INNOVATION, PATENTS AND TRADE:
A FIRM-LEVEL ANALYSIS

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Innovation, patents and trade: A firm-level analysis

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Abstract. Using microdata 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 horizontally differentiated product model in which an innovative exporter competes for market share in a destination against many non-innovative rivals. We argue that as the competition among the exporters of the non-innovative product becomes more intense, the innovative firm exports more compared with its non-innovative rivals in more distant markets, a prediction that is empirically confirmed in the dataset for Greek innovative exporters.

Résumé. Innovation, brevets et commerce : analyse au niveau de l'entreprise. À l'aide de microdonnées d'entreprises relatives aux exportations et aux activités de brevetage international, nous montrons que les exportateurs grecs innovants, identifiés par leurs dépôts de brevets, réalisent des gains à l'exportation nettement supérieurs en misant davantage sur les volumes de vente que sur l'augmentation des prix. Pour expliquer cette situation, nous avons élaboré un modèle de différenciation horizontale de produits dans lequel les exportateurs novateurs sont en compétition avec de nombreux concurrents non innovants afin de gagner des parts de marché. Nous montrons qu'à mesure que la compétition s'intensifie entre les exportateurs de produits non innovants, l'entreprise innovante exporte davantage que ses concurrents vers les marchés plus éloignés ; cette

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prédiction se vérifie de façon empirique grâce aux données relatives aux exportateurs grecs innovants.

JEL classification: F14, L15, O34

1. Introduction

Innovative activity is associated with export intensity. Several studies over the last decade have shown substantial evidence to support the strong link between exports and innovation at the firm level (Aw et al. 2011, Arndt et al. 2012, Aghion et al. 2018). Despite the significant insights on this strong relationship, there is no evidence on the decomposition of export sales by innovative firms, captured by the prices charged and quantities sold across markets. This paper attempts to shed some light in the exporting behaviour of innovators focusing on the decomposition of export sales and using a newly composed dataset for innovative Greek manufacturing exporters.

We explore the differences in the behaviour of innovative firms versus non-innovative ones in export markets. Patents grand intellectual property rights and are widely employed by firms to protect their inventions.[1] Thus, we identify innovators through their patent filing activity as in Aghion et al. (2018).[2] In particular, we use patent filing at the firm level to capture product and process innovation, and provide a comprehensive theoretical and empirical analysis on the implications of innovation for exporting activity. To this end, we first examine the behaviour of Greek innovative exporters, classified as innovators based on their international patent filing, versus non-innovative exporters. Our descriptive analysis shows that exporting firms with patent applications account for approximately 1.3% of total manufacturing exporters, a finding that agrees with studies for the US (Graham et al. 2018) and France (Aghion et al. 2018). Yet this relatively small percentage of exporters accounts for 23.6% of total export sales. We then establish that, in contrast to conventional wisdom, innovators obtain their high export sales through larger volumes exported, rather than higher prices.

Motivated by this stylized fact, we build a horizontally differentiated product model in which an innovative firm competes for market share against many non-innovative rivals. We show that in more distant markets, higher transportation costs reduce the sales of non-innovative firms to a greater

1 Early research examined the role of patents on firm's market value (Austin 1993, Blundell et al. 1999, Kogan et al. 2017). Patents have also been shown to play an integral part to economic growth (Aghion and Howitt 1992, O'Donoghue and Zweimüller 2004). More recent studies have also shown that firms that engage in patenting increase their sales and exports (Balasubramanian and Sivadasan 2011), attract venture capital (Haeussler et al. 2014) and increase the likelihood of technology transfer (Elfenbein 2007, Gans et al. 2008).

2 See section 2 for the detailed presentation of the dataset.

extent, implying that the innovative firm gains in market share. This is in line, although in a different setting, with the Alchian–Allen result broadly known as "shipping the good apples out" (Alchian and Allen 1964). A novel finding that stems from our analysis is that as the competition among the exporters of the non-innovative product becomes more intense, the innovative firm will export more compared with its non-innovative rivals in more distant markets, reinforcing our Alchian–Allen-like result. We then take this prediction to the data. Our empirical results confirm the main prediction of the model in a variety of specifications, which check for robustness to the degree of patent strength in the destination country, the definition of competition and the inclusion of domestic patent filing.

Our paper relates to the literature on micro-exporting that examines the behaviour of exporting firms with innovative activities (see, among others, Atkeson and Burstein 2010 and Caldera 2010).[3] Atkeson and Burstein (2010) develop a model that analyzes the impact of a change in trade costs on heterogeneous firms' decisions to exit, export, and innovate and find that resulting changes in these decisions may be largely offset by the response of product innovation so that welfare is not affected. Caldera (2010) investigates the relationship between innovation and the export behaviour of firms using data from a representative panel of Spanish firms over 1991–2002 and finds a positive effect of firm innovation on the probability of participation in export markets that depends on the type of innovation. We contribute to this literature by looking at innovative exporters through the lens of international patent activity across foreign markets. To our knowledge, our paper is the first that shows how competition and distance to the foreign market are associated with the export volumes sold by innovators versus the non-innovative exporters.

Our work is also related to the literature that aims to identify and quantify the implications of international patenting activity. Harhoff et al. (2009) have examined at the country level the flows of patenting activity within the European Patent Office and their findings indicate the size of countries, their wealth and the distance between their capital cities as significant determinants of patent flows. Chan (2010) has analyzed the international patent profiles of nine agricultural biotechnology firms from 1990 to 2000 and finds that invention quality plays an important role in firms' decisions to patent abroad. Albeit innovating firms conduct a large part of their activity in foreign markets, this literature has not explicitly considered the relationship between patent filing and exporting at the firm level.

The paper closest in spirit to ours is Aghion et al. (2018), who investigate the effects of export shocks on innovation and distinguish between two types of impacts.[4] On the one hand, a positive shock increases market size, intensifying

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3 Bernard et al. (2012); they review the empirical studies in trade at the firm level.

4 See Shu and Steinwender (2018) for an extensive review on the impact of trade shocks on productivity and innovations.

all firms' incentives to innovate. On the other hand, it raises competition as more firms enter the export market, resulting in lower profits and weaker incentives to innovate. Overall, the positive impact of the export shock on innovation is magnified for high productivity firms, whereas it will adversely affect innovation in low productivity firms. Using data for French manufacturing firms, the authors show that patenting increases more with export demand for initially more productive firms, but this effect is reversed for the least productive firms as the negative effect of increased competition dominates. Our paper contributes to this analysis by highlighting the dominant role of quantities in the export sales of innovators and by exploring the effects of competition in conjunction with the distance to the foreign market for the behaviour of innovators and the volume of their sales.

