Innovation, Patents and Trade: A Firm-level Analysis

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Abstract: Using micro data of firm exports and international patent activity we find that Greek innovative exporters, identified by their patent filing activity, have substantially higher export revenues by selling higher quantities, rather than charging higher prices. To account for this evidence, we set up a model of vertically differentiated products. In a foreign market, the innovative exporter produces a high-quality good under monopoly rights and faces competition by non-innovative Greek exporters. We argue that, if the number of non-innovative firms is large and thus competition among them is stiff, the innovative firm will sell higher quantities in more distant markets. This prediction is empirically confirmed, suggesting that innovation coupled with patent rights and market characteristics are important determinants of firm export behavior.

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1. Introduction

Innovative activity at the firm level is associated with export intensity. Aw et al. (2011) have found that firms select in both innovation and exporting, which in turn fuels firm productivity.[1] For these innovative products and services, firms have the option to claim protection in the countries they wish to sell, typically through Intellectual Property Rights (IPR) via patents, which grant a monopoly over the invention for a limited number of years in exchange for full disclosure.[2] Notably, international patenting has been continuously expanding by firms and organizations. According to European Patent Office's (EPO) data, 2014 saw the highest number of patent applications (274,174), of which 65% originated from non-EPO member countries.[3] Similarly, in the United States Patent and Trademark Office (USPTO), 52% of issued utility patents in 2014 were granted to non-US entities.[4]

Our paper attempts to shed some light in the exporting behavior of innovative exporters, identified by their international patent applications. To this end, we match detailed export data from Greek firms on their export values, volumes and prices (unit values) per product across different destinations during 2005-2007, with their international patent applications and patents issued since 1993. Our descriptive analysis shows that exporting firms with patent applications account for approximately 1% of total exporters, a finding that agrees with studies in the US (Graham et al., 2015). Yet, this relatively small percentage of exporters accounts for 17.7% of total export sales. We establish empirically that, in contrast to conventional wisdom, the relatively higher export sales by patent applicants compared to non-applicants are generated by larger *volumes* exported, rather than higher prices.

Based on these stylized facts, we build a model of a foreign market with vertically differentiated products, in which the innovative exporter produces a high-quality good under monopoly rights and faces competition by non-innovative exporters. We argue that, if the number of non-innovative firms is large and thus competition among them is stiff, the innovative firm will sell higher quantities in more distant markets. This prediction is empirically confirmed, suggesting that innovation coupled with patent rights and market characteristics, like distance and

[1] See the references therein for evidence from micro-trade data on the strong positive correlation between exporting and R&D activity.
[2] This period usually lasts 20 years from application date. For a recent literature review on the economics of patents see Hall and Harhoff (2012).
[3] http://www.epo.org/about-us/annual-reports-statistics/statistics/filings.html
[4] http://www.uspto.gov/web/offices/ac/ido/oeip/taf/st_co_14.htm

competition, are important determinants of firm export behavior. These results are robust to the sample used and to the degree of patent strength in the destination country.

Our paper relates to two main literatures. First, it relates to the fast growing literature of micro-exporting where a number of recent studies provided substantial insights on the behavior of exporting firms with innovative activities (see, among others, Atkenson and Burstein, 2010; Caldera, 2010; Aw et al., 2011).[5] We contribute to this literature by looking at innovative exporters through the lens of international patent activity across foreign markets and show how market structure and destination distance are associated with the export volumes sold by innovators. Second, it relates to the literature that aims to identify and quantify the implications of international patenting activity. Harhoff et al. (2009) examined at the country level the flows of patenting activity within the EPO, while Chan (2010) examined the international patent profiles of nine agricultural biotechnology firms. Albeit innovating firms conduct a large part of their activity in export markets, this literature has not explicitly considered the relationship between patent filing and exporting at the firm level.

In the next section, we discuss how the data were constructed, with emphasis placed on firms with patent applications, and outline our baseline empirical specifications. In Section 3 we present some descriptive statistics and stylized facts. Section 4 outlines the theoretical framework and Section 5 tests the main empirical implications. Finally, Section 6 concludes the paper.

2. Data and specifications

Data construction. We merge data from two main sources. First, we obtain detailed data on the exporting activity of all Greek firms from the Intrastat databank. This database, available via the Hellenic Statistical Authority (ELSTAT), collects information on dispatches of goods in all countries. In particular, it collects information on the quantity and value for each firm in each country at the 5-digit SITC level of product disaggregation (SITC5). In line with the related literature, we exclude a number of outliers attributed to prices. In particular, for each firm we drop observation units for which the SITC5 product price is lower than the tenth percentile of that firm's SITC5 price in all other countries. Further, we exclude observations where the SITC5 price exceeds by ten times the median of that SITC5's price. After posing these restrictions, approximately 7% of our sample is excluded.

[5] For a review of empirical studies in trade at the firm level see Bernard et al. (2012).

