R&D Expenditures and Geographical Sales Diversification

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Abstract

This paper empirically examines the role of diversification in export markets on firm-level R&D activities taking account of the potential endogeneity in this relationship. We show that geographical sales diversification across different regions of the world induces UK firms to increase their R&D expenditures, as firms must innovate and develop new products to maintain a competitive edge over their rivals. This finding is robust to a battery of sensitivity checks. Furthermore, we find no evidence of reverse causality between R&D and sales diversification.
(JEL Classification Numbers: G31, G32, C24)

Key words: R&D investment, Exports, Geographical diversification, Instrumental variables Tobit

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Abstract

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1. Introduction

Firms face ever-increasing competition from globalization and e-commerce as their competitors may more easily establish a presence in both domestic and foreign markets. Competition, in an environment which is generally characterized by global supply chains, strengthens the importance of innovation in product development as well as efficient production. In this context innovation often emerges as an outcome of research and development (R&D) activities and plays a vital role in maintaining firms' profitability and their competitive edge in a globalized market.[2]

It has long been recognized that R&D activities bring additional intangible benefits which may help firms overcome barriers to exporting.[3] In particular, given the availability of detailed firm-level data on export sales, researchers have begun to investigate the linkages between R&D expenditures and firms' export behavior. Yet, this line of research has mostly focused on the question of whether R&D affects firms' exports. However, as Harris & Moffat (2011) suggest, exporting does not require prior R&D innovation. It is also recognized that exporting firms may access strategic knowledge, as exporting allows them to improve their innovative capacities.[4]

In this paper, in contrast to much of the literature, we hypothesize that firms operating in diversified export markets are more likely to engage in R&D activities. According to Porter (1990), innovation can help a firm achieve a competitive advantage in international markets over potential competitors. Kotabe (1990) suggests that multinational firms may have better access to global resources to enhance their innovative capabilities.[5] In particu-

[2]See Acs & Audretsch (1988), Mairesse & Mohnen (2005).

[3]See, for instance, Cohen & Levinthal (1989), Teece & Pisano (1998), and Harris & Li (2009).

[4]See, for example, Bishop & Wiseman (1999) and Blind & Jungmittag (2004).

[5]Research has also shown that multinational companies are more susceptible to agency costs, as monitoring of such companies is more challenging. Doukas & Pantzalis (2003) document that the effects of agency

lar, having access to a wider customer base may encourage a firm to innovate via increased R&D activities, as innovation allows the company to achieve strategic competitiveness. Nevertheless, the literature on the potential association between export market diversification and R&D activities is meager. To our knowledge, the only study is by Hitt et al. (1997) which investigates the linkages between innovation and firm performance, focusing on a cross section of 295 large US firms. They show that an entropy-based measure of international diversification has a positive effect on R&D intensity, measured as expenditures per employee (p. 785, Table 3).[6] However, most of the papers in this genre focus on the effects of R&D activities on firm performance rather than the role of export market diversification on R&D expenditures.[7]

To investigate the effects of export sales diversification in different export markets on firms' R&D activities, measured by the ratio of R&D expenditures to total assets, we construct a large unbalanced panel of UK quoted manufacturing firms obtained from the Extel Financials database produced by Thomson Financial. The dataset provides us information on firm-specific variables on an annual basis over 1990–2008 for 19 industry classifications for which we have 3,880 observations. Our empirical model takes into account several firm-specific factors including the effects of foreign productive assets, size, leverage, cash holdings,

costs on long term debt are exacerbated by the degree of firms' foreign involvement (p. 89). Some researchers suggest global diversification can reduce shareholder wealth (e.g., Denis et al. (2002)), while Doukas & Kan (2006) argue against this claim.

[6]Hitt et al. (1997) use averages of the data over 1998–1990 to smooth annual fluctuations in observed variables; see p. 778.

[7]Researchers have studied the effects of international diversifications on stock market valuation of firms: Dos Santos et al. (2008) find that a significant valuation discount applies to product diversification but not to international diversification. Ursacki & Vertinsky (1992) suggest that multinational banks may benefit from broadening the geographical scope of their business.

new equity issuance and cash flow to control for firm heterogeneity.

In examining the role of export sales diversification on R&D expenditures, we specifically consider the impact of firm-level export sales in different regions of the world. To do this we construct two diversification measures which are commonly used in the literature: the Herfindahl–Hirschmann concentration index and an entropy-based index. These two measures allow us to quantify the market presence of the firm in the rest of the world. Our dataset includes firm-level exports to four broadly defined regions: Europe, the Americas, the Middle East and Africa, and Asia and Australia. We calculate firm-specific diversification indices for each measure to test our hypothesis that as a firm exports to regions beyond its home region—i.e., the more diversified is a firm in its export sales—the firm must be involved in more innovative activities to be competitive in that wider range of markets. In doing so we expect to find that a UK firm exporting to the rest of the world other than its home market will increase the scale of its R&D activities, while the firm that focuses on sales in the home region will not necessarily do so. Our reasoning for this behavior is that a product that is suitable for the domestic market and those of nearby countries may not be as attractive to those customers more distant from the domestic market, requiring the firm to initiate or increase the scale of R&D activities.

In estimating the impact of export market diversification on R&D expenditures, one must carefully account for the bias that could be introduced due to the presence of zero values of R&D expenditures as well as that could arise due to endogeneity of the diversification measure. Our dependent variable, the ratio of R&D expenditures to total assets, is bounded by zero. Linear regression techniques do not respect that lower bound, nor do they take into account the likelihood that a firm may not choose to engage in R&D activity. To overcome these difficulties—the bias that can arise due to the presence of endogenous variables in our model as well as the presence of zeros—we employ the instrumental variables Tobit model, estimated by maximum likelihood. We check for the validity of our instruments by implementing an overidentification test.