It should be pointed out that a vast literature has examined the nexus between productivity and exporting activity at the firm level while several empirical studies investigate the link between innovation and productivity.[5] While innovation can be related to productivity, it is not synonymous. The Organisation for Economic Co-operation and Development (OECD) defines innovation as "*a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)*" (OECD 2018). Productivity describes how available resources have been deployed, given by economic output per unit of input. The unit of input can be labour hours (labour productivity) or all production factors including machines and energy. Productivity therefore can increase as a firm becomes more efficiently organized but innovation can be a separate process; for example, smaller "bricks and mortar" bookstores go out of business because consumers prefer to buy e-books, even though these bookstores were efficiently organized. Our analysis assumes that there are shocks—independent from productivity—that affect a firm's ability to file for patents in different countries. These shocks could be related to other drivers of innovation, such as ownership, business environment and other related factors (European Bank for Reconstruction and Development 2014). Bearing in mind the possible link between productivity and innovation, we focus on innovation and exporting behaviour while trying to control for the impact of productivity.

5 There is an extensive literature, based on Melitz (2003) and Bernard et al. (2003), that emphasizes the productivity and welfare gains from intra-industry trade in markets with heterogeneous firms. Bernard et al. (2007, 2012), Redding (2011), Melitz and Trefler (2012), and Melitz and Redding (2014) provide extensive surveys of related theoretical and empirical literature. Early studies linking innovation with productivity have shown a positive association (Crépon et al. 1998), subsequent studies have shown that there is significant heterogeneity associated with this relationship. For example, Griffith et al. (2006), using firm-level data for France, Germany, Spain and the UK, find mixed evidence on the association of innovation and productivity.

The rest of the paper is organized as follows. Section 2 discusses how the dataset was constructed, emphasizing the data on firms with patent applications, and provides descriptive statistics and stylized facts. Section 3 outlines the theoretical framework and section 4 tests the main empirical implications. Section 5 concludes the paper.

2. Data and stylized facts

In this section, we present the dataset of Greek exporters and the main characteristics of innovative firms. We also present some stylized facts of innovative versus non-innovative firms that motivate our theoretical model that follows in section 3.

2.1. Data construction

In this subsection, we explore the data on the innovative activity of Greek exporters. To this end, we merge data from two main sources. First, we obtain detailed data on the exporting activity of all Greek firms from the Intrastat–Extrastat 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 five-digit SITC level of product disaggregation (SITC5). In line with the literature, we exclude a number of outliers related to prices: (i) at the firm level, we drop observation units for which the SITC5 product price is lower than the 5th percentile and higher than the 95th percentile of that firm's SITC5 price in all countries and (ii) at the product level, we exclude observations where the SITC5 price exceeds by ten times or is less than 10% of the median of that SITS5 price (see, for example, Martin 2012). After imposing these restrictions, approximately 9.6% of our sample is excluded. Following, among others, di Comité et al. (2014), Harrigan et al. (2015), Görg et al. (2017), we focus on manufacturing products, covered by the following SITC categories: *chemicals and related products*, *manufactured goods classified chiefly by material*, *machinery and transport equipment* and *miscellaneous manufactured articles*.

As in Aghion et al. (2018), an exporting firm is labeled as an innovator if it has filed at least one patent in international patent offices.[6] Notably, international patenting has been continuously expanding by firms and organiza-

6 All our results hold if we consider patent grants instead of patent applications. An alternative approach would be to use R&D expenditures, which are an input to the innovation process, while patents are considered the output of a firm's R&D (Pakes and Schankerman 1984). Obtaining credible R&D data at the firm level is not possible for firms that are not publicly listed. Related studies have even encountered issues in compiling R&D data from accounting data (Hall et al. 2007 and Brav et al. 2018, among others). Nagaoka et al. (2010) provide an overview on the use of patents as an innovation indicator.

tions. According to the United States Patent and Trademark Office (USPTO), 52% of issued utility patents in 2014 were granted to non-US entities.[7] Similarly, according to the European Patent Office (EPO), in 2014, 51% of patent applications originated from non-EPO member countries.[8] Greece applied for 843 patent applications over the years 2007–2016 and is among the countries with the lowest EPO applications per capita. This is to be expected as Greece is also among the countries with low R&D investment intensity (European Commission 2008). However, it should be emphasized that Greek entities have a strong presence in other offices across the world. Indicatively, over the period 2006–2011, Greek entities filed 680 patent applications in the USPTO compared with 507 applications in the EPO.

The patent activity by Greek firms is obtained through PATSTAT, which collects data on patent applications and granted patents for approximately 100 patent authorities.[9] We first extract all patents and patent applications regardless of jurisdiction, which were indicating a Greek-located assignee.[10] Then, firms in Intrastat–Extrastat and PATSTAT are manually matched. We find 76 manufacturing firms that have at least one exporting entry and have filed at least one non-Greek patent application between 1993 and 2007. Our final sample consists of the identity of exporting firms, their exporting profiles, and patent application activity (during the 2005–2007 period). The sample period for exporters is chosen based on data availability for innovators and the need to avoid using data for subsequent years due to the world financial crisis that might have affected the nature of exporting in a small open economy like Greece (Behrens et al. 2013).[11] Additional firm level data (age, employment and total assets) are collected from the ICAP database on Greek firms. 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.

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7 The data can be accessed at www.uspto.gov/web/offices/ac/ido/oeip/taf/st_co_14.htm.

8 The data can be accessed at www.epo.org/about-us/annual-reports-statistics/statistics.html.

9 The data can be accessed at www.epo.org/searching/subscription/raw/product-14-24.html.

10 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 also the owner, the two entities coincide.

11 In fact, in the 2005–2007 period the Greek economy did not experience significant shocks. Specifically, this period follows the euro adoption in 2002 and the hosting of the Olympic Games in 2004 and proceeds the financial crises of 2008 and 2010.

A more detailed 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 been only scantly used in industry-level analyses (Schmoch et al. 2003, Lybbert and Zolas 2014).[12]

2.2. Descriptive statistics and stylized facts

About 1.3% of Greek exporters have filed at least one foreign patent application; this amounts to 76 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 5,601. The number of countries in which *tradepat* firms export is 124 whereas the total number of destinations for Greek exports is 150. The total sales in these 124 countries amount to 99% 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 (€50.5 million versus €2.9 million) during the 2005–2007 period. Further, *tradepat* firms account for approximately 23.6% 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 13.6 products and the *nontradepat* firm eight products, while the average *tradepat* firm exports in 20.1 destinations, compared with 5.2 by an average *nontradepat* firm.

In panel B, we present the same statistics after disaggregating the data at the firm–year level. The average annual sales of a *tradepat* firm amount to €18.4 million and those of a *nontradepat* firm amount to €1.2 million. A *tradepat* firm exports on average 7.9 products to 15.4 destinations in each year, whereas a *nontradepat* firm exports on average 5.4 products to 4.1 destinations. Overall, the findings of panels A and B imply that the characteristics of Greek innovative exporting firms are substantially different compared with the rest of exporters, a finding that agrees with Balasubramanian and Sivadasan (2011) and Graham et al. (2018) for the US and with Aghion et al. (2018) for France.

