would imply that during the crisis firms might have been more likely to favour the short-term nature of the export and hence to sell their products under decreasing domestic demand rather than the long-term and more uncertain and intangible nature of the R&D in their investment decision. Hence, we formulate the following:

HYPOTHESIS 3a: The crisis has increased the probability of engaging in export strategies.

If export and R&D are activities which reinforce one another, and during credit shocks the value of long-term investments is reduced relative to short-term ones, adding export when the firm is already performing R&D may be worthy, but not vice versa. Therefore, we formulate the following hypotheses about the presence of asymmetry in sequential adoption during the financial crisis:

HYPOTHESIS 3b: The crisis has reduced the probability that exporting firms embark on R&D strategies (sequential adoption from export to both), but not the probability that R&D firms embark on export strategies (sequential adoption from R&D to both).

Finally, empirical work analysing the relationship between firms' activities have generally followed two different approaches. The first approach detects synergies and adoption dynamics through the likelihood of adoption of various combinations of strategies (e.g. Battisti et al., 2015; Astebro et al., 2016; Cassiman and Veugelers, 2006; Fares, 2014). This is the approach we have used to define hypotheses 1 to 3. The second approach uses performance (either profitability or productivity) associated with the adoption status of two strategies (e.g. Kretschmer et al., 2012; Mohnen and Roller, 2005 or Golovko and Valentini, 2011), although with no attention to the adoption sequence eg. adopting export before R&D or R&D before export. An exception is the work of Peters et al. (2015) who find that in the case of Germany, exporting firms have a higher payoff from R&D investment and invest in R&D more frequently than firms that only sell in the domestic market. However, the opposite adoption sequence and hence the causal direction is not tested. In line with the performance based approach and to corroborate our research hypotheses, we explore the effects of different combinations of export and R&D strategies and their adoption order also on the firm's performance.

3. *DATA AND DESCRIPTIVES*

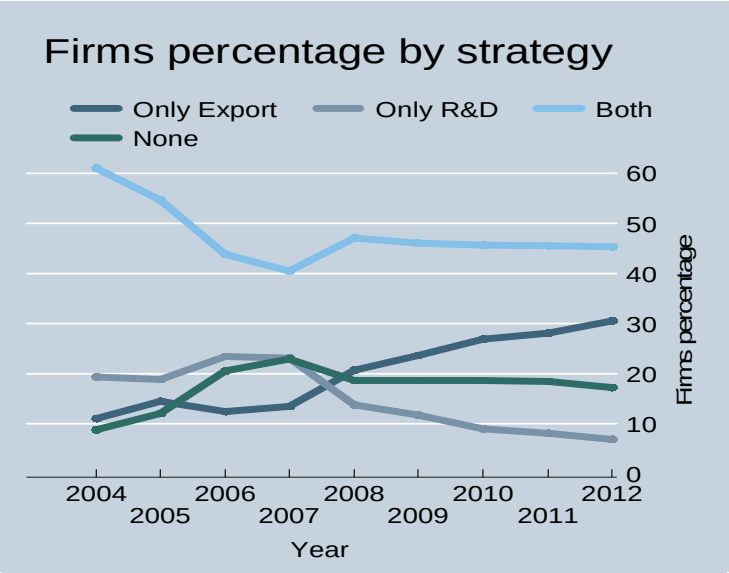
The dataset used in this study is the Spanish Technological Innovation Panel (PITEC). It represents the contribution of Spain to the Europe-wide Community Innovation Survey (hereafter, CIS) and is the result of the collaboration between the Spanish National Statistics Institute and COTEC Foundation with the aim of providing data to the CIS.[6] Different from many European Community Innovation Surveys, the Spanish CIS is a panel data covering the period 2004- 2013. The longitudinal dimension covers not only an entire business cycle but, of interest to us, also the years of the 2008 crisis. PITEC contains detailed firm level information on a number of firm characteristics such as ownership, number of employees and turnover. Importantly to us PITEC contains information on R&D and export behaviour over time. Firm level data on export and R&D is notoriously difficult to find. Datasets such as FAME, AMADEUS or ORBIS contain some information on exports, but very limited information on R&D. Hence, PITEC is deemed to be the best database for observing the adoption dynamics of R&D and Export strategies over time (Barge-Gil, 2010).[7] Our final working sample is an unbalanced longitudinal panel of 5,304 firms in 2004 reducing to 4,549 firms in 2013.

To investigate the firm's adoption strategy, we define four mutually exclusive variables ie.: firms that export and perform R&D (Both); firms that only export (Export only); firms that only perform R&D (R&D only); and firms that neither export nor perform R&D (None).

[6] See http://icono.fecyt.es/PITEC/Paginas/por_que.aspx for further details.

[7] PITEC contains information on both manufacturing and services companies. However, in this paper we concentrate on the sample of manufacturing firms. Exporting services may be completely different from exporting manufacturing goods since not all services are tradable, tangible or durable. Also, 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.