Our empirical findings provide evidence that export market diversification has a positive impact on R&D activities of firms. More specifically, we find that both the Herfindahl–Hirschmann concentration index and the entropy-based measure exert a positive and significant effect on firms' R&D expenditures. Our model also shows that the financial strength of a firm, captured through its stock of cash, net equity issuance, foreign productive assets as well as its size, positively affect R&D expenditures. To examine the sensitivity of our results, we implement a battery of additional specifications. We initially show that the use of a dynamic partial-adjustment framework, allowing R&D expenditures to evolve in a smooth path, does not alter our findings about the importance of diversification on R&D expenditures.[8] We next entertain the possibility that our results may reflect reverse causality: that is, R&D-intensive firms may be more diversified in their choice of export markets.[9] Our investigation reveals that there is no evidence of reverse causality. Finally, we subject our findings to two additional robustness tests. The first specification considers only R&D-intensive firms as we consider the bidirectional examination of this relationship, and the second specification separates home (UK) sales from exports to other European markets. Results from these additional sensitivity checks provide further support to our hypothesis that diversification induces firms to carry our more R&D expenditures.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature. Section 3 presents the model and describes our data. Section 4 provides the empirical results and Section 5 concludes.

[8] See for instance Hall, Bronwyn H. (2002) and Hall, Bronwyn H. & Lerner, Josh (2009) who argue that firms' R&D expenditures are smoothed to maintain their stability.

[9] There is significant research that examines the role of R&D expenditures on exports which has shown that R&D expenditures facilitate firms' entry into export markets. See Harris & Moffat (2011) for an extensive review of this literature.

2. Literature Review

It is well documented in the literature that in an imperfectly competitive market, an R&D–active firm can innovate, increase its productivity and gain a competitive edge over its rivals in the domestic and foreign markets.[10] As detailed data on firm-level exports and R&D expenditures have became available, empirical researchers have provided more detailed account of the linkages between R&D expenditures, productivity and exports. For instance, researchers using data from several countries, including Sterlacchini (2001), Bleaney & Wakelin (2002), Barrios et al. (2003), Ozcelik & Taymaz (2004), Roper et al. (2006), Girma et al. (2008), and Harris & Li (2009), investigate whether R&D expenditures facilitate firms' entry into export markets. The conclusion of this strand of literature is that firms that are heavily involved in R&D activities are more likely to be exporters.[11]

It is equally important to recognize the possibility that more vigorous competition and differing consumer preferences in foreign markets may induce firms to carry out R&D activities so that they can improve their innovative capabilities and stay ahead of their rivals: i.e. the so called *learning by exporting* hypothesis.[12] However, there is only a handful of studies that evaluate this hypothesis. Clerides et al. (1998) argue that the stochastic processes that generate cost and productivity trajectories should improve with changes in exporting status if learning-by-exporting plays an important role. They provide evidence using data from Mexico, Colombia and Morocco. Salomon & Shaver (2005) and Aw et al. (2007) recognize that learning-by-exporting can lead to increased innovation. Girma et al. (2008) investigate

[10] See along these lines Acs & Audretsch (1988), Cohen & Levinthal (1989), Cohen & Levinthal (1990), Teece & Pisano (1998), Mairesse & Mohnen (2005).

[11] The empirical literature cited above base their investigation on analytical models such as those developed by Posner (1961), Krugman (1979), Dollar (1986), Greenhalgh et al. (1994), Grossman & Helpman (1995).

[12] See Greenaway & Kneller (2007) and Wagner (2005) for a survey of the productivity and exports literature.

the bidirectional relationship between R&D and export activity and finds that while previous exporting experience enhances the innovative capability of Irish firms, this is not true for the British firms in their sample. Hall et al. (2009) show that enhanced international competition leads to higher levels of R&D, while Damijan et al. (2010) find that exporting influences innovation. More recently, Aw et al. (2011) develop a dynamic framework to model exporting and R&D and show that current R&D directly impacts the probability of exporting, while current exporting alters the return to R&D. They present evidence that exporting enhances productivity, while exporting firms invest more in R&D.

Following this line of reasoning, we argue that learning-by-exporting becomes even more crucial for firms exporting to countries further distant from their home markets, as they will face more competitive pressures and different consumer preferences.[13] We expect that as firms expand their export markets to different regions then their own, they may devote more resources to innovation in the form of R&D expenditures. Along these lines, Hitt et al. (1997) focus on a cross section of 295 large US firms and show that international diversification has a positive effect on R&D intensity (p. 785, Table 2).[14] Yet, to our knowledge, there are no other studies that explore the importance of diversification of export markets on the firm's R&D activities, as most of the research in this genre focuses on the effects of diversification on firm performance.

2.1. Methodological Issues

An important methodological issue arises when considering the modeling of our dependent variable, the ratio of R&D expenditures to total assets (TA), which is bounded from below. In any sample of firm-level data, it is likely that a number of firms will report zero values

[13]It is equally possible as Kotabe (1990) suggests that diversified firms have easier access to financial resources allowing them to smooth their R&D expenditures.

[14]Also see Van Biesebroeck (2005) and De Loecker (2007) who find that productivity increases after firms enter the export market in Ivory Coast and Slovenia, respectively.

for this category of expenditure in a given year. However, in a standard regression context, the empirical distribution of the series due to the prevalence of zero values is neglected. In confronting this issue, some authors (e.g., Czarnitzki & Toole (2011)) have made use of censored normal regression techniques such as the Tobit model. In our empirical investigation we, too, make extensive use of the Tobit model.