Panel C 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 four times higher than firm–country–year observations of *nontradepat*

12 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).

TABLE 1
Patent applications and exporting firms (2005–2007)

	tradepat firms (76 obs.)	*nontradepat firms* (5,601 obs.)
A. Firm level		
Sales	50.5	2.9
Products	13.6	8.0
Destinations	20.1	5.2
	tradepat (208 obs.)	*nontradepat* (12,983 obs.)
B. Firm–year level		
Sales	18.4	1.2
Products	7.9	5.4
Destinations	15.4	4.1
	tradepat firms (3,209 obs.)	*nontradepat firms* (53,124 obs.)
C. Firm–country–year level		
Sales per destination	1.2	0.3
Products per destination	1.8	2.4
	tradepat firms (5,862 obs.)	*nontradepat firms* (127,940 obs.)
D. Firm–country–product–year level		
Unit value	77.7	61.1
Quantity	444.5	105.1

NOTES: *tradepat* and *nontradepat* denote firms with and without international patent applications, respectively. Figures reported denote the averages. Sales are in million euros and quantities are in thousand kilos.

firms (€1.2 million versus €0.3 million). 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.

Given that for each firm i we observe the annual sales and quantities of product k sold in destination d during the period 2005–2007, to further explore the relationship between export sales and patent applications at the firm–country level, we estimate the following specification:

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

where $value_{i,d,t}$ denotes the 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 0 otherwise), f_i denotes time-invariant firm variables (age) and $f_{i,t}$ denotes time-variant firm variables to control for size (number of products per firm, employment, assets) and productivity (number of destinations per firm), d_d denotes time-invariant country variables (distance) and $d_{d,t}$denotes time-variant country variables (GDP per capita).

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). For instance, we include country fixed effects as an alternative to origin–destination distance and GDP per capita. Column (1) uses the entire sample. The coefficient of patent application dummy, APP, is positive

TABLE 2
Patent applications and export sales

Dependent variable: *export sales*

	(1)	(2)	(3)	(4)
application	1.411***	1.346***	0.471***	0.429***
	(0.224)	(0.223)	(0.158)	(0.160)
# destinations per firm			0.432***	0.277***
			(0.0335)	(0.033)
# of products per firm			0.046	0.079***
			(0.030)	(0.030)
age			−0.041	−0.051
			(0.047)	(0.047)
employment			−0.066*	−0.070*
			(0.039)	(0.039)
total assets			0.396***	0.405***
			(0.036)	(0.037)
distance		−0.156***		−0.252***
		(0.016)		(0.015)
gdp per capita		−0.085***		−0.067***
		(0.016)		(0.017)
R-squared	0.045	0.023	0.166	0.126
Observations	56,177	56,177	51,907	51,907
Country FEs	YES	NO	YES	NO

NOTES: All variables are in natural logs. All regressions include a constant. Standard errors are clustered at the firm level.

and significant at the 1% level. Given that the coefficient is a quasi-elasticity, it is interpreted as follows: firm–country pairs that are associated with a patent application have $e^{1.411} - 1 = 310\%$ more sales per year than firm–country pairs that are not. In column (2), we introduce distance and GDP per capita as covariates. Sales are negatively related to distance and 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 firm size (number of products, number of employees and total firm assets). We also include the number of destinations for each firm, which is used as a proxy for firm productivity (Berman et al. 2012) and is associated positively with export sales. The point estimates of the patent application dummy *APP* are reduced (0.471 and 0.429 in columns (3) and (4), respectively) but remain significant at the 1% level.

In panel D of table 1, 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 27% higher prices compared with *nontradepat* firms, but *tradepat* firms sell 423% higher quantities than *nontradepat* firms at this level of disaggregation.

These summary statistics provide strong indication that higher revenues of *tradepat* firms come mainly from increased quantities, rather than prices. To explore more thoroughly this conjecture, we estimate the following specification, which exploits the information on quantities and prices (unit values) at the firm–country–product level:

$$Y_{i,d,k,t} = \alpha_0 + \alpha_1 APP_{i,t} + f_i + f_{i,t} + d_d + d_{d,t} + \varepsilon_{i,d,t}, \tag{2}$$

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. We define f_i, $f_{i,t}$, d_d and $d_{d,t}$ as above. All regressions include product fixed effects and the standard errors are clustered at the firm–product level. Finally some regressions include destination fixed effects that account for bilateral tariffs, demand conditions, market toughness, and other economic factors that influence exporters in any given destination market (Manova and Zhang 2012).

When testing the patterns of *tradepat* versus *nontradepat* firms, the composition of the control group must be taken into account. This is particularly important for the classification of firms as *nontradepat* firms and the relationship with patent filing by *tradepat* firms across destinations. Therefore, we first consider a broad sample that includes 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 assessment 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 the effects of patent filing on export margins and neutralize the issue of product composition, 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 example, if a *tradepat* firm exports five products to a single country, we include in the sample of *nontradepat* firms only the observations from their exports of 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 issues of product composition and representativeness are then eliminated, but the coverage of the sample is reduced, 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. Table 3 presents the 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).

TABLE 3
Patent applications and components of export sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Dependent variable: *export sales*								
application	1.020***	1.046***	0.559***	1.021***	1.053***	0.543***	1.084***	0.503***
	(0.084)	(0.083)	(0.0800)	(0.084)	(0.0834)	(0.082)	(0.102)	(0.099)
distance		−0.001	−0.048***		−0.0311***	−0.082***		−0.084***
		(0.008)	(0.008)		(0.0110)	(0.011)		(0.019)
gdp per capita		−0.050***	−0.084***		−0.0222	−0.0510***		0.026
		(0.010)	(0.001)		(0.0135)	(0.014)		(0.027)
R-squared	0.241	0.231	0.270	0.218	0.206	0.250	0.261	0.301
B. Dependent variable: *export price*								
application	−0.066*	−0.044	0.020	−0.0622	−0.0438	0.0467	−0.107**	−0.008
	(0.040)	(0.040)	(0.042)	(0.0399)	(0.0399)	(0.043)	(0.0434)	(0.048)
distance		0.0119***	0.022***		0.0191***	0.0308***		0.0251***
		(0.003)	(0.003)		(0.00482)	(0.005)		(0.008)
gdp per capita		0.145***	0.150***		0.123***	0.127***		0.133***
		(0.004)	(0.004)		(0.00536)	(0.005)		(0.010)
R-squared	0.760	0.755	0.760	0.728	0.724	0.725	0.755	0.751
C. Dependent variable: *export quantity*								
application	1.087***	1.090***	0.539***	1.084***	1.097***	0.496***	1.191***	0.511***
	(0.105)	(0.104)	(0.100)	(0.105)	(0.103)	(0.102)	(0.122)	(0.119)
distance		−0.011	−0.0703***		−0.0502***	−0.113***		−0.110***
		(0.009)	(0.010)		(0.0123)	(0.013)		(0.021)
gdp per capita		−0.195***	−0.234***		−0.145***	−0.178***		−0.107***
		(0.011)	(0.0187)		(0.0157)	(0.016)		(0.030)
R-squared	0.481	0.475	0.504	0.435	0.428	0.460	0.466	0.496
Observations	133,496	133,496	125,201	68, 557	68,557	63,734	22,313	20,830
No. of firms	5,676	5,676	4,381	5,614	5,614	4,319	3,469	3,081