Figure 1. Distribution of firms by strategy (percentage of total)



Source: PITEC Survey, 2004-2013.

Figure 1 plots the percentage of Spanish firms in the sample that engage in 'Export only', 'R&D only', 'Both' and 'None' strategies between 2004 and 2013. While nearly half of the firms in the sample engage in both activities, the reduction in the percentage of firms that engage in 'R&D only' against an increase in firms that engage in 'Export only' is apparent. Also noticeable is the significant change in the proportion of firms that engage in either export and/or R&D strategies from 2008 onwards, which coincides with the beginning of the crisis. While the percentage of 'Export only' firms dramatically increases, the percentage of firms investing in 'R&D only' suffers an almost equally significant reduction. The proportion of firms that engage in both activities the largest in the sample, indicating that joint adoption is the most popular strategy. From about 60% its share has steadily declined until the 2008 crisis and has remained stable at around 45% since.

To gain a better insight into the adoption sequence we report in Table 1, 2 and 3 the transition probability matrices for the whole observation period (2004-2013), for the period before and after the 2008 financial crisis respectively. For each period the transition probability matrix shows the probability that a firm adopts a strategy t (reported in the top row), given its adoption status in t-1 (reported in the first column).

Table 1-Transition Probabilities (Whole period)

	Export only$_t$	**R&D only$_t$**	**Both$_t$**
None$_{t-1}$	13.82	5.58	1.86
Export only $_{t-1}$	76.22	1.41	11.71
R&D only $_{t-1}$	4.11	57.47	21.79

Source: PITEC Survey, 2004-2013

Table 2-Transition Probabilities (Pre-Crisis)

	Export only$_t$	**R&D only$_t$**	**Both$_t$**
None$_{t-1}$	6.75	7.42	2.18
Export only $_{t-1}$	65.79	2.96	15.28
R&D only $_{t-1}$	3.38	62.60	16.22

Source: PITEC Survey, 2004-2013

Table 3-Transition Probabilities (Post-Crisis)

	Export only$_t$	**R&D only$_t$**	**Both$_t$**
None$_{t-1}$	17.84	5.01	2.08
Export only $_{t-1}$	79.32	0.91	10.88
R&D only $_{t-1}$	4.92	51.08	30.19

Source: PITEC Survey, 2004-2013

Table 1 shows that it is far more likely that firms adopt 'Export only' ($E_t|None_{t-1}$= 13.82) rather than 'R&D only' strategies ($R\&D_t|None_{t-1}$ =5.58). As shown in column '$Both_t$ the likelihood to adopt R&D after Export ($Both_t|E_{t-1}$= 11.71) and export after R&D ($Both_t|R\&D_{t-1}$=21.79) are significantly higher than the likelihood to adopt both in time t ($Both_t|None_{t-1}$= 1.86). Hence, sequential adoption is more likely than simultaneous adoption, and the most likely adoption sequence is R&D first followed by Export second.

The transition matrices in table 2 and 3 indicate that since the crisis more firms have engaged in export rather than in R&D activities irrespective of the state of the firm in t-1 ($None_{t-1}$, Export only $_{t-1}$ or R&D only $_{t-1}$). As shown in the first row of the column '$Export\ only_t$', the probability to adopt an 'Export only' strategy Post-2008 is significantly higher than Pre-2008 ($E_t|None_{t-1}^{POST}$ =17.84 and $E_t|None_{t-1}^{PRE}$ = 6.75). The same applies to the decision to adopt an export strategy by R&D firms as shown in the last row of column '$Both_t$' ($Both_t|R\&D_{t-1}^{POST}$ = 30.19 and $Both_t|R\&D_{t-1}^{PRE}$=16.22). The opposite happens for R&D. Post-2008 the likelihood to adopt an 'R&D only' strategy by firms that in time t-1 adopted neither strategy is lower than Pre-2008 ($R\&D_t|None_{t-1}^{POST}$=5.01 and $E_t|None_{t-1}^{PRE}$=7.42, see '$R\&D\ only'_t$ column). A similar contraction can be observed in the probability that 'Export only' firms in time t-1, adopt also an R&D strategy in time t ($Both_t|E_{t-1}^{POST}$ =10.88 and $Both_t|E_{t-1}^{PRE}$ = 15.28). Contrary to the probability of sequential adoption, the likelihood to adopt both Export and R&D simultaneously remains low and almost unchanged before ($Both_t|None_{t-1}^{PRE}$ = 2.18) and after ($Both_t|None_{t-1}^{AFTER}$=2.08) the crisis.

Overall the transition matrix suggests that simultaneous adoption of two strategies is less likely than sequential adoption of any single strategy; the adoption sequence matters and it is not symmetric. It also shows that the impact of the 2008 crisis has significantly affected the likelihood of the adoption sequence and hence, the strategic choice of the firms.

Table 4 reports the preliminary analysis of the differences in firm performance, measured as sales per worker (in euros), for the various adoption strategies and also depending on their adoption sequence.

Table 4-Test of the differences in the firm performance (sales per worker in €) from export and R&D strategies.