The second difficulty in estimating the effects of diversification on R&D expenditures is the endogeneity problem. Firms' decisions to begin selling overseas and to innovate could be made simultaneously, as they might face a positive demand shock which leads to both expansion into new markets and an increase in their R&D investment. In this case we face the crucial problem of endogeneity which leads to biased estimates, as some explanatory variables are not orthogonal to the error process. We employ two approaches to address this important issue. First, we make use of the instrumental variables maximum likelihood Tobit estimator (Miranda & Rabe-Hesketh (2006)), employing second and third lags of endogenous variables as instruments. The validity of these instruments is gauged by an overidentification test. Second, we consider reverse causality as a robustness check, and reestimate the model using the diversification measure as the dependent variable.[15]

3. Empirical Implementation

3.1. Test Design

To analyze the link between firms' R&D intensity and their geographical diversification of export sales, we use the following econometric specification:

$$RD/TA_{i,t} = \alpha_0 + \alpha_1 Diversification_{i,t-1} + \alpha_2 ForeignAssets_{i,t-1}$$

[15]In a standard instrumental variables linear regression, such an approach would be unnecessary, as normalization of the relationship is arbitrary. In the context of the instrumental variables Tobit likelihood function, that principle does not apply. As a significant fraction of firm-years have diversification measures equalling zero, estimation of a Tobit model in this context is appropriate.

$$
\begin{aligned}
&+ \quad \alpha_3 NewEquity_{i,t-1} + \alpha_4 \log(Employment)_{i,t-1} + \alpha_5 Debt/TA_{i,t-1} \qquad (1)\\
&+ \quad \alpha_6 Cash/TA_{i,t-1} + \sum_{j=1}^{J} \beta_j Dev_{i,t-1} + \mu_j + \tau_t + \epsilon_{i,t}
\end{aligned}
$$

where i indexes the firm, j the industry, and t the year. Our dependent variable is $RD/TA_{i,t}$, the ratio of research and development expenses to beginning-of-period total assets. It is useful to note at this junction that some researchers have measured R&D intensity relative to sales, rather than total assets, but this latter measure may be unduly sensitive to variations in demand which have little to do with the intensity of research efforts.

The key coefficient of interest is α_1, which determines the response of R&D expenditures to $Diversification_{i,t-1}$, a measure of geographical sales diversification in the previous year. To test the hypothesis that firms that have access to diversified export markets are more R&D-active, we use two different diversification indices constructed using information on firms' export sales to four regions: Europe; America; Middle East and Africa; and Asia and Australia. Our first export diversification measure is a transformation of the well-known Herfindahl–Hirschmann concentration index:

$$
Diversification\ HHI_{it} = 1 - \sum_{r=1}^{n} x_{r,i,t}^2
$$

Given the above definition and the regions where UK firms export, the values of our diversification measure will be within the [0.0, 0.75] interval for each firm. When this measure equals zero, HHI equals one, as that company sells only to the European market. The highest possible value of this measure is 0.75, which corresponds to a HHI of 0.25, representing equal sales in each region. Our second diversification measure is entropy-based and quantifies the expected value of the information contained in a specific realization of the random variable.[16]

[16] See Shannon (1948) for more along these lines. Note that Hitt et al. (1997) also implement this measure.

The measure takes the following form:

$$Diversification\ Entropy_{it} = -\sum_{r=1}^{n} x_{r,i,t} \log(x_{r,i,t})$$

where in the case of $x_{r,i,t} = 0$ for some i and t, the value of the corresponding term is taken to be 0, which is consistent with the well-known limit that $lim_{p\to 0+}(p \log p) = 0$. The upper bound is attained when a firm exports evenly to all regions. Therefore, this measure will be bounded within the $[0.0, \log(4)]$ interval. We should note that although these two diversification measures are expected to be correlated, they represent different approaches in forming a scalar measure of the firm's export sales diversification.

Given that our data are comprised of UK firms, their domestic sales are naturally included in sales in the European region, so that a firm with purely domestic sales would still be classed as selling in Europe even if they had no export sales. Even though a UK-based firm that exports to other European markets may be subject to exchange rate risk, foreign income risk, and the like, it will be considered as undiversified given the definition of our diversification measure. In our empirical models, to account for the volatility that is expected to arise due to fluctuations in cash flows, we use two different risk measures as discussed below.[17] Separately, as our dataset provides information on domestic sales, we can calculate the amount of exports to European markets as the difference between recorded sales to the European region and the UK. However, because measurement error introduced by this calculation may weaken our inference, we consider this further distinction only as a robustness check rather than implementing it throughout the empirical analysis.

[17] We do not introduce a measure to proxy for exchange rate volatility in our model as R&D expenditures are related to long term projects; short-term variations in the exchange rate should not affect our results. To establish robustness, we compute a measure of exchange rate volatility based on trade-weighted real exchange rate data and introduce it into the model in place of the year dummies. The results show that the coefficient on this exchange rate volatility measure is not significant.

Our model contains several variables as controls in the estimated equation. As a firm's presence in foreign markets may also be represented by its foreign direct investment (FDI), we include $ForeignAssets$, a binary variable equal to one if the firm reports the ownership of foreign productive assets that year. Next, we incorporate three control variables into the model which are commonly used in the literature: firm size, computed as the natural logarithm of the number of employees ($\log(Employment_{i,t})$); leverage, measured as the ratio of last period's total debt to total assets ($Debt/TA_{i,t-1}$); and liquidity, calculated as the ratio of last period's cash and equivalents to total assets ($Cash/TA_{i,t-1}$).[18] We also make use of the ratio of last period's new equity issuance to total assets ($NE/TA_{i,t-1}$). Throughout our investigation, to reduce the bias caused by simultaneity in firms' financial decisions with R&D expenditure decisions, we make use of lagged values of leverage, liquidity and new equity issuance rather than their contemporaneous observations.[19]