NOTES: All variables are in natural logs. All regressions include a constant and product fixed effects. Standard errors are clustered at the firm–product level. Columns (1), (4), (7) include destination–product fixed effects. Columns (3), (6) and (8) include *# destinations per firm*, *# products per firm*, *employment*, *age* and *assets*. The control groups are defined as follows. Columns (1) to (3): firms that share at least one common product with tradepat firms in the 124 countries where *tradepat* firms sell. Columns (4) to (6): observations of products sold by *tradepat* firms in the 124 countries where *tradepat* firms sell. Columns (7) and (8): observations of country–product pairs that match those of *tradepat* firms in the 124 countries where *tradepat* firms sell.

In particular, columns (1) to (3) in table 3 consider only the 5,600 *nontradepat* firms that share at least one common product with the focal group and export to the 124 countries in which *tradepat* firms sell. Overall, the 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, employment and total assets as controls to account for productivity and size effects, which reduces our sample due to missing accounting data for a subset of firms. Columns (4) to (6) consider the common products of the (5,538) firms without applications with the focal group. As above, column (6) includes firm controls and the sample reduces due to missing data. Yet, the results confirm that higher sales stem from higher quantities rather than higher prices. Columns (7) to (8) consider only the common country–product pairs of *tradepat* and *nontradepat* firms. There are 1,933 common country–product pairs populated by 3,394 nontradepat firms and 75 tradepat firms. The results are similar to those reported earlier on.

A potential caveat to these findings is that the innovative exporters (*tradepat* firms) sell more products to more destinations. These innovative exporting firms might sell their core product(s) at higher prices, but because they have more products sold to more destinations, price regressions at the firm–product–country level might yield an incomplete picture. To address this criticism, we exploit information for the "core" products, defined as products that exceed 40% of total firm sales, at the firm–product level and compute the corresponding price by summing the firm's export sales and quantity at the associated firm–product level for every given year. We calculate the price of product k exported by firm f by dividing the aggregate export sales of the product over the aggregate export quantities. We then run a set of regressions for sales, quantities and prices keeping only observations that correspond to "core" products. The empirical results, reported in the online technical appendix, confirm the main finding from the stylized facts reported earlier on: patent applicants have higher export sales than non-applicants with this difference generated by higher quantities exported.[13]

In section 3, we outline a model that aims at accommodating these facts and deriving testable empirical implications.

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13 We thank a referee for pointing out this aspect regarding the price regressions. Similar results are obtained when the threshold value for the definition of the core product(s) is set at the 20% of total firm sales. In the results reported in the online technical appendix to the paper, we also report evidence for: (i) the whole set of exported products and (ii) a more conservative approach on data trimming with a 1% to 99% interval. All the empirical results are similar to those reported in the main text.

3. A model of innovation and exporting with horizontal differentiation

Consider that domestic firms export in a foreign market. We develop a horizontally differentiated product model in which an innovative firm competes for market share against many non-innovative rivals. The transportation cost and the degree of competition in the market, captured by the distance to the destination country and the number of competitors, respectively, are key factors in understanding exporting behaviour of innovative and non-innovative firms.

3.1. Consumers' preferences

In a foreign market, there exist $n \geq 2$ non-innovative domestic exporters whose products are similar (not necessarily identical).[14] The degree of differentiation among the non-innovative products is captured by $g \in (0,1]$. In this market, there exists also an innovative firm who has invested in product innovation and has succeeded to differentiate its product by more compared with its non-innovative rivals. We assume that the degree of differentiation between the innovative and non-innovative products is $b \in (0,1)$, where $b < g$. The innovative firm may hold intellectual property rights over its innovations, but it faces direct competition for consumers in the product market.

Following Singh and Vives (1984), we assume that the market is populated by a continuum of identical consumers with mass equal to 1 and a representative consumer's utility is a linear quadratic function over all goods. The innovative firm produces q_I and charges p_I for its units. It faces the (inverse) demand

$$p_I = \alpha - q_I - bQ_N, \tag{3}$$

where $Q_N = \sum_{i=1}^{n}$ denotes the total production from all non-innovative firms and α stands for the maximum willingness to pay in the foreign market. Each non-innovative firm i's demand is

$$p_i = \alpha - q_i - bq_I - gQ_{-i}, \tag{4}$$

14 We perform this analysis taking the number of exporters in a foreign market as given. Instead, we can examine the number of local firms that: (i) survive in a foreign market in the long run (n that solves $\pi_I^* + n\pi_i^* = 0$) or (ii) maximize the profits of all domestic exporters in a foreign market (n that solves $\partial(\pi_I^* + n\pi_i^*)/\partial n = 0$). However, this paper analyzes the exporting behaviour of domestic (Greek) firms who are already selling in a foreign market during the periods under examination. It does not analyze whether these firms will remain profitable in the long run. The number of exporters may also be different than what would maximize the total profits. There are no entry or exit barriers in place that can reverse the decision of a firm who wants to enter the market when entering is profitable, or exit the market when it makes losses. A welfare analysis of the number of exporters that maximizes the consumer surplus and all exporters' profits is also beyond the score of this paper.

where Q_{-i} is the total output produced by the $n-1$ non-innovative rivals of firm i.