	Difference		
	Whole period	**Pre 2008**	**Post 2008**
Individual adoption			
Export only vs None	66,800.44***	64,833.31***	68,418.51***
R&D only vs None	29,392.34***	20,301.35***	41,872.77***
Export only vs R&D only	37,408.10***	44,531.96***	26,545.75***
Joint adoption			
Both vs None	84,031.2***	67,274.28***	97,589.87***
Sequential adoption			
Both vs Export only	17,230.76***	2,440.971	29,171.36***
Both vs. R&D only	54,638.86***	46,972.94***	55,717.11***

*Source: PITEC Survey, 2004-2013*** Significant at 1% level*

The results suggest that firms that perform 'R&D only', 'Export only' or 'Both', have significantly higher performance than firms that do engage in neither strategy with 'Both' being clearly the most rewarding. They also suggest that embarking on 'Export only' generates higher performance than embarking on 'R&D only'. The greater impact of the export strategy is also visible when comparing individual versus sequential adoption. The performance associated with the adoption of export strategies by R&D companies (Both vs R&D only) is higher than the performance generated by the adoption of R&D strategies by export companies (Both vs Export only) indicating a clear asymmetry in the performance from the adoption sequence. Indeed, the joint adoption of both strategies (Both vs None), is the most rewarding strategy irrespective of the adoption sequence (whether sequential or simultaneous). After the crisis, the returns from the adoption of export strategies are consistently higher across the board.

4. ***MODELLING AND VARIABLES***

4.1 **Methodology**

To test the first three hypotheses concerning the decision to embark on R&D and/or export strategies by firm i in time t, we use discrete choice models for panel data of the type

$$Y^{*j}_{it} = \beta X'_{It} + u^{j}_{it} \quad (1)$$

where the dependent variable (Y^{*j}_{it}) is a latent (unobservable) variable representing the increase in the relative discounted utility derived from adopting each one strategy j = Export, R&D and X_{it} is a vector of explanatory factors. As this variable is unobservable to us we allow the dependent variable to be proxied by a binary variable (y^{j}_{it}) that takes value one if the relative utility associated with the strategy is positive, namely:

$$y^{j}_{it} = 1 \text{ if } Y^{*j}_{it} > 0$$
$$y^{j}_{it} = 0 \text{ if } Y^{*j}_{it} < 0$$

By using a probabilistic approach we test if the prior adoption decision of any one strategy leads to a posterior increase in the likelihood of adoption of the strategy under consideration. In particular, to test for the presence of sequential adoption (H1) we introduce in the regression equation a lagged term (y^{r}_{it-1}) aimed at modelling any increase in the likelihood of adoption of any one strategy j associated with the previous adoption of strategy r, $r \neq j$, eg if the prior adoption of R&D (Export) increases the probability of adoption of Export (R&D) strategy.

In order to test the first hypothesis concerning the presence of sequential adoption and the direction of the adoption sequence while taking into account the potential simultaneity in the firms' decisions to export and/or to perform R&D, we estimate a bivariate probit. This specification accommodates both R&D and Export adoption dynamics by including past R&D and export status when explaining the current probability to export (perform R&D).

We estimate the biprobit model by maximum likelihood assuming a Normal non-linear cumulative distribution function as well as random effects. Although the fixed effect model would have had the advantage of allowing the explanatory variables to be correlated with the individual effects, it would have had the shortcoming of eliminating a large number of observations. To allow the individual effect to be correlated with the regressors, we apply the Mundlak (1978) approach. Following this method, we proxy the individual effects by the

individual mean of the time-varying covariates allowing for correlation between the individual effect and the observed characteristics. [8]

$$y_{i,t}^{j} = \begin{cases} 1 \; if \; \theta_0^{Export} y_{i,t-1}^{Export} + \theta_1^{R\&D} y_{i,t-1}^{R\&D} + \beta^j X_{it} + z_t + s_i + \varepsilon_{it}^{j} \geq 0 \\ 0 \; Otherwise \end{cases} \qquad (2)$$

Where θ_0^{Export} and $\theta_1^{R\&D}$ are the marginal impacts associated with the adoption status of firm i at time t-1, β_{it} is the vector of the marginal impacts of the control variables X_{it}, z_t is the usual vector of years, s_i is the vector of the industry dummies and ε_{it} is the error term.

Due to interdependences in the export and R&D decisions the error terms of the two equations are likely to be correlated. Hence, following Battisti et al. (2015) we use a bivariate probit that we estimate via the maximum likelihood. The resulting latent bivariate model is specified as:

$$\begin{cases} y_{i,t}^{Export} = \theta_0^{Export} y_{i,t-1}^{Export} + \theta_1^{R\&D} y_{i,t-1}^{R\&D} + \beta^{Export} X_{it} + z_t + s_i + \varepsilon_{it}^{Export} \qquad (3a) \\ y_{i,t}^{R\&D} = \theta_0^{Export} y_{i,t-1}^{Export} + \theta_1^{R\&D} y_{i,t-1}^{R\&D} + \beta^{Export} X_{it} + z_t + s_i + \varepsilon_{it}^{R\&D} \qquad (3b) \end{cases}$$

Because one of the purposes of the study is to analyse the sequential adoption between export and R&D (H1), special attention will be paid to the significance of the previous adoption status via the significance of θ_0^{Export} in the R&D adoption strategy equation and $\theta_1^{R\&D}$ in the Export adoption strategy equation.