The patent activity by Greek firms is obtained through PATSTAT, which collects and maintains information on patent applications and granted patents for approximately 100 patent authorities.[6] The first step was to extract all patents and patent applications regardless of jurisdiction, which were disclosing a Greek-located assignee.[7] After information for patents and patent applications was collected, firms in Intrastat and PATSTAT were manually matched. We found 79 firms that have at least one exporting entry and have filed for at least one non-Greek patent application between 1993-2007. Our final sample consists of exporting firms, their exporting profiles and patent application activity during the 2005-2007 period.[8]

We note that a finer level of matching at the product-patent level is not a feasible task. Patents are not classified based on industry classifications, but follow other types of classifications with the more widely used being the International Patent Classification (IPC) system. While there have been studies that have attempted to match industry classifications, such as SITC, with IPC, they come with several caveats and have only been scantly used in industry level analyses (Schmoch et al., 2003; Lybbert and Zolas, 2014).[9]

Baseline empirical specifications. For each firm *i*, we observe the annual sales and quantities of product *k* (SITC5 classification) sold in destination *d* during the period 2005-2007. Our first baseline specification is at the firm-country level and takes the following form:

$$\ln(value_{i,d,t}) = \alpha_0 + \alpha_1 APP_{i,t} + d_d + f_i + \varepsilon_{i,d,t} \tag{1}$$

where $value_{i,d,t}$ is the amount of sales that firm i has in destination d at year t, $APP_{i,t}$ takes the value of 1 if firm i has filed for a patent application overseas during the period 1993-t and zero otherwise, d_d is a set of country dummies and f_i is a set of firm variables.[10]

Our second specification exploits the information on quantities and prices (unit values), at the firm-country-product level. We consider the following specification:

[6] http://www.epo.org/searching/subscription/raw/product-14-24.html

[7] There are two entities disclosed in a published patent application. The inventor(s) and the assignee(s). The assignees are essentially the patent owners. In cases where the inventor is the owner the two entities coincide.

[8] Additional firm level data, like firm employment and age, are collected from the ICAP database on Greek firms. Country-specific variables are obtained from various sources. The distance of each country's geographic center to Greece is obtained by Mayer and Zignago (2011) and GDP per capita is collected from the Penn World Tables.

[9] Even in a narrowly defined field such as pharmaceutical compounds, the matching between patents and sales still comes with several challenges (Kyle and Qian, 2014).

[10] The results hold if we consider patent grants instead of patent applications.

$$\ln(Y_{i,d,k,t}) = \alpha_0 + \alpha_1\, APP_{i,t} + d_d + f_i + \varepsilon_{i,d,t} \quad (2)$$

where $Y_{i,d,k,t}$ is the value, or price, or quantity, of product k sold by firm i in destination d in year t.

3. Descriptive statistics and stylized facts

As mentioned in the introductory section, about 1% of Greek exporters have filed at least one foreign patent application; this amounts to 79 exporting firms. In our setup, we denote the firms with at least one patent application as *tradepat* firms and those without as *nontradepat* firms, and exclude from our sample the firms that do not export a common SITC5 code with *tradepat* firms. Further, we exclude countries to which *tradepat* firms do not export. This reduces the sample of *nontradepat* firms to 6,085 observations; further the number of countries in which *tradepat* firms export is 125 whereas the total number of destinations for Greek exports is 150. The total sales of the remaining firms in these countries for these product categories account for approximately 89% of total export sales.

Panel A in Table 1 shows that *tradepat* firms have disproportionately larger exports than *nontradepat* firms: an average *tradepat* firm has thirteen times higher exports than an average *nontradepat* firm (€50.4m versus €3.68m) during the 2005-2007 period. Further, *tradepat* firms account for approximately 17.7% of total exports of Greek firms during this period. Therefore, a small fraction of firms that file for patent applications account for a disproportionately larger share of exports. In terms of export intensity, the average *tradepat* firm exports 14.1 products and the *nontradepat* firm 8.7, while the average *tradepat* firm exports in 20 destinations, compared to 5.1 by an average *nontradepat* firm. These findings imply that Greek firms with patent applications are distinctively different firms compared to the rest, a finding that agrees with Balasubramanian and Sivadasan (2011) and Graham et al. (2015) for US firms.

Panel B in Table 1 compares *tradepat* and *nontradepat* firms at the firm-country-year level. In firm-country-year observations of *tradepat* firms, export sales are approximately four times higher than firm-country-year observations of *nontradepat* firms (1.21 versus 0.34 mn Euros). With respect to the number of products, *nontradepat* firms appear to export a slightly higher number of products per destination than firm-country observations of *tradepat* firms.

To further explore the relationship between export sales and patent applications, in Table 2 we present a number of specifications based on equation (1), in which the observation unit is the firm-country-year observation (aggregation across products). Firm-product fixed effects are included in all regressions to capture cost and quality characteristics (Manova and Zhang, 2012). Also, country fixed effects are included in regressions that do not include destination distance and gdp. Finally, some specifications include firm variables to control for size and productivity.

Column (1) uses the entire sample and the coefficient of patent application dummy, *APP*, is positive and significant. Given that the coefficient is a quasi-elasticity it is interpreted as follows: firm-country pairs that are associated with a patent application have $e^{1.176}$-1=224% more sales per year than firm-country pairs that are not associated with a patent application. In Column (2) we introduce the natural logs of distance and gdp per capita as covariates. Sales are negatively related to distance and insignificantly with gdp per capita. The coefficient of *APP* decreases slightly and remains robustly significant. In Columns (3) and (4) we include firm variables that aim at capturing size and productivity. The (log of) number of destinations for each firm is used as a proxy for firm productivity (Berman et al., 2012) and is associated positively with export sales. The variables related to firm size, like the number of products and the number of employees, are positively related to sales, while the age of the firm is negatively associated with export sales. The patent application dummy *APP* is reduced (0.48), but it is still significant at the 5% level.