3.2. Firms' profits

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 per unit of their exports, $\tau > 1$, which can be considered as an ad valorem tax equivalent and is uniform for all firms regardless of the product characteristics. In our model, the transportation cost increases with distance: the per-unit cost increases as the good is shipped to more distant markets. To satisfy their demands, the innovative and non-innovative firms produce by bearing linear costs, $c_I q_I$ and $c_N q_i$, respectively, where $c_I < c_N$ and $\alpha > \tau c_N$. We assume that the innovative firm has also invested in process innovation, allowing this firm to gain a cost advantage vis-à-vis its non-innovative rivals. The following assumption $(A1)$ sets an upper bound on the per-unit transportation cost to guarantee that all firms will find it profitable to produce in equilibrium:

$$(A1): \tau < \frac{\alpha(2-b)}{2c_N - bc_I}.$$

All firms compete in the product market à la Cournot. 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 the strategic decisions of exporters are their production levels. The profit functions of the innovative firm and a non-innovative competitor i are, respectively,

$$\pi_I = (p_I - \tau c_I)q_I = (\alpha - q_I - bQ_N)q_I - \tau c_I q_I, \tag{5}$$

$$\pi_i = (p_i - \tau c_N)q_i = (\alpha - q_i - bq_I - gQ_{-i})q_i - \tau c_N q_i. \tag{6}$$

3.3. Optimal production and the effects of distance and competition

Firms choose the output level that maximizes their net profits by solving the following n equations:

$$\begin{aligned} \alpha - 2q_I - bQ_N - \tau c_I &= 0, \\ \alpha - 2q_1 - bq_I - g(q_2 + \cdots + q_n) - \tau c_N &= 0, \\ &\vdots \\ \alpha - 2q_n - bq_I - g(q_1 + \cdots + q_{n-1}) - \tau c_N &= 0. \end{aligned}$$

In equilibrium, each non-innovative competitor chooses the same output, $q_1^* = \cdots = q_n^* = q_i^*$, reducing the $n \times n$ system of first-order conditions to

$$a - 2q_I^* - bnq_i^* - \tau c_I = 0, \tag{7}$$

$$a - 2q_i^* - bq_I^* - g(n-1)q_i^* - \tau c_N = 0. \quad (8)$$

We obtain the optimal quantities

$$q_I^* = \frac{a - \tau c_I}{2} - \frac{bn}{2v}\left[(2-b)a - \tau(2c_N - bc_I)\right], \quad (9)$$

$$q_i^* = \frac{1}{v}\left[(2-b)a - \tau(2c_N - bc_I)\right], \quad (10)$$

where $v \equiv 4 - b^2 n + 2g(n-1) > 0$. Each firm's equilibrium quantity decreases with its own marginal cost, while it increases with the marginal cost of its rivals. As c_N increases, the non-innovative exporters produce less, losing share in the foreign market, which favours the innovative firm. The innovative firm also benefits when its own product becomes more differentiated. As b decreases, the competition of the innovative exporter with its non-innovative rivals becomes less intense, allowing the innovator to sell more.

In equilibrium, the innovative firm exports more compared with a non-innovative rival, implying that each non-innovative exporter ships fewer units out:

$$q_I^* - q_i^* = \frac{\alpha(n-1)(g-b) + \tau c_N(2+bn) - \tau c_I[2+b+g(n-1)]}{v} > 0, \forall n, b, g. \quad (11)$$

The distance between the country of origin and the foreign market is a key factor in the exporting decisions of firms. The transportation cost increases with distance, weakening all firms' incentives to ship their products in markets that are further away: the equilibrium quantities decrease with τ,

$$\frac{\partial q_I^*}{\partial \tau} = -\frac{c_I[2+g(n-1)] - bnc_N}{v} < 0, \quad (12)$$

$$\frac{\partial q_i^*}{\partial \tau} = -\frac{2c_N - bc_I}{v} < 0, \quad (13)$$

and so does the total production of the non-innovative exporters,

$$\frac{\partial Q_N^*}{\partial \tau} = -\frac{n(2c_N - bc_I)}{v} < 0. \quad (14)$$

The effect of an increase in distance on equilibrium export levels can be analyzed by considering the shift of the market share between the innovative and non-innovative rivals. A larger 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" also holds in this setting: consumption will shift towards the innovative product as the transportation cost increases:

$$\frac{\partial(q_I^* - Q_N^*)}{\partial \tau} = \frac{(2+b)nc_N - c_I[2+nb+g(n-1)]}{v} > 0. \quad (15)$$

The innovative exporter will be benefited even further as the number of non-innovative firms who export in the same foreign market also increases:

$$\frac{\partial(q_I^* - Q_N^*)}{\partial\tau\partial n} = \frac{(2+b)(2-g)(2c_N - bc_I)}{v} > 0. \tag{16}$$

Therefore, the model predicts that as the competition among the exporters of the non-innovative product becomes more intense, the marker shifts towards the innovative firm even further, implying that the innovator will export even more compared with its non-innovative rivals in more distant markets. The Alchian–Allen-like result is reinforced as the competition between the non-innovative firms is intensified. In the next section, using our dataset, we perform an empirical analysis to test this prediction.[15]

The analysis of the stylized facts in section 2 reveals that innovating exporters do not charge substantially higher prices than their non-innovative competitors, but they produce more and compete in quantity. The equilibrium prices of the innovative and non-innovative products are, respectively,

$$p_I^* = \frac{a[2 - bn + g(n-1)] + bn\tau c_N + \tau c_I[2 - b^2 n + g(n-1)]}{v}, \tag{17}$$

$$p_i^* = \frac{a(2-b) + \tau c_N[2 - b^2 n + 2g(n-1)] + b\tau c_I}{v}. \tag{18}$$

Their difference gives

$$p_I^* - p_i^* = \frac{a(g-b)(n-1) + \tau c_I[2 - b + g(n-1) - b^2 n] - \tau c_N z}{v}, \tag{19}$$

where $z \equiv 2 + 2g(n-1) - nb(1+b)$. As the number of the non-innovative firms increases, the total production of these firms will also increase, resulting in a lower equilibrium price p_i^*. The non-innovative product will be sold at a lower price than the innovative product, but the prices are not substantially different. Equation (19) shows that the difference in prices, $p_I^* - p_i^*$, is smaller as a smaller number of non-innovative firms sell in a foreign market and as the innovative and non-innovative products are less differentiated (larger b).[16]

15 In the online technical appendix, we consider a standard vertically differentiated product model in which an innovative exporter sells a high-quality product and competes vertically with n non-innovative exporters who offer a lower-quality variant of the product. We show that all the main findings hold in this setup as well.

16 To illustrate our results, we can consider the numerical example where $a = 80$, $n = 2$, $b = 0.4$, $g = 0.9$, $c_I = 25$, $c_N = 30$ and $\tau = 1.4$. We get $p_I^* - p_i^* \approx 0.68$, while $q_I^* - q_i^* \approx 7.68$, implying that firms charge similar prices but the innovative firm produces substantially more.

4. Empirical test

In this section we analyze how the origin–destination distance and the degree of competition affect the export volumes of innovative and non-innovative firms using the dataset on Greek exporting firms.

4.1 Empirical specification

Incorporating patent applications in micro-trade data allows for testable predictions. According to the theoretical model, the question of interest is how innovative (*tradepat*) firms, captured by patent filing, behave differently in terms of export volumes compared with non-innovative (*nontradepat*) exporters as destination distance and competition change This leads to the following testable empirical hypothesis.

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 increases.*

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

$$q_{i,d,k,t} = \gamma_0 + \gamma_1 APP_{i,t} + \gamma_2 (APP_{i,t} \times high\_comp_{d,k,t}) + f_i + \delta_{ik} + \varepsilon_{i,d,t}, \quad (20)$$

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 $(APP_{i,t} \times high\_comp_{d,k,t})$ is an interaction term of the patent application dummy with a dummy variable on high competition in the destination–product pair. In our baseline 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 (given by the median of four firms in our sample), and 0 otherwise.