This is the model we use to test H1 and H2 as it allows us not only to test for the presence of sequential adoption and the direction of the adoption sequence, by analysing the significance of the R&D status in *t-1* in the export decision equation 3a ($\theta_1^{R\&D}$) and the significance of the export status in *t-1* in the R&D equation (θ_0^{Export}), but also the presence of simultaneous adoption by checking the significance of the correlation coefficient between the residuals of the export and R&D equations (ρ). Finally, we test for the presence of any significant shift in

[8] Besides Mundlak (1978), the Blundell et al. (1999) approach was also tested. This approach controls for correlated unobserved firms' heterogeneity adding the presample means of the dependent variables as a substitute of the fixed effects. We do not report those estimates as (at least) two years are needed to calculate the pre-sample means, and one year for the lagged dependent variable. Hence, 3 years of observations would be lost and the sample would have started in 2007, leaving only one year of observations before the crisis.

the adoption strategy before and after the crisis (H3a and b) via a series of interactions with a step dummy variable taking value one form 2008 onwards.

To corroborate the results obtained through the nonlinear specifications of the probabilistic models, we use a performance based approach to explore the effects of the various combinations of strategies on firms' growth. Hence, the estimating equation:

$$Growth_{it} = \theta_0^{Export} y_{i,t}^{Export} + \theta_1^{R\&D} y_{i,t}^{R\&D} + \theta_2^{NONE} y_{i,t}^{NONE} + X_{it}\beta + u_t + s_i + \epsilon_{it} \qquad (4)$$

where $\theta_0^{R\&D}$, θ_1^{Export} and θ_2^{NONE} identify the effects of the strategic status in time t-1 on the firms' growth where,[9] X_{it} is a vector of control variables that might affect firms' growth, u_t is a vector of year dummies, s_i is a vector of industry dummies and ϵ_{it} is a disturbance that may be autocorrelated along *t* or contemporaneously correlated across *i*.[10]

4.2 Variables

In the probabilistic models (Hypothesis 1, 2 and 3) our dependent variable $y_{i,t}^{j}$ is a dummy variable taking value one if the firm engages in strategy j = 'Export', 'R&D', and zero otherwise. In the performance models, following Golovko and Valentini (2011) our dependent variable is the firm's real sales growth in time *t* with respect to *t-1 (*$Growth_{it}$*)*.[11]

In either case, we include as controls, a series of variables commonly used in the related literature, such as *Size* measured as the logarithm of the number of employees. Large firms usually have larger internal funds than SME and have better access to financial markets (Damijan and Kostevc, 2011). SME are usually more risk averse, which may make them more reluctant to external debt to finance exporting or innovation ventures.[12] Finally, large firms may enjoy economies of scale, which would allow them to increase the profitability of export and innovative activities. Hence, a positive effect of size on the probability of export and/or performing R&D is expected. *Foreign* participation is also included as it is expected to facilitate the internationalisation strategy. The costs to enter foreign markets might be lower

[9] In the bivariate probit models the dependent variable for export (R&D) include those that export only (do R&D only) and those that do both. In the growth model the strategies are singled out as Export only, R&D only, Both, None.

[10] The control variables used in these regressions are the same than those used in the nonlinear models.

[11] We use as a deflator the producer price index from Instituto Nacional de Estadística (www.ine.es).

[12] As can be seen in Bernard et al. (2007), Eaton et al. (2008), and Damijan et al. (2010), while large firms usually export to many countries and a large number of products, small firms usually only export to one or two countries and a small number of products, being then more vulnerable to foreign market failure.

for foreign-owned firms due to the benefits from networks and other resources of the parent company (Kneller and Pisu, 2007), while leaving open the R&D strategy. The demand condition of the industry the firms belong to is also included via the variable *Industry conditions*. We also use as control variables two variables that reflect internal and external financial constraints, *"Lack of internal funds"* and *"Lack of external funds"*. Performing export activities carries a higher risk - compared to domestic sales -, associated with fluctuations in exchange rates or the reinforcement of contracts (Wagner, 2014). In the case of R&D, the existence of imperfect capital markets hinders the uptake of funding by companies to carry out investments, especially if it comes to investment in R&D. On the contrary, a contraction in demand could lead the firm to look overseas to place its products. We expect both demand and financial constraints to affect and moderate the decision to change strategy. Industry and year dummies are used in all regressions. Table 5 provides detailed information on all the variables involved in the estimations.