Turning back to Table 1, in Panel C we compare the components of export sales, namely quantities and unit values (obtained as export revenues over quantities) at the firm-country-product-year level. We observe that *tradepat* firms sell at approximately 55% higher prices compared to *nontradepat* firms, but *tradepat* firms sell 275% higher quantities than *nontradepat* firms. These simple summary statistics provide some indication that higher revenues of *tradepat* firms come mainly from increased quantities, rather than prices.

Table 3 explores more thoroughly this conjecture by presenting results from equation (2) at the firm-country-product-year level through correlations between patent applications and sales (Panel A), unit values (Panel B) and quantities (Panel C). We note that when testing the patterns of *tradepat* versus *nontradepat* firms, the composition of the control group must be taken into account. This is particularly true for the definition of *nontradepat* firms and the relationship with patent filing across destinations. In our first, broad, sample we include in the control group all observations from *nontradepat* firms that sell at least one common product with *tradepat* firms to any destination in which *tradepat* firms export. In other words, we exclude firms that don’t sell common products with *tradepat* firms. Yet this assumes that *nontradepat* firms compete with *tradepat* firms in all products exported, including those not exported by *tradepat* firms. This could interfere with the identification of the effects of patent filing, as *nontradepat* firms might shift their product mix towards products not exported by *tradepat* firms to avoid competition by innovators. To isolate precisely the effects of patent filing on export margins and neutralize this product composition issue, we want to hold as constant as possible the product range. One solution is to restrict the sample to products exported by both *tradepat* and *nontradepat* firms to any destination in which *tradepat* firms sell. This is less restrictive than it might seem. For instance, if a *tradepat* firm exports 5 products to a single country, we keep in the sample of *nontradepat* firms only the observations from their exports in these products to any destination to which *tradepat* firms export. The composition issue is mitigated, but the disadvantage of this solution is that the control group contains country-product observations to which *tradepat* firms may not sell. To minimize this representativeness issue, a solution is to keep in the control group only product-destination pairs that are common with *tradepat* firms. Both the product composition and representativeness issues are then eliminated, but this reduces the coverage of the sample, since common product-country pairs in the destinations by *tradepat* firms represent a small share in total exports of *nontradepat* firms.

No sample is therefore an ideal solution to our assessment on the effects of patent applications on export margins and we experiment with different variants of sample selection. Columns (1)-(3) consider only the 6,085 *nontradepat* firms that share at least one common product with the focal group and export to the 125 countries in which *tradepat* firms sell. Overall, results show that country-product pairs by *tradepat* firms are associated with increased export sales stemming from higher volumes sold, whereas the coefficient on unit values is small and insignificant. Note that in column (3) we include the number of destinations per firm, number of products per firm, age and employment as controls to account for productivity and size effects, which reduces our sample of *nontradepat* firms to 4,679. Columns (4)-(6) consider the common products of the firms without applications (5,547 firms in total) with the focal group. As above, Column (6) includes firm controls and the sample reduces due to missing data, yet the results are by and large confirm that higher sales stem from higher quantities rather than higher prices. Columns (7)-(8) consider only the common country-product pairs *tradepat* and *nontradepat* firms alike. These amount to 2,076 pairs, whereas in the control group we have at least one entry for

1,541 pairs. The results are similar to those reported earlier on.

The overall picture points to the main finding from the stylized facts: patent applicants have higher export sales than non-applicants with this difference generated by higher quantities exported. In the next section we outline a model that aims at accommodating these facts and deriving testable empirical implications.

4. The Model

We develop a standard vertically differentiated product model, in which firms' profit depends on the degree of vertical and horizontal competition among the rivals (Gabszewicz and Thisse, 1979; Shaked and Sutton, 1983). In particular, an innovative firm with monopoly rights over its technologies compete for market share against many non-innovative and homogeneous-product rivals.

Consumers' preferences. Consider that domestic firms export in a foreign market. There exists a innovative exporter who sells its high-quality (innovative) product and holds intellectual property rights over its innovations. In turn, this firm does not face direct competition for consumers who are willing to buy innovative products. However, it faces competition from n non-innovative domestic exporters, who offer a lower-quality (non-innovative) variant of the good. Thus, each of latter firms competes vertically with the innovative monopolist and horizontally with its $n-1$ non-innovative rivals.

The market is populated by a continuum of identical consumers with mass equal to 1. The consumers are uniformly distributed along this vertical market and differ in the marginal willingness-to-pay for this attribute, θ_i , which is also uniformly distributed on the [0,1] interval.[11] The dispersion in θ could be driven by differences in consumer income, or more generally by differences in preferences. We assume that the preferences of consumer *i* for product *k* are described by the indirect utility function

$$V_{ij} = \theta_i s_k - p_k,$$

where s_k is the value of the attribute for product *k*, where the latter will be indexed by *H* and *L* if

[11] Fixing the upper and lower bounds of the distribution does not result in any loss of generality, given that units of product quality can be arbitrarily rescaled.

it produced by the innovator and the $n-1$ non-innovative rivals respectively, and p_k is the price of product *k*. The innovative firm exports a higher quality product than its non-innovative rivals, implying that $s_H > s_L$. Consumers also have the option of making no purchase and earning a utility of zero.