To address hypothesis 1, we first run the above specification separately for countries with a distance greater than or less than 1,050 km, which is the median of distances of the destination countries from Greece, and compare the estimated coefficients from these two estimations. We focus on the signs and the 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 origin–destination distance. We expect γ_2 to be positive for the more distant countries compared with countries that are close to Greece. 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 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 income in the destination countries) 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 as a proxy for productivity, number of products per firm, age and employment as proxies for size and firm–product pair fixed effects, δ_{ik}.

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

4.2 Baseline regressions

Table 4 presents the regression results. In columns (1) and (2), we consider as control group firms that sell at least one common product in the 42 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 90% of their total exports in our sample period. The first column presents the results for distant countries and column (2) for countries closer to Greece. 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 1% level for distant countries and insignificant for those that are closer. 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. Similar results emerge in columns (3) and (4), when we narrow the group to only observations from products sold by *tradepat* firms. The coefficient on the interaction term is again positive and significant at the 1% 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 10% level. In columns (6) to (8), we further narrow our control group considering only country–product pairs for which *tradepat* firms export. We get similar signs for the coefficients of the interaction term for distant and close countries, albeit the sample size for this specification is substantially smaller compared with column (5), which increases the standard errors and eliminates the significance of the estimated coefficients.

The analysis so far focuses on destinations in which the innovative firm filed a patent application. Hence, a consideration might be that 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

TABLE 4
The effects of destination, distance and competition on export quantities of *tradepat* firms vs. *nontradepat* firms (42 countries)

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	**0.414***** **(0.158)**	**−0.185** **(0.236)**	**0.433***** **(0.159)**	**−0.155** **(0.236)**	**0.00239** **(0.203)**	**0.313** **(0.201)**	**0.186** **(0.274)**	**0.122** **(0.277)**
application X distant X high_comp					**0.440*** **(0.226)**			**0.202** **(0.336)**
application	0.595*** (0.128)	0.945*** (0.216)	0.534*** (0.130)	0.889*** (0.216)	0.483*** (0.179)	0.464*** (0.177)	0.323 (0.249)	0.326 (0.252)
distant					−0.216*** (0.073)			−0.540** (0.251)
high_comp	0.513*** (0.0355)	0.117*** (0.0433)	0.496*** (0.0489)	0.0811 (0.0789)	0.294*** (0.071)	0.526*** (0.135)	0.157 (0.294)	0.0712 (0.229)
application X distant					0.002 (0.188)			0.170 (0.306)
distant X high_comp					0.054 (0.079)			0.366 (0.256)
Observations	56,194	63,291	28,584	31,100	55,463	7,934	11,438	19,372
R-squared	0.536	0.471	0.491	0.420	0.457	0.574	0.455	0.499

NOTES: All variables are in natural logs. All regressions control for GDP per capita and include product fixed effects and a constant. Standard errors are clustered at the firm–product level. Columns (1) to (4) include *# destinations per firm, # products per firm*, and Columns (5) to (8) include additionally *age, employment* and *total assets*. The control groups are defined as follows. Columns (1) and (2): firms that sell at least one common product with *tradepat* firms in the 42 countries where *tradepat* firms have patent filings. Columns (3) to (5): observations of products sold by *tradepat* firms in the 42 countries where *tradepat* firms have patent filings. Columns (6) to (8): country–product pairs that match those of *tradepat* firms. Columns (1), (3) and (6) include countries that are located further than 1,050 km from Greece. Columns (2), (4) and (7) include countries that are located within 1,050 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 further than 1,050 km from Greece, and 0 otherwise. *high_comp* is a dummy that takes the value of 1 if in country d for product k in year t or there are more than four Greek firms exporting, and 0 otherwise.

TABLE 5

Effects of destination, distance and competition on export quantities of *tradepat* firms vs. *nontradepat* firms (124 countries)

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	**0.546*****	**−0.111**	**0.598*****	**−0.114**	**0.0958**	**0.355****	**−0.104**	**−0.277**
	(0.132)	**(0.221)**	**(0.133)**	**(0.220)**	**(0.193)**	**(0.173)**	**(0.227)**	**(0.200)**
application X distant X high_comp					**0.474****			**0.774*****
				(0.207)			**(0.274)**	
application	0.287**	0.694***	0.186	0.660***	0.426**	0.315*	0.624***	0.743***
	(0.113)	(0.201)	(0.116)	(0.201)	(0.170)	(0.168)	(0.212)	(0.178)
distant					−0.173***			−0.233
					(0.0655)			(0.210)
high_comp	0.495***	0.161***	0.423***	0.173**	0.312***	0.539***	0.397	0.361*
	(0.033)	(0.043)	(0.044)	(0.074)	(0.066)	(0.110)	(0.243)	(0.195)
application X distant					−0.172			−0.532**
					(0.173)			(0.237)
distant X high_comp					0.0336			0.0584
					(0.073)			(0.217)
Observations	65,650	59,545	34,662	29,064	63,726	9,335	11,491	20,826
R-squared	0.552	0.490	0.502	0.442	0.463	0.563	0.456	0.498

NOTES: The control group is defined in the 124 countries where *tradepat* firms sell. See table 4 for further details on the definitions of variables and estimation details.

these 124 countries. In the regressions split to distant and close countries for the various controls groups, the coefficients for distant countries are positive and significant at the 1% level in columns (1) and (3) and at the 5% level in column (6), whereas they turn out insignificant for close destinations in all specifications. The same holds when the sample is pooled and the triple interaction term is included, which is positive and significant at the 5% level and 1% level in columns (5) and (8), respectively. These findings strengthen the main result that higher export volumes in a destination where the *tradepat* firm has filed a patent application cannot be attributed to monopolistic rights generated by patent filing.

4.3. Patent strength

Patenting is an "expensive sport." Berger (2004) 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 in the required fees to be paid.[17] 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 trigger *and* hinder patented exports.

The impact of international patent strength has also received attention in the relevant literature. Maskus and Penubarti (1995) were the first to consider empirically the impact of patent laws in international trade. The related literature has shown that patent strength is positively related to trade and has studied extensively this relationship for specific countries (see Smith 1999 for the US and Rafiquzzaman 2002 for Canada) and industries (Galushko 2012 for the seed industry). It has also quantified the different implications that patent rights may have on developed and developing countries (Schneider 2005, Ivus 2010).[18] Palangkaraya et al. (2017) estimate the 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. After controlling for the quality of the invention, they find evidence that both effects are negative. Recently, Maskus and Yang (2018) find strong evidence that the policy shift towards stronger patent protection has significantly boosted exports in relatively R&D-intensive industries, a result that also holds for patent-intensive goods.