Firms' decisions to invest in research and development activities are subject to both common and idiosyncratic shocks. To account for these factors, we augment Equation (1) with a set of industry indicator variables (μ_j) and interactions of those indicator variables with a measure of firm deviations, $Dev_{i,t}$. These deviations, computed for the ratio of last period's cash flow to total assets ($CF/TA_{i,t-1}$), capture firm-specific or industry-wide deviations of the firm's inflow of funds. The first measure, which captures the deviation of expected cash flow from the observed value, is based upon a panel data AR(1) regression:

$$CF/TA_{i,t} = \gamma_0 + \gamma_1 CF/TA_{i,t-1} + \nu_i + \xi_{i,t}$$

where ν_i is a firm fixed effect. The sequence of residuals from this regression, $\hat{\xi}_{i,t}$, are

[18] We have also interacted the diversification measures with industry dummies and obtained qualitatively similar results.

[19] Results when we use contemporaneous observations are similar to those we report in our tables and are available upon request.

employed as the firm deviation measure $Dev_{i,t}$. These residuals may be viewed as in-sample forecast errors in forecasting the cash flow ratio for that firm. More concretely, we define the firm deviation as

$$Dev_{it}^{f} = CF/TA_{i,t} - (\hat{\gamma}_0 + \hat{\gamma}_1 CF/TA_{i,t-1} + \hat{\nu}_i)$$

This measure acts as a proxy for the extent of uncertainty that the firm faces with respect to its inflow of funds.[20]

The second proxy measures the degree to which the firm's cash flow ratio diverges from that of its industry, defined as:

$$Dev_{it}^{ind} = CF/TA_{i,t} - \widetilde{CF/TA}_{i,t}$$

where $\widetilde{CF/TA}_{i,t}$ is the median value of $CF/TA_{i,t}$ for all firms in industry j at time t. This deviation measure reflects how the firm's value of their cash flow to total assets ratio differs in that year from the industry median.[21]

Our model, Equation (1), also includes a full set of time fixed effects (τ_t). Finally, ϵ_{it} is an idiosyncratic error term.

3.2. Data

In our empirical analysis, we use an unbalanced panel extracted from the Extel Financials database produced by Thomson Financial. Our estimation sample is compiled in the following way. We first dropped observations corresponding to service industries and those firms who had fewer than five years of coverage. We also removed firm-years with incomplete

[20]We also experimented with a firm-specific AR(1) model for CF/TA. The results from this set are qualitatively similar and we choose not to report them for brevity.

[21]Using both definitions, we also considered three alternatives to the ratio of CF/TA: the ratio of sales to total assets, cash to total assets, and sales per employee. Results were broadly similar to those produced by CF/TA as reported here.

sales data. Our resulting sample consists of a panel of about 3,880 firm-year observations pertaining to 795 companies over the period from 1990–2008 for 19 industry classifications. We winsorized variables in the model at the 5 and 95 percent thresholds.[22]

Descriptive statistics for the firm-year observations entering the analysis are presented in Table 1. Average R&D spending is about 2% of the assets but highly skewed towards the top end. Average export sales diversification is about 23%, increasing to 32% when five regions are considered. It appears that many firms are involved in exporting as the median figure stands at 19% and the third quartile is at 47%. Interestingly, half of the firms in the dataset report the presence of foreign productive assets in their capital stock. The descriptive statistics also show that firm size varies considerably less than firms' liquidity and debt ratios. Finally, we see that only a quarter of firms raise funds through the equity markets.

4. Empirical Results

We estimate Equation (1) for several alternative specifications for the full sample, including either firm-specific or industry-level deviations of firms' cash flow ratios: deviations obtained from the panel data AR model or those from the industry median. The foot of each table presents the *Firm Deviations p-value* which corresponds to the test for the joint significance of the coefficients associated with the deviations of cash flow, interacted with each of the 19 industry indicator variables. For brevity, these 19 coefficients are not reported in the tables.[23] Note that both measures of cash flow deviations are jointly significant for most of the models at the 5% level or better and their effect significantly varies across industries, as verified by the p-value of the test for their joint significance. Given this initial observation, in what follows we focus on the impact of diversification on R&D expenditures and the remain-

[22] We also experimented with less restrictive thresholds and obtained qualitatively similar results.

[23] Expanded results are available on request.

ing control variables. All models are estimated by implementing the instrumental variables Tobit estimator, where we instrument the endogenous variable with its lags. We test the validity of our instrument set with an overidentification test and show that our instruments are valid and the model is properly specified. The last row of each table provides the p-value of that χ^2 test statistic. Hence, we make no further comments along these lines as we discuss our estimates.

4.1. Export market diversification: Basic model

Table 2 presents estimates of Equation (1). The results presented in Columns 1 and 3 are obtained using the Herfindahl-based diversification index and those in Columns 2 and 4 are based on the entropy-based diversification index. The results in the first two columns are obtained when we measure the firms' cash flow deviations from their expected value, while the results in columns 3 and 4 result from measuring the firms' cash flow deviations from the industry average. We expect *a priori* that the coefficient of diversification will be significant and positive if our hypothesis should receive support from the data. Indeed, looking at the table, we see that the Tobit estimates provide strong evidence in support of our hypothesis: export market diversification has a positive impact on R&D expenditures for the UK firms regardless of the diversification index used. These estimates suggest that a one standard deviation increase in diversification leads to an 0.41% increase in R&D activities. Given that the average of R&D expenditures to total assets ratio is on the order of 2%, this is a significant change.