Firms' demands and profits. To derive the demand for each variant of the product, we first determine the critical value $\widehat{\theta}_1$, at which a consumer is indifferent between purchasing from the innovative exporter and purchasing from a non-innovative competitor. We have $\widehat{\theta}_1 s_H - p_H = \widehat{\theta}_1 s_L - p_L$, implying that

$$\widehat{\theta}_1 = \frac{p_H - p_L}{s_H - s_L}. \tag{3}$$

Thus, every consumer *i* with $\theta_i > \widehat{\theta}_1$ will purchase from the innovative firm, whose demand function becomes $q_H = 1 - \widehat{\theta}_1$. Let also $\widehat{\theta}_0$ be the willingness-to-pay for quality of the consumer who is indifferent between purchasing from a non-innovative firm and not purchasing at all. We set $\widehat{\theta}_0 s_L - p_L = 0$, which gives $\widehat{\theta}_0 = \frac{p_L}{s_L}$. Every consumer *i* with a value of θ_i in the interval $[\widehat{\theta}_0, \widehat{\theta}_1]$ purchases from a non-innovative firm. Provided also that θ_i has a uniform distribution, the sales volume of all non-innovative firms is $Q_L = \left(\widehat{\theta}_1 - \widehat{\theta}_0\right)$, where $\widehat{\theta}_1$ is given in (3).

To satisfy their demands, the innovative and non-innovative firms produce by bearing convex costs, $c_H\left(q_H\right)^2$ and $c_L\left(q_L\right)^2$, respectively, where $c_H < c_L$. We assume that the innovative firm has invested in product *and* process innovation, implying that the production of the innovative product is associated with lower cost than the production of its lower-quality variant. In addition, all firms incur a trade cost in order to ship their products from the country of origin where the production takes place to the consumers in the country of destination. This is an iceberg transportation cost, $\tau > 1$, per unit of their exports, which can be considered as an ad valorem tax equivalent and is uniform for all firms regardless of the product's quality. In our model, it increases with distance: the per-unit cost increases as the good is shipped to more distant markets.

In contrast to the literature on vertically differentiated product markets that considers price competition among the rivals, we assume that firms compete in quantities. The finding that the Greek innovative exporters do not set substantially different prices, but their higher export revenues are driven by the volume of their sales, indicates that firms compete for market share through quantities. Thus, we consider that exporters' strategic decisions are their production levels, and express their prices as functions of their outputs:

$$p_H = \left[(1-q_H)s_H - Q_L s_L\right],$$
$$p_L = s_L(1-q_H-Q_L).$$

The profit functions of the innovative firm and a non-innovative competitor *i* are, respectively,

$$\pi_H = (p_H - \tau c_H q_H)q_H = \left[(1-q_H)s_H - Q_L s_L - \tau c_H q_H\right]q_H$$
$$\pi_L^i = \left(p_L - \tau c_L q_L^i\right)q_L^i = \left[s_L\left(1-q_H-q_L^i-Q_L^j\right)-\tau c_L q_L^i\right]q_L^i,$$

where $Q_L^j \equiv \Sigma_{j\neq i} q_L^j$ denotes the total output produced by the $n-1$ non-innovative rivals of firm *i*.

Optimal production. Firms choose the output level that maximizes their net profits. Taking and solving the first-order conditions gives

$$q_H^* = \frac{1}{\lambda}\left[s_L\left(s_H + n(s_H - s_L)\right) + 2s_H\tau c_L\right],$$

$$q_L^{i*} = \frac{s_L}{\lambda}(s_H + 2\tau c_H),$$

where $\lambda \equiv 2s_L\left[s_H + (n+1)\tau c_H\right] + 4\tau c_L(s_H + \tau c_H) + ns_L(2s_H - s_L)$.

Each firm's optimal quantity decreases with its own marginal cost, while it increases as rivals' production becomes more costly. In particular, as c_L increases, the non-innovative exporters produce less, loosing share in the foreign market. This favors their innovative rival by allowing the latter firm to expand its own business. The innovative firm also benefits from a quality improvement of its own product, since the quality difference between the two variants increases. The vertical competition becomes less intense, allowing the innovator to sell more, while exercising a larger price-cost margin. An increase in s_H shifts the innovative firm's demand curve outward and, thus, has the opposite effects on the non-innovative firms' sales. Consumers flee to the innovative firm.[12]

In equilibrium, the innovative firm exports more compared to its non-innovative rivals, $q_H^* - q_L^{i*} > 0$, regardless of the degree of competition among its competitors. Even if the market for the lower-grade product is also monopolized, fewer units of this product will be shipped out.[13] The distance between the country of origin and the foreign market also plays a key role on firms' exporting behavior. The transportation cost increases with distance, weakening firms' incentives to ship their products in markets which are further away. However, a higher τ decreases the total production of the non-innovative firms to a greater extent, implying that the innovative firm gains in market share in more distant markets. The Alchian-Allen-like result ("shipping the good apples out") holds: consumption will shift toward the high-grade product as the transportation cost increases, $\frac{\partial\left(q_H^* - Q_L^{i*}\right)}{\partial\tau} > 0$. The innovative monopolist will be benefited even further, as the number of non-innovative firms who export in the same foreign market also grows larger. Thus, as the competition among the exporters of the non-innovative product becomes more intense, the innovative firm will export more compared to its non-innovative rivals in more distant markets.[14]

5. Empirical test

Empirical specification. According to our model, incorporating patent applications in micro-trade data allows for testable predictions. The main question of interest is how innovation

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[12] In a setting with a high-quality dominant firm and a low-quality fringe, where firms compete in prices and $c_H < c_L$, Balan and Deltas (2013) show that an increase in the dominant firm's quality increases the willingness to pay of the consumers with high θ by more than those with low θ and leads to a pivoting of the inverse demand curve.