Table 5-Variables definition

DEPENDENT VARIABLES	
Bivariate Probit Model	
Y^{Export}	Dummy variable that takes value 1 if the firm export in t.
$Y^{R\&D}$	Dummy variable that takes the value 1 if the firm has any expenses on internal or external R&D in t.
Growth Model	
Growth	Log ($sales_t/sales_{t-1}$)
EXPLANATORY VARIABLES	
Size	Logarithm of the number of employees.
Foreign	Dummy variable equal to 1 if a firm has a foreign participation lower than 50%
Internal	Internal financial constraints. It takes the value 1 if the answer to the question "*asses the importance of lack of internal funds hampering innovation*" is high.
External	External financial constraints. It takes the value 1 if the answer to the question "*asses the importance of lack of external funds hampering innovation*" is high.
Industry conditions	Log of the mean turnover by industry and year.
C8	Dummy variable equal to 1 for years after 2007.

Source: PITEC Survey, 2004-2013

5. RESULTS

Simultaneous versus sequential adoption and adoption sequence

In table 6 we report the results of the biprobit model used in modelling the probability to adopt the various combination of R&D and Export strategies. Column 1 in Table 6 shows the significant positive effect of the decision to export by firms already performing R&D ($\theta^{R\&D}$= 0.255), while the effect of the decision to perform R&D by firms already exporting can be found in column 2 ($\theta^{E} = 0.272$). Jointly the two results confirm the significance of sequential adoption (H1), with the adoption of R&D strategy being slightly more likely that the reverse (H2). To control for unobserved heterogeneity and as a robustness check, following Mundlak (1978), the individual mean of the time-varying covariates are included as explanatory variables (see model 2 in table 6). This technique was proposed as a way to relax the assumption that the observed variables are uncorrelated with the unobserved variables. The results are consistent across the two models.

Table 6-Biprobit model estimations for the export and R&D decisions

	Model 1		Model 2 Mundlak correction		Model 3		Model 4 Mundlak correction	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Export	R&D	Export	R&D	Export	R&D	Export	R&D
$Export_{t-1}$	**2.045*** **	**0.272*** **	**2.045*** **	**0.271*** **	**2.006*** **	**0.300*** **	**2.008*** **	**0.303*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
$R\&D_{t-1}$	**0.255*** **	**2.238*** **	**0.250*** **	**2.233*** **	**0.284*** **	**2.054*** **	**0.282*** **	**2.054*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
C8					**0.605*** **	**-0.098*** **	**0.621*** **	**-0.071***
					(0.000)	**(0.010)**	**(0.000)**	**(0.065)**
$C8*Export_{t-1}$					0.008	**-0.076** **	0.006	**-0.080** **
					(0.831)	**(0.018)**	(0.863)	**(0.013)**
$C8*R\&D_{t-1}$					-0.028	**0.256*** **	-0.033	**0.249*** **
					(0.398)	**(0.000)**	(0.321)	**(0.000)**
Size	**0.147*** **	**0.177*** **	**0.200*** **	**0.310*** **	**0.150*** **	**0.173*** **	**0.216*** **	**0.302*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Foreign	0.068	0.032	-0.102	**-0.115***	0.062	0.033	-0.108	-0.115
	(0.281)	(0.581)	(0.172)	**(0.097)**	(0.327)	(0.574)	(0.144)	(0.101)
Internal	0.007	**-0.040***	**0.046***	0.015	0.004	**-0.038***	0.041	0.020
	(0.749)	**(0.068)**	**(0.086)**	(0.596)	(0.831)	**(0.081)**	(0.120)	(0.488)
External	0.026	**0.091*** **	-0.013	0.013	0.025	**0.090*** **	-0.011	0.009
	(0.233)	**(0.000)**	(0.629)	(0.649)	(0.249)	**(0.000)**	(0.668)	(0.739)
Industry conditions	0.006	0.022	0.013	0.023	**0.200*** **	**0.161*** **	**0.195*** **	**0.147*** **
	(0.897)	(0.705)	(0.793)	(0.688)	**(0.000)**	**(0.002)**	**(0.000)**	**(0.005)**
Mean Size			**-0.057** **	**-0.137*** **			**-0.070*** **	**-0.134*** **
			(0.031)	**(0.000)**			**(0.007)**	**(0.000)**
Mean Foreign			**0.495*** **	**0.399*** **			**0.498*** **	**0.404*** **
			(0.000)	**(0.002)**			**(0.000)**	**(0.002)**
Mean Internal			**-0.100** **	**-0.149*** **			**-0.093** **	**-0.157*** **
			(0.026)	**(0.001)**			**(0.036)**	**(0.001)**
Mean External			**0.106** **	**0.212*** **			**0.099** **	**0.220*** **
			(0.022)	**(0.000)**			**(0.030)**	**(0.000)**
Mean Industry conditions			**-0.090***	**-0.143*** **			**-0.097** **	**-0.158*** **
			(0.054)	**(0.004)**			**(0.036)**	**(0.002)**
Constant	-1.634**	-2.396**	-0.245	-0.065	-5.428***	-4.619***	-3.703***	-1.778
	(0.039)	(0.011)	(0.821)	(0.957)	(0.743)	(0.871)	(0.000)	(0.119)
Residual. Correlation	ρ =0.14		ρ = 0.14		ρ = 0.13		ρ = 0.13	
	(s.e. = 0.013)		(s.e. = 0. 013)		(s.e. = 0.013)		(s.e. = 0. 013)	
LR test ρ = 0	$\chi^2(1)$ = 114.103		$\chi^2(1)$ = 110.442		$\chi^2(1)$ = 97.488		$\chi^2(1)$ = 93.871	
Log-likelihood	-32640.44		-32594.44		-32900.62		-32851.46	
Nº observations	46,792		46,792		46,792		46,792	
	(6,512 firms)		(6,512 firms)		(6,512 firms)		(6,512 firms)	