Next we explore the role that control variables play in the model. We observe that firm size, captured by employment, also has a positive impact on firms' R&D spending. That is, larger firms spend relatively more on R&D expenditures as a fraction of their total assets than do their smaller counterparts. Although firms' ownership of foreign productive assets has a positive effect on R&D expenditures, this impact is not significant.[24]

It is well accepted that the financing of R&D capital is mostly hindered by its intangible nature, rendering it unavailable as collateral. As many studies have shown, this causes the funding of R&D expenditures to be more dependent on internal funds than capital expenditures on plant and equipment.[25] In this respect 'pecking order' theories have shown that new equity issuance is a higher-cost source of funds due to high fixed costs, such as underwriting fees, and its dilution of shareholder wealth. To this end, the sizable coefficients on cash holdings in the results described above highlight the importance of a firm's cash buffer in supporting their R&D expenditures. Here, we also observe that the firm's debt burden impedes R&D expenditures as expected. These results are not surprising: (i) R&D investment contributes to the stock of intangible capital and cannot be used as collateral; and (ii) R&D expenditures have a lengthy and highly uncertain payback.

In our investigation, we also consider the findings of Brown et al. (2009) and Carpenter & Petersen (2002) as we evaluate whether new equity issuance plays an important role, over and above the effects of leverage and cash holdings. This is reasonable, as financing R&D activities through the issuance of equity may be particularly important for those firms that are severely restricted due to inadequate internal funds. Table 2 provides evidence that new equity sales have a positive impact on UK firms' R&D expenditures.

4.2. Robustness Checks

In this section, we implement several different specifications to check for the model's sensitivity to certain alternative specifications. In what follows, we examine (i) the persistence in R&D expenditures by introducing the lagged dependent variable in the basic specifica-

[24] The dataset does not provide information as to where the R&D activities are carried out. Though it would be interesting to examine factors that promote home *versus* foreign R&D activities as data become available, our main concern is the behavior of firms' total R&D expenditures.

[25] For an overview of this literature, see Baum et al. (2013).

tion; (ii) the possibility of reverse causality; (iii) the subset of positive R&D firms as we scrutinize both directions of causality; and (iv) separating domestic sales from exports to other European markets.

4.3. Dynamics and Export Market Diversification

In this subsection we introduce the lagged dependent variable into Equation (1) to consider the persistence of R&D expenditures. As Hall, Bronwyn H. & Lerner, Josh (2009) stress (p. 5), a multi-year purchase of machinery could be rescheduled in the face of financial exigencies, but it would be much more difficult to temporarily reduce R&D expenditures. They indicate that this is perhaps the most important distinguishing characteristic of R&D investment, and leads to firms' smoothing R&D spending over time so that they may retain their skilled human capital.

In the context of instrumental variables Tobit modeling, adding the lagged dependent variable to capture the smooth behavior of R&D expenditures leads to a downward bias in the estimates (see Greene (2004)). However, this bias is likely to decline as the time series dimension of the panel increases. Given that most firms in our data have a reasonably long time series (1990–2008), the effect of this bias can be expected to be minimal. Furthermore, we should note that our results could be expected to be even stronger if bias-corrected estimates could be computed.[26] The results for such a model where we add the lagged dependent variable are given in Table 3. Notice that the coefficient of the lagged dependent variable is positive and significant, suggesting that those firms that are involved in R&D activities in the previous period tend to continue their R&D programme in subsequent periods. However, the extent of persistence does not seem to be high, as the coefficient is on the order of

[26]We have also experimented by estimating the dynamic specification by employing the Wooldridge (2005) approach. Unfortunately, in most cases we encountered convergence problems. As a consequence we proceeded with standard instrumental variable Tobit results.

0.44–0.45.

When we focus on the coefficient of the diversification index, regardless of the measure used, we find that it has a positive sign for both panel and industry based cash flow deviations. Given the coefficient estimates, the long run effect of diversification for the model in column 1 can be calculated around 1.3%: a figure not significantly different from that in Table 2. Similar observations are valid for the other columns. We consider that this provides meaningful support for our claim that diversified export markets induce firms to engage in R&D activities.

When we inspect the remaining coefficient estimates, we find results similar to those in Table 2, except that the coefficient of cash to total assets is positive but no longer significant. The ratio of debt to total assets has a negative but insignificant impact on R&D activities.

4.4. Exploring the Possibility of Reverse Causality from R&D Expenditures to Export Diversification

Given that earlier research has shown that investment in R&D facilitates firms' entry into export markets, it is important to consider if the results that we have shown so far are the consequence of a feedback effect due to reverse causality. Hence, we examine the following instrumental variables Tobit model to explore this possibility:

$$\begin{aligned} Diversification_{i,t} &= \gamma_0 + \gamma_1 RD/TA_{i,t-1} + \gamma_2 ForeignAssets_{i,t-1} \\ &+ \gamma_3 NewEquity_{i,t-1} + \gamma_4 \log(Employment)_{i,t-1} + \gamma_5 Debt/TA_{i,t-1} \\ &+ \gamma_6 Cash/TA_{i,t-1} + \sum_{j=1}^{J} \zeta_j Dev_{i,t-1} + \mu_j + \tau_t + \epsilon_{i,t} \end{aligned} \tag{2}$$

where we use the same control variables and instrument structure as in our main results. Results for this model are given in Table 4. Looking at the first row of the table we see that R&D expenditures has a positive but insignificant effect on firms' export diversification. This observation holds for both diversification measures. Based on the findings reported in Table 4, there is no empirical support for reverse causality from R&D expenditures to export diversification. Turning to the control variables, we observe that lagged foreign assets, firm size as captured by log of employment, debt ratio and cash stock have a positive and significant impact on diversification, yet new equity has no significant effect.

4.5. Focusing on Positive R&D firms only

The next two robustness checks focus only on positive R&D expenditure firms as we again examine bidirectional causality.[27] Table 5 presents results for Equation (1) estimated for only those firms with positive R&D investment. Using this subsample, we then examine the possibility of reverse causality given in Equation (2) and report regression results in Table 6.