[13] We perform this analysis by considering the markets in which both types of firms are present. For instance, if only non-innovative Greek firms export say in Albania, we cannot shed insights in their export behavior.

[14] Notice that an increase in the transportation cost, τ, trivially increases the optimal prices of both variants of the product, but the price of the innovative product increases by more ($\frac{\partial\left(p_H^* - p_L^{i*}\right)}{\partial\tau} > 0$), which implies that the critical value $\widehat{\theta}_1$, at which a consumer is indifferent between purchasing from the innovative or a non-innovative competitor, increases. Only consumers with a higher willingness-to-pay buy the innovative product and its quality decreases in more distant markets. Thus, the high-quality monopolist profits more by selling fewer units at a higher price. In particular, consumers with willingness-to-pay slight lower than $\widehat{\theta}_1$ who buy from the innovative firm in markets close to the country of origin, flee to the low grade of the product in more distant markets since the innovative product becomes more expensive due to the transportation cost. However, p_L and thus $\widehat{\theta}_0$ also increase with τ. Consumers whose willingness-to-pay is low are allowed to get the non-innovative product in markets that are close to Greece, they be excluded in more distant markets where p_L increases. Overall, although fewer consumers purchase the innovative product in markets further away, there are fewer consumers for the non-innovative product as well, i.e. ($\widehat{\theta}_1 - \widehat{\theta}_0$) decreases with τ.

captured by patent applications affects export volumes at the firm level through distance and competition. In this section we establish that the observed firm level behavior is consistent with our model. Specifically, the observed differences in exported quantities between *tradepat* and *nontradepat* exporters allow for the channel that links the model to the behavior of innovators compared to non-innovators.

Hypothesis 1. A *tradepat* exporter will have higher export volumes than its *nontradepat* competitors in more distant destinations when the number of competitors in the destination is higher.

In the empirical analysis we use our data on Greek exporters to examine the relationship between exported quantities by innovators and non-innovators with respect to distance and competition by outlining the following general specification:

$$\ln(q_{i,d,k,t}) = \gamma_0 + \gamma_1 APP_{i,t} + \gamma_2 (APP_{i,t} \text{ X } high\_comp_{d,k,t}) + f_i + \delta_{ik} + \varepsilon_{i,d,t}$$

where $q_{i,d,k,t}$ denotes the volume (quantity of physical output) of product k by firm i shipped to destination d in period t, $APP_{i,t}$ is the patent application dummy, and ($APP_{i,t}$X$high_comp_{d,k,t}$) is an interaction term of the patent application dummy with a dummy variable on high competition in the destination-product pair. In our regressions, the latter takes the value of 1 if there are more than four Greek firms exporting in a destination a specific product at a given year, which is the median in our sample, and zero otherwise.

To address Hypothesis 1, we first run the above specification separately for countries above and below the 1050km distance, which is the median in our sample of destinations, and compare the estimated coefficients from these two estimations. The primary interest is in the signs and significance levels of γ_2 in each regression, which reflect the conditional correlations between quantities exported at the firm-destination-product level and the impact of competition on *tradepat* firms depending on the destination distance. Specifically, we expect γ_2 in the case of distant countries to be positive and larger than in the case of close countries. It should be emphasized that, as in Manova and Zhang (2012), the coefficient γ_2 cannot be given a causal interpretation because export volume and many firm attributes are both affected by unobserved firm characteristics. Moreover, these two variables are the joint outcome of firms' profit maximization and, hence, simultaneously determined. Notice that we always control for gdp per capita (proxy for destination income) and the effects of the *APP*, *high_comp* and *dist* variables independently or in paired terms. We also include the number of destinations per firm, number of products per firm, age and employment as additional covariates and firm-product pair fixed effects, δ_{ik}.

Alternatively, we test for the joint significance of distance and competition between *tradepat* and *nontradepat* exporters by pooling all observations and including the additional triple interaction term ($APP_{i,t}$ X *high_comp* X *dist*). We expect the coefficient of this triple interaction term to be positive.

Baseline regressions. Table 4 presents the regression results In columns (1) and (2) we consider as control group firms that share at least one common product and sell in the 43 destinations where *tradepat* firms have filed for an application. Albeit the set of countries is narrowly defined, the overall sales of *tradepat* and *nontradepat* firms in these destinations account for approximately 80% of their total exports in our sample period. The first column presents the results for distant countries and column 2 for close ones. In line with Hypothesis 1, the coefficient on the interaction term between the application and the high competition dummies is positive and significant at the 10% level for distant countries and insignificant for close ones. This effect does not mask any direct effects captured by the *APP* and/or *high_comp* variables individually, which both enter with positive and statistically significant signs. A similar picture emerges in columns (3) and (4), in which a more narrowly defined group consisting of observations from products sold by *tradepat* firms is used. The coefficient on the interaction term is positive and significant at the 5% level for distant countries, whereas it is insignificant for close destinations. In column 5 we pool all observations in a single regression and introduce the triple interaction term. This eliminates the significance of the interaction term between *APP* and *high_comp*, whereas in line with Hypothesis 1 the triple interaction is positive and statistically significant at the 5% level. In Columns (6)-(8) we further narrow our control group considering only country-product pairs for which *tradepat* firms export. We get a similar picture on the coefficients of the interaction term for distant and close countries. The coefficient on the triple interaction term in column (8) remains positive but is now insignificant, probably due to the substantially smaller sample size for this specification compared to column (5).