*Note:Robust p-values in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Source: PITEC Survey, 2004-2013*

In order to quantify how likely is a firm to engage in simultaneous versus sequential adoption (H1) and also to compare the likelihoods of the various adoption strategies we calculate the predicted probabilities of performing both activities in t depending on the export and R&D strategies undertaken by firms in t-1, and then run a test of differences in the predicted probabilities for baseline firms.[13] That is, we explore how the probability of performing both

[13] In nonlinear models the estimated coefficients are not the marginal effects and the interpretation of marginal effects of dummy variables is not very meaningful. That is why it is more appropriate explaining the difference in probabilities of performing both activities in t depending on the firm status in t-1 in terms of probabilities rather than through the marginal effects.

activities in t changes when a firm was only exporting in t-1 comparing with those that were only performing R&D in t-1, or how does the probability of performing both activities in t change when the firm was only exporting in t-1 comparing with those that were neither exporting nor performing R&D in t-1, etc.[14]

The test of the differences is reported in the first column of Table 7 and confirms the previous findings. Firstly, the probability of performing both activities in time t given that the firm was either only exporting or only performing R&D in t-1, is higher than the probability of performing both activities when the firm was neither performing R&D nor exporting (see Export only$_{t-1}$ vs None$_{t-1}$=10.76 and R&D only$_{t-1}$ vs None$_{t-1}$=19.39 in Table 7) and hence, the greater likelihood of sequential adoption with respect to joint adoption (H1). Secondly, it is more likely that R&D firms start engaging in export rather than the opposite (R&D only$_{t-1}$ vs Export only$_{t-1}$=8.62), confirming not only the importance of sequential adoption but also that the adoption order matters (H2).

Table 7-Test of differences in the probability of performing both activities in t by export and R&D strategies undertaken by firms in t-1 (percentage points)

	Difference (percentage points)		
Sequential Vs Simultaneous adoption	***Whole period***	***Pre 2008***	***Post 2008***
Export only$_{t-1}$ vs None $_{t-1}$	10.76***	11.89***	10.36***
R&D only $_{t-1}$ vs None $_{t-1}$	19.39***	12.09***	26.42***
Sequential adoption order			
R&D only $_{t-1}$ vs Export only $_{t-1}$	8.62***	0.20	16.05***
Nº observations (6,512 firms)	45,179	12,602	32,577

*Note: *** Significant at 1% level; Source: PITEC Survey, 2004-2013*

The impact of the crisis

In order to check whether the crisis has had any effects on the export intensity (H3a) and on the likelihood of adoption of export and R&D (H3b), we use the level and the interaction terms between the *previous status variables* (*Export$_{t-1}$* and *R&D$_{t-1}$*) and a dummy variable that takes value 1 for the years beyond 2007 (*C8*). The interaction term should pick up the effects of the deepening of the crisis depending on the adoption status and hence any induced asymmetries in the adoption sequence. The results are presented in model 3 and 4 in Table 6.

[14] Table 7 is an improvement from Table 1 as it takes into account the fact that the adoption decisions are correlated and also we control for a number of covariates.

Starting with model 3, our estimates for previous adoption status ($Export_{t-1}$ and $R\&D_{t-1}$) are consistent with the findings of model 1 and 2. They maintain their expected signs and significance in both the export and R&D equations. We find evidence in support of H3a that overall, the impact of the crisis has increased the likelihood to export ($\beta^{C8} = +0.605$), although not that of the likelihood to carry out R&D ($\beta^{C8} = -0.098$).

The interaction terms are significant only in the R&D equation ($\beta^{C8*Export} = 0.256$), indicating that the impact of the crisis has slightly increased the persistence of R&D strategies, hence reducing the probability of their dismissal. At the same time, it has decreased the likelihood of sequential adoption of R&D for firms that already carried out export strategies ($\beta^{C8*Export} = -0.076$). We find that the crisis has also made the R&D strategy more persistent (+0.256) increasing the likelihood that, despite the hardship of the crisis, R&D is not dismissed. Also in this case we apply the Mundlak approach (see model 4 in table 6) and the results are unchanged. In summary, since 2008, the likelihood of exporting has increased but not that of doing R&D. Although firms are less likely to dismiss existing R&D strategies, they are less likely to adopt R&D if they are already exporting, providing evidence of asymmetry in the adoption decision, with the adoption of Export strategies after R&D more likely than its opposite (H3b).