17 See also European Commission (2011) for a detailed review of costs arising from international patent filing.

18 See Akkoyunlu (2013) and the references cited therein.

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. 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 86 out of 124 countries to which *tradepat* firms export.[19] In table 6, we re-estimate table 5 for these 86 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 most specifications (with two exceptions). 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 in columns (1), (3) and (6), and insignificant in columns (2), (4) and (7) for closer destinations. The triple interaction terms in the pooled sample is positive and statistically significant at the 1% level in columns (5) and (8). In general, there is no evidence that controlling for patent strength affects the association implied by hypothesis 1.

4.4. Foreign competition

The concept of competition is important for the implications of the theoretical model. Measuring competition through a dummy depending on whether the number of other Greek firms that export a specific product in a destination at a given year exceeds or is below the median gives a satisfactory proxy of the degree of *domestic* competition faced by the firm and is aligned with the assumptions of the theoretical model. However, a legitimate concern is that Greek innovative firms face to a large extent competition in export markets from foreign firms, rather than solely from domestic ones. In addition, there are markets with specific geographic or cultural characteristics (e.g., Cyprus,

19 The data can be found at `nw08.american.edu/~wgp`.

TABLE 6
Controlling for patent strength

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	**0.704***** **(0.152)**	**−0.192** **(0.249)**	**0.730***** **(0.154)**	**−0.197** **(0.248)**	**0.0511** **(0.223)**	**0.412**** **(0.203)**	**−0.205** **(0.242)**	**−0.308** **(0.217)**
application X distant X high_comp					**0.657***** **(0.249)**			**0.870***** **(0.311)**
Application	0.228* (0.120)	0.761*** (0.224)	0.154 (0.122)	0.726*** (0.222)	0.446** (0.196)	0.368** (0.185)	0.731*** (0.219)	0.759*** (0.185)
Distant					−0.151** (0.076)			−0.402 (0.308)
high_comp	0.489*** (0.039)	0.198*** (0.050)	0.464*** (0.0526)	0.220** (0.089)	0.419*** (0.077)	0.627*** (0.138)	0.177 (0.359)	0.281 (0.291)
application X distant					−0.213 (0.206)			−0.482* (0.256)
distant X high_comp					−0.080 (0.087)			0.112 (0.318)
patent strength	0.115 (0.139)	0.397*** (0.134)	0.192 (0.179)	0.367* (0.205)	0.437*** (0.126)	1.137** (0.463)	1.295*** (0.406)	1.161*** (0.286)
Observations	51,147	50,783	26,769	24,299	51,068	7,026	9,529	16,555
R-squared	0.568	0.497	0.514	0.451	0.468	0.579	0.460	0.506

NOTE: See table 4 for further details on the definitions of the variables and estimation details.

Albania), in which Greek exports account for a large fraction of their imports in specific products. In these firm–product–destination pairs an increased number of Greek competitors might be driven by the relatively large volume of exports, rather than the degree of competition.

To address these issues, we construct a proxy for foreign competition by calculating the share of Greek exports of product k to destination d to total exports of product k to destination d. For this purpose, we obtain data from UN Comtrade International Trade Statistics database on bilateral imports at the product level.[20] Specifically, we extract import data from Greece and the World (all countries) reported for all destination–commodity (five-digit SITC) combinations for the 2005–2007 period. Incorporating these variables in our data set required matching five-digit SITC Rev.3 commodities with five-digit SITC Rev.4 commodities in some cases. Then, we construct our foreign competition index by taking the value of imports of destination d of product k in period t from Greece relative to the value of total imports (i.e., from all source countries) in destination d of product k in the same period.[21] This is clearly identical to the value of Greek exports of product k shipped to destination d in period t relative to the value of world exports of product k to destination d:

$$foreign\ competition = \frac{\text{value of Greek exports of prod. } p \text{ in dest. } d}{\text{value of world exports of prod. } p \text{ in dest. } d}. \quad (21)$$

For example, the index of foreign competition for product "vacuum pumps" in Austria in 2005 is the value of imports of "vacuum pumps" to Austria from Greece in 2005 over the value of total imports of "vacuum pumps" to Austria in the same year. The value of this index is between 0 and 1 for all destination–commodity combinations. A higher share of Greek exports implies less competition in the foreign market. Table 7 replicates table 6 (which includes patent strength) adding *foreign competition* as an additional covariate. The variable *foreign competition* enters with a positive and statistically significant sign at the 1% level. As above, the results retain their robustness. The coefficients on the interaction in table 6 are again positive and statistically significant for distant countries in columns (1) and (3) and positive but insignificant in column (6). The coefficients for closer destinations are found to be insignificant in columns (2), (4) and (7). The triple interaction terms in the pooled sample is positive and statistically significant at the 10% level in column (5) and at the 5% level in column (8). Therefore, these findings confirm the evidence obtained in the previous specifications in line with hypothesis 1.

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20 Data can be accessed at `comtrade.un.org/data`.

21 Although our main data set allows us to calculate the value of total Greek exports of product k to destination d, for consistency we prefer having the same data source for the denominator and nominator of our *foreign competition index*. Nevertheless, our results remain very similar if we use Intrastat–Extrastat data for calculating the value of Greek exports.

TABLE 7
Controlling for foreign competition

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	0.648***	−0.128	0.668***	−0.134	0.0327	0.250	−0.311	−0.491*
	(0.184)	(0.300)	(0.186)	(0.299)	(0.274)	(0.236)	(0.271)	(0.251)
application X distant X high_comp					0.563*			0.932**
					(0.308)			(0.364)
application	0.303**	0.738***	0.254*	0.708**	0.466*	0.589***	0.887***	0.987***
	(0.140)	(0.280)	(0.144)	(0.280)	(0.251)	(0.222)	(0.246)	(0.219)
distant					0.0179			−0.570
					(0.101)			(0.382)
high_comp	0.335***	0.104*	0.307***	0.113	0.289***	0.613***	−0.171	0.0255
	(0.0471)	(0.0581)	(0.0636)	(0.106)	(0.0977)	(0.160)	(0.433)	(0.350)
application X distant					−0.0566			−0.514*
					(0.266)			(0.307)
distant X high_comp					−0.133			0.344
					(0.111)			(0.388)
patent strength	0.717***	2.000***	0.775***	1.538***	1.236***	1.808***	2.545***	1.861***
	(0.217)	(0.188)	(0.275)	(0.283)	(0.191)	(0.559)	(0.602)	(0.374)
foreign competition	5.948***	1.632***	8.729***	1.238***	1.470***	6.197***	1.080**	0.666*
	(0.700)	(0.137)	(1.576)	(0.223)	(0.199)	(2.222)	(0.436)	(0.344)
Observations	30,263	40,102	16,893	19,900	36,793	5,386	7,980	13,366
R-squared	0.597	0.512	0.535	0.461	0.478	0.583	0.465	0.506

NOTE: See table 4 for further details on the definitions of the variables and estimation details.