A consideration to the above results might be that we focused on destinations in which the innovators have filed for a patent application. Hence the observed export performance might be due to property (monopolistic) rights, rather to the innovating nature of the firm. To address this issue, in Table 5, we expand our sample to all countries in which the innovators export. Table 5 presents the results from the corresponding regressions based on observations from these 125 countries. In the regressions split to distant and close countries for the various controls groups, the coefficients for distant countries are positive and significant, whereas they turn out insignificant for close destinations. The same holds when the sample is pooled and the triple interaction term is included, which is positive (and significant in the broader sample). The persistence of the overall picture implies that higher export volumes in a destination where the *tradepat* firm has filed an international patent application cannot be attributed to any monopolistic rights.

Patent strength. Patenting is an "expensive sport". Berger (2005) estimated that the cost of obtaining a single European Patent could reach up to 30,000 Euros when legal counsel and drafting services are included to the fees required to be paid.[15] Further, these rights are not set in stone as once the patent is granted the possibility of infringement always looms with potentially significant losses for the patent holder (Lanjouw and Schankerman, 2001; Galasso and Schankerman, 2015). Notably, although the patent system is important for innovative exporters if they believe they have an advantage over domestic incumbents, the patent regime may also discourage exports if a related patent already exists in the destination country. Therefore, enforceable patent rights may a priori both trigger and hinder patented exports.

Not surprisingly, the impact of international patent strength has received attention in the relevant literature. Maskus and Penubarti (1995) were the first to consider empirically the impact of patent laws in international trade. This literature has shown patent strength is positively related to trade and has been studied extensively for specific countries (see Smith, 1999, for the US and Rafiquzzaman, 2002, for Canada) and industries (Galushko, 2012, for the seed industry) and to quantify the differential implications that it may have on developed compared to developing countries (Schneider, 2005; Ivus, 2010).[16] Recently, Palangkaraya et al. (2017) estimate the

[15] See also European Commission (2011) for a detailed review of costs arising from international patent filing.
[16] See Akkoyunlu (2013) and the references cited therein.

impact of patent examination outcomes on export flows at the industry level by examining the bias against foreigners and the fear of infringement suits in the destination country and find, after controlling for the quality of the invention, evidence that both effects are negative.

In our context, innovative activity in the form of patent filing might simply mask strong patent protection, since the two variables are positively associated (Allred and Park, 2007). When faced with costs in terms of patent protection, a firm will have a tendency to file for a patent in the country in which it expects a high volume (and value) of export sales. Those effects could interfere with the identification of Hypothesis 1 regarding the volume of export sales and ideally we would like to isolate its prediction, uncontaminated by cross-country differences coming from legislation, enforcement and other institutional factors regarding the protection of patents.

Although the extended sample of Table 5 partly addresses this issue, we also control for patent strength by adopting the most widely used patent strength index by Ginarte and Park (1997) and Park (2008). The index rates the strength of national patent laws, based on extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, duration of protection, and is available for 87 out of 125 countries to which *tradepat* firms export.[17] In Table 6 we re-estimate Table 5 for these 87 countries and control for the patent strength with higher index scores indicating stronger levels of protection. Its coefficient enters with a positive sign and is significant in all specifications (with one exception). This finding is consistent with the aforementioned literature which finds a positive association between patent strength and export sales at the industry level. A rise in patent strength indicates that firms are more likely to sell their innovative products in these countries as the fear of infringement is mitigated.

The results regarding Hypothesis 1 are similar to those obtained in Tables 4 and 5. Specifically, the coefficients on the interaction in Table 6 is again positive and statistically significant for distant countries (columns 1, 3 and 6) and insignificant in columns 4 and 7 for close countries, whereas it turns out negative and marginally significant in column 4. The triple interaction term in the pooled sample is positive and statistically significant at the 1% level in column 5. In general, there is no evidence that controlling for patent strength affects the association implied by Hypothesis 1.

[17] The data can be found at http://nw08.american.edu/~wgp.

6. Conclusions

In this paper we have examined the relationship between innovation reflected in patent filing behavior and export behavior at the firm-product level. Exploiting a unique cross section of detailed Greek exports and patent data we are able to add insights on the behavior of applicants versus non-applicants. To our knowledge, this is the first paper that attempts to answer this question in the micro-exporting literature. Our results show that patent applicants export more per product than non-applicants. This result on higher export values is driven primarily from higher export volumes, rather than increased pricing. To account for this evidence, we set up a model of vertically differentiated products. In a foreign market, the innovative exporter sells a high-quality good under monopoly rights and faces competition by non-innovative exporters. We argue that, if the number of non-innovative firms is large and thus competition among them is stiff, the innovative firm will sell higher quantities in more distant markets, a prediction that is robustly confirmed in our data.

Overall, our findings are relevant for the policy agendas in Greece and other similar European countries, for which European authorities have placed high priority in boosting competitiveness through innovation, especially in light of the financial crisis. Notably, Greece ranks very low in terms of patent application per capita among the 28 EU countries.[18] Innovative exporters are often at a disadvantage as third parties producing and selling patented products in foreign markets due to the high costs associated with obtaining protection, a situation that is further aggravated by the fragmentation of licensing agencies. Our findings indicate that the presence of innovators with international patent rights can enhance competition, as their higher revenues stem from selling higher quantities, rather than charging higher prices generated by monopolistic rights, and that these firms should be encouraged to enter in distant and more competitive markets.