In order to further explore the possible impact of the crisis upon the adoption decision, we repeat the test of differences in the predicted probabilities over the partition of the sample before and after the crisis. The results are reported in Table 7 and indicate that the probability of performing both activities in t by R&D firms ($R\&D\ only_{t-1}$) with respect to firms that did not previously engaged in any activity ($None_{t-1}$) was 12.09% before the crisis, increasing to 26.42% after the crisis. Hence, the crisis doubled the likelihood to adopt an export strategy by existing R&D firms rather than be adopted simultaneously with R&D. The same cannot be said about the adoption of R&D. Although, they were more likely to be adopted sequentially rather than simultaneously their likelihood of adoption slightly decreased from 11.89% to 10.36% after the crisis. The crisis has made the adoption of the export strategy by R&D firms 16% more likely than the adoption of the R&D strategy by export firms. Therefore, in line with hypothesis 3a, we find that the crisis has increased the likelihood to export more than the likelihood to carry out R&D and this applies across all joint adoption strategies.

Across model specifications we find evidence of size effects to be more prominent for R&D than for Export strategies, while demand side effects are more significant for Export strategies. As expected, larger firms (*size)* and favourable industry conditions (*industry conditions*) or

sustained firm specific demand (firm demand), significantly affect the firm strategy. Large firms are more likely to engage in R&D than in export strategies. Finally, we also found weak evidence that internal financial constraints negatively affect the decision to do R&D, but not that of exporting.

In all regressions, the estimated correlations (ρ) between the residuals of export and R&D equations are positive and significant. This confirms the simultaneity of firms' export and R&D investment decisions and hence the need to jointly estimate the two decisions when analysing the factors affecting the probability of performing any of both activities (simultaneous adoption).

The analysis of the results presented in this section shows that although export positively affects the likelihood of sequential adoption, the crisis has changed the strength of this sequentiality (H3b). From 2008 onwards, the likelihood of investing in R&D by exporting firms has decreased while the probability of exporting has increased across the board and independently of the previous status. That is, the crisis has encouraged internationalization more than innovation. The conclusions are unchanged when the crisis effect is analysed for each, individual and combined, strategy in isolation. In line with hypothesis 3b, the probability of start performing R&D when the firm was already exporting has decreased, whereas the probability of exporting when the firm had already invested in R&D has increased. Once again, we find that there is reinforcement from only R&D to R&D plus export, but not from only export to export plus R&D.

5.1 **Growth regressions**

Further to the probability approach we use a profitability based approach to test the returns to the various adoption strategies, alongside the presence of any changes that the crisis has generated in this relationship. Following Love et al. (2014), we set up the strategy-switch possibilities which will allow us to analyse the extra gains (if any) of sequential and simultaneous adoption. For this purpose, we define the variables '*Export to Both'* and '*R&D to Both'* taking on value 1, if the firm followed the indicated adoption sequence and zero otherwise. We also define the variable '*None to Both*' for those firms that adopted Export and R&D simultaneously. We also define the variable '*R&D to R&D*' and '*Export to Export'* for those firms that were only performing one and continue to perform only one activity.

In this way we can analyse not only whether sequential has a stronger effect on sales growth than simultaneous adoption, but also whether there exists a difference between adding export

when the firm was already performing R&D or adding R&D when the firm was already exporting (asymmetries in sequential adoption). The results of the heteroschedasticity corrected fixed effect panel data are reported in Table 8.

Table 8-Estimations for firms' growth depending on previous status

	(1)	(2)	(3)
VARIABLES	**Whole Period**	**Pre-2008**	**Post-2008**
Sequential adoption			
Export to Both	**0.021***	-0.008	**0.034*****
	(0.052)	(0.749)	**(0.003)**
R&D to Both	**0.045*****	0.044	**0.043*****
	(0.000)	(0.168)	**(0.000)**
Simultaneous adoption			
None to Both	0.015	0.101	-0.015
	(0.714)	(0.203)	(0.709)
Export to Export	-0.001	**-0.019***	0.006
	(0.911)	**(0.068)**	(0.323)
R&D to R&D	**0.044*****	**0.069*****	0.012
	(0.000)	**(0.000)**	(0.250)
Controls			
Size	**0.024*****	**0.011*****	**0.030*****
	(0.000)	**(0.002)**	**(0.000)**
Foreign	0.004		-0.003
	(0.752)		(0.812)
Internal	**-0.031*****	**-0.025*****	**-0.034*****
	(0.000)	**(0.004)**	**(0.000)**
External	0.004	0.008	0.003
	(0.494)	(0.383)	(0.660)
Industry conditions	**0.095*****	**0.246*****	**0.072*****
	(0.000)	**(0.001)**	**(0.003)**
Constant	**-1.757*****	**-4.498*****	
	(0.000)	**(0.001)**	
Observations	46,258	16,538	29,720
R-squared	0.050	0.011	0.059
Number of firms	6,386	6,206	5,768

*Note:Robust p-values in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Source: PITEC Survey, 2004-2013*

As can be seen in column 1, there are significant gains attached to the sequential adoption decision. *'Export to Both'* and *'R&D to Both'* are positive and significant while *'None to Both'* is not significant, corroborating the two conclusions reached with the probabilistic approach: the higher importance of sequential rather than simultaneous adoption (H1) and the higher returns associated with the adoption of export strategies after R&D (H2).