Focusing first on the results presented in Table 5, we see that the coefficients associated with both diversification measures are positive and significant. In fact, these coefficient estimates are even greater than what we reported in Table 2 earlier, as we would expect in this selected subsample. When we turn to control variables, we see that while the cash-to-assets ratio has a positive and significant impact on R&D activities, net equity issuance does not appear to exert any significant effects. Furthermore, debt and foreign productive assets do not play significant roles in R&D expenditures for R&D-active firms. However, the coefficient of firm size is negative and significant, implying that smaller R&D-active firms make a greater effort to diversify. This observation is sensible, as small, innovative firms tend to expand into new markets as they strive to take advantage of the unique characteristics of their products.

When we consider Table 6, once again we find no evidence of reverse causality. R&D expenditures do not appear to have any significant impact on diversification. Turning to firm-specific variables, we observe that foreign productive assets, firm size and cash stock

[27] We do not consider this restricted sample in the main results of our paper as the restriction introduces the possibility of selection bias: an issue that is avoided by including zero-R&D firms in the main analysis.

have a positive and significant impact on diversification, while the remaining variables have no significant effects.

4.6. Europe as a Separate Region

The original sample provides information on exports of UK firms to four regions: Europe, the Americas, the Middle East and Africa, and Asia and Australia. In this dataset, domestic (UK) sales are aggregated into exports to Europe. Separately, the dataset provides sales in the home market (UK) only. Hence, it may be possible to extract information on exports to European destinations only, as we can remove the firm's UK sales from exports to the European region. This is straightforward, but raises a potential problem of measurement error. Thus, we present these imputed intra-European sales only as a robustness check. Given this finer classification of sales destinations, we recompute measures of diversification for five regions: the UK, Europe excluding UK sales, the Americas, the Middle East and Africa, and Asia and Australia, and present the results in Table 7. In this set of results, regardless of the measure used, we observe that diversification has a positive impact on R&D expenditures. Furthermore, the control variables play a similar role as discussed in Table 2. Overall, we conclude that those results in Table 7, along with those we presented earlier, support our hypothesis that sales diversification induces firms to carry our more R&D activities.

5. Conclusions

Researchers have been investigating various factors that induce firms to carry out R&D activities. However, this literature has not provided a rigorous study on the importance of export market diversification on R&D expenditures. In this paper we empirically scrutinize the impact of export market diversification on R&D expenditures in a panel of UK manufacturing firms. In estimating the impact of export market diversification on R&D expenditures, we account for the bias that could be introduced due to the presence of zero values of R&D

expenditures as well as that could arise due to endogeneity of the diversification variable. Hence, we implement instrumental variables techniques in the context of the Tobit model. We check for the validity of our instruments and show that our models are properly specified and the instruments are valid.

Our empirical model controls for several firm-specific variables which are shown to be important in the literature, including foreign productive assets, firm size, leverage, liquidity, as well as new equity issuance. Finally, we compute and separately incorporate two different risk measures based on firm-specific or industry cash-flow deviations, because export-diversified firms may face fluctuations in their cash flows which could in turn affect their R&D activities.

We carry out our analysis using a large unbalanced panel of UK quoted manufacturing firms obtained from the Extel Financials database produced by Thomson Financial. The database provides us information on firm-specific variables on an annual basis over 1990–2008 for 19 industry classifications, for which we have firm level export data on four broadly defined regions. Given this information, we compute two different export sales diversification measures, one based on the Herfindahl–Hirschmann concentration index, and the other an entropy-based index, to seek support for our hypothesis from the data.

Our results provide strong evidence that a higher degree of export market diversification induces firms to initiate (or increase the scale of) their R&D expenditures. That is, as firms export their products to more distant markets, they require greater R&D investment to remain competitive in the global markets. These findings support the view that firms selling to a broader range of markets must be more innovative if they are to maintain a competitive edge over their rivals. To check the robustness of our claim, we estimate several additional specifications considering (i) persistence in R&D expenditures; (ii) the possibility of reverse causality; (iii) the subset of positive R&D firms, as we scrutinize for both directions of causality; and (iv) a finer classification of diversification, as we separate European sales of firms into UK and non-UK markets.

For future research it would be useful to expand this analysis to other countries. For instance it would be interesting the test the importance of export market diversification for Japan and Germany, both of which have an important presence in world export markets. Likewise, a similar investigation for China, South Korea, Thailand and Taiwan would be illuminating, as it would allow one to consider whether these countries can continue to expand their exports and GDP, as many argue that technological development is the main engine of growth.

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Table 1: Descriptive statistics, 1990–2008.

	Mean	SD	Q1	Q2	Q3	N
R&D Expenditures/Total Assets	0.02	0.05	0.00	0.00	0.02	3,880
HHI Diversification (4 regions)	0.23	0.23	0.00	0.19	0.47	3,880
HHI Diversification (5 regions)	0.32	0.26	0.00	0.38	0.55	3,880
Entropy Diversification (4 regions)	0.37	0.37	0.00	0.35	0.68	3,880
Entropy Diversification (5 regions)	0.54	0.44	0.00	0.60	0.93	3,880
Foreign Productive Assets	0.52	0.50	0.00	1.00	1.00	3,880
New Equity/Total Assets	0.08	0.20	0.00	0.00	0.05	3,880
log(Employment)	7.46	2.32	6.09	7.45	8.94	3,880
Total Debt/Total Assets	0.20	0.14	0.09	0.19	0.27	3,880
Cash/Total Assets	0.11	0.10	0.03	0.07	0.15	3,880

Notes: Q1, Q2, and Q3 are the first, second and third quartiles, respectively. N is the number of firm-years. $R\&D/TA$ is the ratio of R&D expenditures to total assets. $HHI\ Sales\ Diversification$ is one minus sum of squared shares of sales to four (or five) regions of the world. $Entropy\ Sales\ Diversification$ is entropy based measure of diversification as discussed in Section 3. $Foreign\ Productive\ Assets$ is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. $New\ Equity/Total\ Assets$ is the ratio of new equity issue to total assets. $\log(Employment)$ is the natural logarithm of the number of employees. $Total\ Debt/Total\ Assets$ is the ratio of total debt to total assets. $Cash/Total\ Assets$ is the ratio of cash and equivalents to total assets.