[18] https://www.epo.org/about-us/annual-reports-statistics/statistics.html.

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Table 1. Patent applications and exporting firms (2005-2007)

	A. firm level	
	non_tradepat firms (6085 obs.)	*tradepat firms (79 obs.)*
sales	3.68	50.44
products	8.72	14.08
destinations	5.84	20
	B. firm-country-year level	
	non_tradepat firms (66347 obs.)	*tradepat firms (3184 obs.)*
sales per destination	0.34	1.21
products per destination	2.4	1.83
	C. firm-country-product-year level	
	non_tradepat firms (159718 obs.)	*tradepat firms (5824 obs.)*
unit value	50.68	78.46
quantity	149.43	410.15

Notes: *non_tradepat* and *tradepat* denote firms without and with international patent applications, respectively. Figures reported denote the averages. Sales are in million Euros and Quantities are in thousand kilos.

Table 2. Patent applications and export sales

	(1)	(2)	(3)	(4)
	Dependent Variable: *export sales*			
application	1.176***	1.116***	0.386**	0.463**
	(0.225)	(0.225)	(0.182)	(0.198)
# destinations per firm			0.478***	0.435***
			(0.0319)	(0.0323)
# of products per firm			0.0869***	0.171***
			(0.0280)	(0.0300)
age			-0.00654***	-0.0124***
			(0.00199)	(0.00205)
employment			0.275***	0.00035***
			(0.0226)	(0.00011)
distance		-0.0870***		-0.202***
		(0.0147)		(0.0151)
gdp per capita		-0.0251*		-0.0165
		(0.0147)		(0.0149)
R-squared	0.034	0.011	0.147	0.089
observations	69,531	69,531	65,497	65,497
country FE	YES	NO	YES	NO

Notes: All variables except *age* are in logs. All regressions include a constant and firm-product fixed effects. Standard errors are clustered at the firm level.

Table 3. Patent applications and components of export sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				A. Dependent variable: *export sales*				
application	0.793***	0.771***	0.534***	0.782***	0.772***	0.536***	0.793***	0.406***
	(0.120)	(0.117)	(0.115)	(0.118)	(0.115)	(0.114)	(0.149)	(0.139)
distance		-0.057***	-0.079***		-0.061***	-0.084***		-0.085***
		(0.009)	(0.009)		(0.012)	(0.013)		(0.022)
gdp per capita		-0.005	-0.022*		-0.006	-0.027*		0.025
		(0.011)	(0.011)		(0.014)	(0.015)		(0.031)
R-squared	0.428	0.417	0.427	0.387	0.375	0.387	0.442	0.445
				B. Dependent variable: *export price*				
application	0.0576	0.0873	0.079	0.058	0.085	0.103*	0.017	0.087
	(0.0546)	(0.055)	(0.058)	(0.054)	(0.054)	(0.058)	(0.063)	(0.068)
distance		0.0234***	0.0253***		0.034***	0.038***		0.030***
		(0.004)	(0.004)		(0.005)	(0.005)		(0.009)
gdp per capita		0.141***	0.139***		0.130***	0.128***		0.128***
		(0.005)	(0.005)		(0.006)	(0.006)		(0.013)
R-squared	0.816	0.812	0.815	0.755	0.751	0.753	0.781	0.777
				C. Dependent variable: *export quantity*				
application	0.735***	0.684***	0.455***	0.724***	0.687***	0.433***	0.776***	0.319**
	(0.137)	(0.133)	(0.134)	(0.135)	(0.131)	(0.134)	(0.166)	(0.159)
distance		-0.080***	-0.104***		-0.096***	-0.122***		-0.115***
		(0.010)	(0.010)		(0.014)	(0.014)		(0.025)
gdp per capita		-0.146***	-0.162***		-0.137***	-0.156***		-0.102***
		(0.013)	(0.013)		(0.017)	(0.018)		(0.036)
R-squared	0.628	0.621	0.627	0.562	0.554	0.561	0.592	0.594
observations	165,542	165,542	157,555	77,200	77,200	72,607	24,692	23,298
# of control firms	6,085	6,085	4,679	6,082	6,082	4,677	3,709	3,081

Notes: All variables are in logs. All regressions include a constant and firm-product pair FE. Standard errors are clustered at the firm-product level. Columns (1), (4), (7) include destination-product fixed effects; Columns (3), (6) and (8) include *log(#destinations per firm), log(#products per firm), log(employment)* and *age*. The control groups are defined as follows. Columns (1)-(3): firms that share at least one common product as tradepat firms in the 125 countries where *tradepat* firms sell. Columns (4)-(6): observations of products sold by *tradepat* firms in the 125 countries where *tradepat* firms sell. Columns (7) and (8): observations of country-product pairs that match with those of *tradepat* firms in the 125 countries where *tradepat* firms sell.