These results are partly in line with the finding of Peters et al. (2015), suggesting that in the case of Germany, exporting firms have a higher payoff from R&D investment. However,

contrary to Peters et al (2015), we find that such effect is significant only when strategies are adopted sequentially (from 'Export only' or from 'R&D only' to 'Both') rather that simultaneously ('None' to 'Both'). We also find that the adoption order matters and that there are asymmetries in sequential adoption. Adopting R&D first and Export strategies second can generate higher growth than the opposite.

This effect is amplified when we split the sample to assess the effect of the crisis on the adoption decision (see column 3 and 4 in table 8). Before the crisis, R&D firms were benefiting from higher growth, while after the crisis performing both activities was clearly the most valuable strategy, confirming the importance of exploiting the existing synergistic effects between export and R&D with the adoption sequence R&D first and export second (R&D to both) being the most rewarding adoption strategy (H3b). These findings are consistent with the probabilistic approach to the analysis of the two adoption sequences.

In line with the probabilistic approach and irrespective of the strategy, we also find that the size of the firm affects the size of the returns. Industry conditions as well as internal liquidity constraints affect the returns from the adoption of the various strategies although in opposite directions. Industry conditions, are a significant driver of the adoption decision while internal liquidity constraints can significant reduce the expected returns from the various adoption strategies.

6. CONCLUDING REMARKS

The paper sheds more light on the synergies between export and R&D, and for the first time explores the direction of their adoption sequence. It also explores the impact that the 2008 crisis has had in this relationship. The results obtained are manifold. First, a positive association between these two activities is detected, irrespective of the specification and the model used confirming that exporting positively affects the probability of performing R&D (and vice versa). We also find that, when joint adopted, the two strategies are more profitable than when only one of them is adopted, confirming the finding of the existing literature. Moreover, in line with our research hypotheses, we find that their *sequential* adoption is significantly more likely and it is associated to higher growth than when the two strategies are adopted *simultaneously*. We also find that the *adoption sequence* matters. Adopting R&D first and export second is more likely and it is associated to higher growth than the opposite. Our

results also reveal that the 2008 crisis has changed the strength of this relationship. During this period the likelihood to start exporting doubled while that of doing R&D remained almost unchanged affecting not only the likelihood of joint adoption but, interestingly to us, also that of sequential adoption. While firms performing R&D became even more likely to start exporting, an increasing number of exporting firms did not perform R&D, reinforcing the asymmetry in the adoption sequence. These results are confirmed not only by the probability of performing any of the activities but also by the size of the firms' growth associated with the various strategies.

Our findings contribute to the understanding of the synergies between two of the most important strategies acknowledged to improve firms' performance and, therefore, economic growth. They highlight that export strategies should go hand in hand with R&D strategies to maximise growth and to maintain the strategic competitive advantage with direct consequences on aggregated country productivity and long-term growth. Policies oriented at export strategies alone while could be beneficial in the short term, they could also expose firms to low-cost competition based on volumes and thinner margin of profits and limited resources to devote to R&D with dangerous lock in effects. For those firms, the lack of R&D could also significantly diminish their absorptive capacity, including the capability to exploit the learning by exporting effect. Hence, we argue that policy should not promote single handed measures facilitating either the international growth of firms or their R&D capability independently of each as higher gains can be generated when they are jointly adopted. Moreover, as the evidence suggests that the adoption order matter and that the highest gains are obtained when export strategies are built on a robust knowledge base, promoting the adoption of R&D first and the adoption of export strategies among firms performing R&D seems to be highly desirable.

Finally, policies aimed to help firms to enter the virtuous circle between export and innovative activities during a periods of crisis, should take into account that firms may prefer to find new customers for their goods to compensate for their drop in demand (sales) and hence *survive one more day* rather than committing to the R&D long term investments and uncertain outcomes. In the long run this could have detrimental effects. The promotion of international activities without the appropriate knowledge base and the absorptive capacity would allow firms to survive in a hardship period but does not guarantee a sustainable comparative advantage in the long run. Identify and analyse the sequence of adoption is a key aspect that will help to achieve the goal.

Even though the results of the study support the view that sequential adoption is more likely than simultaneous adoption, we know very little about their drivers. Similarly, we have explored the changes in the sequential adoption due to the crisis, but our knowledge of the channels causing these switches is very limited and they are a fertile ground for future research.

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