Table 2: IV Tobit Results, basic specification.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
	(1)	(2)	(3)	(4)
HHI Sales Diversification$_{t-1}$	0.018***		0.016***	
	(0.006)		(0.006)	
Entropy Sales Diversification$_{t-1}$		0.011***		0.010***
		(0.004)		(0.004)
Foreign Productive Assets$_{t-1}$	0.003	0.003	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
(New Equity/Total Assets)$_{t-1}$	0.018**	0.018**	0.018**	0.018**
	(0.009)	(0.009)	(0.008)	(0.008)
Log(Employment)$_{t-1}$	0.001**	0.001**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
(Total Debt/Total Assets)$_{t-1}$	-0.013**	-0.012*	-0.011	-0.010
	(0.007)	(0.007)	(0.007)	(0.007)
(Cash/Total Assets)$_{t-1}$	0.023*	0.023*	0.024*	0.025**
	(0.012)	(0.012)	(0.012)	(0.012)
Firm-years	1,980	1,980	2,001	2,001
Firm deviations p-value	0.000	0.000	0.002	0.002
Overid p-value	0.134	0.179	0.064	0.092

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The ratio of R&D expenditures to total assets, $R\&D/TA$, is the dependent variable. HHI *Sales Diversification* is one minus sum of squared shares of sales to four regions of the world. *Entropy Sales Diversification* is entropy based measure of diversification as discussed in Section 3. *Foreign Productive Assets* is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. *Total Debt/Total Assets* is the ratio of total debt to total assets. *Cash/Total Assets* is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.

Table 3: IV Tobit Results, dynamic specification.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
HHI Sales Diversification$_{t-1}$	0.007**		0.006**	
	(0.003)		(0.003)	
Entropy Sales Diversification$_{t-1}$		0.005***		0.004**
		(0.002)		(0.002)
(R&D/Total Assets)$_{t-1}$	0.449***	0.449***	0.444***	0.444***
	(0.027)	(0.027)	(0.026)	(0.026)
Foreign Productive Assets$_{t-1}$	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
(New Equity/Total Assets)$_{t-1}$	0.016**	0.016**	0.020***	0.020***
	(0.006)	(0.006)	(0.007)	(0.007)
Log(Employment)$_{t-1}$	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
(Total Debt/Total Assets)$_{t-1}$	-0.003	-0.003	-0.001	-0.000
	(0.004)	(0.004)	(0.004)	(0.004)
(Cash/Total Assets)$_{t-1}$	0.004	0.004	0.005	0.005
	(0.005)	(0.005)	(0.005)	(0.005)
Firm-years	1,980	1,980	2,001	2,001
Firm deviations p-value	0.000	0.000	0.000	0.000
Overid p-value	0.156	0.234	0.090	0.136

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The ratio of R&D expenditures to total assets, $R\&D/TA$, is the dependent variable. HHI *Sales Diversification* is one minus sum of squared shares of sales to four regions of the world. *Entropy Sales Diversification* is entropy based measure of diversification as discussed in Section 3. *Foreign Productive Assets* is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. *Total Debt/Total Assets* is the ratio of total debt to total assets. *Cash/Total Assets* is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * $p\leq 0.10$, ** $p\leq 0.05$, *** $p\leq 0.01$. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.

Table 4: IV Tobit Results, reverse causality.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
	HHI	Entropy	HHI	Entropy
	(1)	(2)	(3)	(4)
(R&D/Total Assets)$_{t-1}$	0.208	0.143	0.250	0.165
	(0.368)	(0.357)	(0.577)	(0.559)
Foreign Productive Assets$_{t-1}$	0.264***	0.256***	0.421***	0.411***
	(0.018)	(0.017)	(0.029)	(0.028)
(New Equity/Total Assets)$_{t-1}$	-0.070	-0.023	-0.098	-0.026
	(0.043)	(0.041)	(0.069)	(0.063)
Log(Employment)$_{t-1}$	0.043***	0.042***	0.069***	0.067***
	(0.005)	(0.005)	(0.008)	(0.008)
(Total Debt/Total Assets)$_{t-1}$	0.130**	0.166***	0.150*	0.205**
	(0.053)	(0.055)	(0.087)	(0.088)
(Cash/Total Assets)$_{t-1}$	0.153**	0.156***	0.221**	0.225**
	(0.063)	(0.059)	(0.103)	(0.098)
Firm-years	1,980	2,001	1,980	2,001
Firm deviations p-value	0.096	0.000	0.151	0.000
Overid p-value	0.245	0.138	0.309	0.196

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The *HHI Sales Diversification* and *Entropy Sales Diversification* measures are the dependent variables. *R&D/TA* is the ratio of R&D expenditures to total assets. *Foreign Productive Assets* is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. *Total Debt/Total Assets* is the ratio of total debt to total assets. *Cash/Total Assets* is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * p$\leq$ 0.10, ** p$\leq$ 0.05, *** p$\leq$ 0.01. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.