Table 4. The effects of destination, distance and competition on export quantities of *tradepat* firms vs. *nontradepat* firms (43 countries)

	Dependent variable: *export quantity*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Distant	Close	Distant	Close		Distant	Close	
application X high_comp	**0.303***	**-0.479**	**0.359****	**-0.417**	**-0.221**	**0.488***	**0.318**	**0.0818**
	(0.170)	**(0.357)**	**(0.173)**	**(0.357)**	**(0.258)**	**(0.257)**	**(0.589)**	**(0.506)**
application X distant X high_comp					**0.573****			**0.395**
					(0.257)			**(0.529)**
application	0.485**	1.055***	0.396*	0.991***	0.674***	0.079	0.124	0.251
	(0.213)	(0.367)	(0.211)	(0.365)	(0.257)	(0.262)	(0.586)	(0.499)
distant					-0.468***			-0.373
					(0.094)			(0.421)
high_comp	0.683***	0.183***	0.629***	0.105	0.261***	0.505***	0.006	0.195
	(0.039)	(0.054)	(0.057)	(0.111)	(0.092)	(0.186)	(0.472)	(0.391)
application X distant					-0.165			-0.035
					(0.236)			(0.516)
distant X high_comp					0.238**			0.127
					(0.101)			(0.421)
observations	71,705	73,449	29,700	30,720	56,857	8,235	12,056	20,291
R-squared	0.684	0.648	0.629	0.574	0.566	0.674	0.589	0.595

Notes: All regressions control for gdp per capita and include firm-product pair fixed effects and a constant. Standard errors are clustered at the firm-product level. Columns (1)-(4) include *log(#destinations per firm), log(#products per firm)*, and Columns (5)-(8) include additionally *log(age)* and *log(employment)*. The control groups are defined as follows. Columns (1)-(2): firms that share at least one common product as *tradepat* firms in the 43 countries where *tradepat* firms have patent filings. Columns (3)-(5): observations of products sold by *tradepat* firms in the 43 countries where *tradepat* firms have patent filings. Columns (6)-(8): country-product pairs that match with those of *tradepat* firms that match with those of *tradepat* firms. Columns (1), (3) and (6) include countries that are located further than 1050 km from Greece. Columns (2), (4) and (7) include countries that are located within 1050 km from Greece. Columns (5) and (8) include all countries. *distant* is a dummy that takes the value of 1 if country *c* is located more that 1050km from Greece and zero otherwise. *high_comp* is a dummy that takes the value of 1 if in country *d*, product *k*, year *t*, there are more than four Greek firms exporting and zero otherwise.

Table 5. The effects of destination, distance and competition on export quantities of *tradepat* firms vs. *nontradepat* firms (125 countries)

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	**0.304****	**-0.267**	**0.414*****	**-0.245**	**0.002**	**0.438****	**0.365**	**0.150**
	(0.128)	**(0.321)**	**(0.130)**	**(0.321)**	**(0.221)**	**(0.210)**	**(0.512)**	**(0.440)**
application X distant X high_comp					**0.454****			**0.292**
					(0.224)			**(0.455)**
application	0.305*	0.846**	0.210	0.817**	0.481**	-0.016	0.109	0.212
	(0.165)	(0.332)	(0.166)	(0.330)	(0.222)	(0.220)	(0.506)	(0.431)
distant					-0.376***			-0.349
					(0.078)			(0.338)
high_comp	0.644***	0.226***	0.546***	0.185**	0.309***	0.468***	0.199	0.323
	(0.033)	(0.052)	(0.045)	(0.093)	(0.078)	(0.142)	(0.399)	(0.331)
application X distant					-0.260			-0.157
					(0.204)			(0.440)
distant X high_comp					0.151*			0.064
					(0.086)			(0.341)
observations	90,635	74,907	42,938	34,262	72,607	10,880	12,418	23,298
R-squared	0.677	0.648	0.619	0.575	0.565	0.665	0.590	0.596

Notes: The control group is defined in the 125 countries where *tradepat* firms sell. See Table 4 for further details on variables' definitions and estimation details.

Table 6. Controlling for patent strength

	Dependent variable: *export quantity*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Distant	Close	Distant	Close		Distant	Close	
application X high_comp	**0.392****	**-0.658***	**0.533*****	**-0.606**	**-0.173**	**0.595****	**0.0151**	**0.0167**
	(0.156)	**(0.384)**	**(0.159)**	**(0.385)**	**(0.272)**	**(0.265)**	**(0.639)**	**(0.577)**
application X distant X high_comp					**0.753*****			**0.488**
					(0.284)			**(0.601)**
application	0.294	1.214***	0.176	1.164***	0.618**	-0.022	0.436	0.321
	(0.184)	(0.395)	(0.185)	(0.395)	(0.271)	(0.268)	(0.637)	(0.570)
distant					-0.311***			-0.391
					(0.095)			(0.476)
high_comp	0.645***	0.283***	0.533***	0.215*	0.450***	0.418**	0.157	0.365
	(0.0385)	(0.0642)	(0.0547)	(0.121)	(0.097)	(0.181)	(0.508)	(0.458)
application X distant					-0.415			-0.248
					(0.259)			(0.582)
distant X high_comp					-0.053			-0.044
					(0.106)			(0.481)
patent strength	0.405***	0.422**	0.247	0.481*	0.624***	1.560***	1.097**	1.161***
	(0.146)	(0.180)	(0.183)	(0.268)	(0.147)	(0.512)	(0.516)	(0.334)
observations	72,024	63,590	33,665	28,518	58,578	8,395	10,285	18,680
R-squared	0.693	0.663	0.638	0.594	0.580	0.686	0.606	0.612

Notes: See Table 4 for further details on variables' definitions and estimation details.