Table 5: IV Tobit Results, positive R&D firms.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
	(1)	(2)	(3)	(4)
HHI Sales Diversification$_{t-1}$	0.027***		0.025***	
	(0.008)		(0.008)	
Foreign Productive Assets$_{t-1}$	-0.002	-0.002	-0.002	-0.002
	(0.004)	(0.003)	(0.003)	(0.003)
(New Equity/Total Assets)$_{t-1}$	0.018	0.018	0.019	0.018
	(0.014)	(0.014)	(0.012)	(0.012)
Log(Employment)$_{t-1}$	-0.002**	-0.002**	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
(Total Debt/Total Assets)$_{t-1}$	-0.014	-0.013	-0.013	-0.011
	(0.009)	(0.009)	(0.009)	(0.010)
(Cash/Total Assets)$_{t-1}$	0.034*	0.035*	0.036*	0.037*
	(0.021)	(0.020)	(0.020)	(0.020)
Entropy Sales Diversification$_{t-1}$		0.017***		0.016***
		(0.005)		(0.005)
Firm-years	1,273	1,273	1,284	1,284
Firm deviations p-value	0.000	0.000	0.000	0.000
Overid p-value	0.134	0.179	0.064	0.092

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The ratio of R&D expenditures to total assets, $R\&D/TA$, is the dependent variable. $HHI\ Sales\ Diversification$ is one minus sum of squared shares of sales to four regions of the world. *Entropy Sales Diversification* is entropy based measure of diversification as discussed in Section 3. $Foreign\ Productive\ Assets$ is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. $Total\ Debt/Total\ Assets$ is the ratio of total debt to total assets. $Cash/Total\ Assets$ is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * p$\leq$ 0.10, ** p$\leq$ 0.05, *** p$\leq$ 0.01. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.

Table 6: IV Tobit Results, reverse causality, positive R&D firms.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
	HHI	Entropy	HHI	Entropy
	(1)	(2)	(3)	(4)
(RD/Total Assets)$_{t-1}$	0.160	0.142	0.170	0.149
	(0.443)	(0.432)	(0.688)	(0.674)
Foreign Productive Assets$_{t-1}$	0.287***	0.273***	0.465***	0.446***
	(0.030)	(0.029)	(0.048)	(0.046)
(New Equity/Total Assets)$_{t-1}$	-0.056	-0.034	-0.069	-0.035
	(0.052)	(0.049)	(0.080)	(0.074)
Log(Employment)$_{t-1}$	0.053***	0.054***	0.084***	0.084***
	(0.007)	(0.007)	(0.012)	(0.012)
(Total Debt/Total Assets)$_{t-1}$	0.060	0.090	0.006	0.056
	(0.070)	(0.070)	(0.112)	(0.110)
(Cash/Total Assets)$_{t-1}$	0.183**	0.181**	0.241**	0.244**
	(0.077)	(0.075)	(0.123)	(0.120)
Firm-years	1,273	1,284	1,273	1,284
Firm deviations p-value	0.000	0.000	0.000	0.000
Overid p-value	0.245	0.138	0.309	0.196

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The *HHI Sales Diversification* and *Entropy Sales Diversification* measures are the dependent variables. *R&D/TA*, is the ratio of R&D expenditures to total assets. *Foreign Productive Assets* is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. *Total Debt/Total Assets* is the ratio of total debt to total assets. *Cash/Total Assets* is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * p$\leq$ 0.10, ** p$\leq$ 0.05, *** p$\leq$ 0.01. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.

Table 7: IV Tobit Results, five regions.

	Panel Data Forecast Errors		Firm–Industry Median Deviations	
	(1)	(2)	(3)	(4)
HHI Sales Diversification$_{t-1}$	0.020***		0.018***	
(5 regions)	(0.006)		(0.006)	
Entropy Sales Diversification$_{t-1}$		0.026***		0.024***
(5 regions)		(0.008)		(0.008)
Foreign Productive Assets$_{t-1}$	0.003	0.003	0.004	0.004
	(0.002)	(0.002)	(0.002)	(0.002)
(New Equity/Total Assets)$_{t-1}$	0.018**	0.017**	0.018**	0.018**
	(0.009)	(0.009)	(0.008)	(0.008)
Log(Employment)$_{t-1}$	0.001**	0.001**	0.001**	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
(Total Debt/Total Assets)$_{t-1}$	-0.013**	-0.012*	-0.011	-0.010
	(0.007)	(0.007)	(0.007)	(0.007)
(Cash/Total Assets)$_{t-1}$	0.023*	0.024*	0.024*	0.025**
	(0.012)	(0.012)	(0.012)	(0.012)
Firm-years	1,980	1,980	2,001	2,001
Firm deviations p-value	0.000	0.000	0.000	0.000
Overid p-value	0.140	0.234	0.083	0.149

Notes: Average marginal effects of the regressors on the expected value of the censored dependent variable are reported. The ratio of R&D expenditures to total assets, $R\&D/TA$, is the dependent variable. HHI *Sales Diversification* is one minus sum of squared shares of sales to five regions of the world. *Entropy Sales Diversification* is entropy based measure of diversification as discussed in Section 3. *Foreign Productive Assets* is a dummy variable equal to one if a firm reports ownership of foreign productive assets and zero otherwise. *New Equity/Total Assets* is the ratio of new equity issue to total assets. log(*Employment*) is the natural logarithm of the number of employees. *Total Debt/Total Assets* is the ratio of total debt to total assets. *Cash/Total Assets* is the ratio of cash and equivalents to total assets. Firm deviations is the test of joint significance of industry dummy variables interacted with panel data forecast errors (p-value reported). Cluster-robust standard errors (by firm) in parentheses. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$. A constant, time dummy variables, and panel data forecast errors (firm–industry median deviations) interacted with industry dummy variables are included but not reported in specifications 1 and 2 (3 and 4). Overid is the test of overidentifying restrictions, p-value reported.