4.5. Domestic patenting

Our sample of innovators includes those Greek exporters that have filed for at least one patent in international patent offices. A complementary approach could also include in the definition of innovative firms those that have filed for a patent in the Greek patent office (Hellenic Industrial Property Organization; HIPO hereafter). The main reason for focusing on foreign patents as a sign of innovation is that HIPO does not have a substantive examination procedure, which implies that practically any entity (individual or firm) that files for a patent application at HIPO will obtain a patent, conditioned that files all necessary documents and the necessary fees are paid. Importantly, obtaining a patent application at the HIPO is relatively cheap, in comparison with most other offices, accumulating to just a few hundred euros.[22]

These facts imply that a patent application at HIPO will not necessarily signal innovative activity. Yet, a common pattern for firms in obtaining a patent is to first file at their domestic office and then file at an international office. The main reasons behind this strategy is to establish priority over the invention and gain a reasonable interval (typically amounting to twelve months) in order to plan to which countries to file and raise the capital required to pursue patenting at international offices. Only firms with a clear international strategy file directly to international offices, circumventing the national office. In the original dataset of 76 innovative exporters, 32 filed in HIPO before they filed in any international office.

To cover the possibility that some innovative exporters prefer the domestic route for patent filing, we alternatively include in our set of innovative exporters those firms that have filed for a patent application at HIPO. This augments the sample of innovators by 14 firms that have filed only at HIPO. In tables 8 and 9, we present the corresponding specifications to those estimated in tables 3 and 6 using the new classification of innovative exporters. In particular, the results in table 8 confirm the main finding from the stylized facts reported in table 3. Patent applicants have higher export sales than non-applicants with this difference generated by higher quantities exported. In fact, in some regressions of panel B for export prices it is found that patent applicants sell at slightly lower prices compared with non-applicants. The results from previous regressions on hypothesis 1 are confirmed in table 9, which estimates the interaction term(s) for the new sample of innovators. The coefficient on the interaction term is positive and significant for distant countries, whereas it is insignificant for closer destinations. Also, similarly to the results reported earlier on, when all observations are pooled in a single regression and the triple interaction term is introduced, it is found to be

22 General guidelines for patent filing at HIPO can be accessed at www.obi.gr/obi/Portals/0/ImagesAndFiles/stories/odhgies_de_pyx_en.pdf. Consult www.obi.gr/OBI/Default.aspx?tabid=201 for the relevant patent fees.

TABLE 8
Patent applications and components of export sales (including firms with patents in Greece)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Dependent variable: *export sales*								
application	0.953***	0.975***	0.525***	0.995***	1.027***	0.535***	1.059***	0.486***
	(0.078)	(0.077)	(0.073)	(0.082)	(0.081)	(0.079)	(0.100)	(0.097)
distance		−0.001	−0.048***		−0.031***	−0.082***		−0.084***
		(0.008)	(0.008)		(0.011)	(0.011)		(0.019)
gdp per capita		−0.049***	−0.083***		−0.0228*	−0.051***		0.026
		(0.010)	(0.010)		(0.013)	(0.014)		(0.027)
R-squared	0.241	0.231	0.270	0.218	0.206	0.250	0.260	0.300
B. Dependent variable: *export price*								
application	−0.088**	−0.074**	−0.016	−0.072*	−0.055	0.033	−0.010**	0.001
	(0.036)	(0.037)	(0.038)	(0.039)	(0.039)	(0.041)	(0.043)	(0.047)
distance		0.0113***	0.0225***		0.019***	0.031***		0.025***
		(0.003)	(0.003)		(0.005)	(0.005)		(0.008)
gdp per capita		0.145***	0.150***		0.123***	0.127***		0.133***
		(0.004)	(0.004)		(0.005)	(0.005)		(0.010)
R-squared	0.760	0.755	0.760	0.728	0.724	0.725	0.754	0.751
C. Dependent variable: *export quantity*								
application	1.042***	1.048***	0.541***	1.067***	1.082***	0.502***	1.159***	0.485***
	(0.096)	(0.095)	(0.091)	(0.102)	(0.100)	(0.098)	(0.121)	(0.117)
distance		−0.012	−0.070***		−0.050***	−0.113***		−0.109***
		(0.009)	(0.009)		(0.012)	(0.013)		(0.021)
gdp per capita		−0.194***	−0.233***		−0.146***	−0.178***		−0.107***
		(0.011)	(0.012)		(0.016)	(0.016)		(0.030)
R-squared	0.481	0.476	0.505	0.435	0.429	0.460	0.466	0.496
Observations	133,496	133, 496	125,201	68, 557	68,557	63,734	22,313	20,830
No. of firms	5,676	5,676	4,381	5,614	5,614	4,319	3,469	3,081

NOTE: See table 3.

TABLE 9
Effects of destination, distance and competition on export quantities (including firms with patents in Greece)

	Dependent variable: *export quantity*							
	(1) Distant	(2) Close	(3) Distant	(4) Close	(5)	(6) Distant	(7) Close	(8)
application X high_comp	**0.671***** **(0.156)**	**0.0561** **(0.207)**	**0.657***** **(0.160)**	**0.0429** **(0.235)**	**0.0156** **(0.262)**	**0.464**** **(0.193)**	**0.0185** **(0.247)**	**−0.005** **(0.226)**
application X distant X high_comp					**0.693**** **(0.281)**			**0.548*** **(0.316)**
application	0.270** (0.113)	0.512*** (0.162)	0.241** (0.120)	0.485** 0.202)	0.487** (0.231)	0.316* (0.171)	0.505** (0.220)	0.452** (0.191)
Distant					−0.146* (0.078)			−0.540* (0.310)
high_comp	0.491*** (0.039)	0.191*** (0.050)	0.475*** (0.053)	0.200** (0.090)	0.424*** (0.079)	0.602*** (0.135)	0.086 (0.362)	0.154 (0.294)
application X distant					−0.248 (0.243)			−0.157 (0.261)
distant X high_comp					−0.085 (0.088)			0.248 (0.321)
patent strength	0.114 (0.139)	0.392*** (0.135)	0.187 (0.179)	0.364* (0.205)	0.434*** (0.126)	1.143** (0.463)	1.294*** (0.406)	1.162*** (0.287)
Observations	51,147	50,783	26,769	24,299	51,068	7,026	9,529	16,555
R-squared	0.568	0.497	0.514	0.450	0.468	0.578	0.460	0.506

NOTE: See table 4 for further details on the definitions of the variables and estimation details.

positive and statistically significant. Overall, the coefficients are similar in magnitude to those reported in table 6 and confirm the model prediction expressed in hypothesis 1.

5. Conclusion

In this paper, we have examined the relationship between innovation reflected in patent filing behaviour and export behaviour 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 behaviour of patent applicants versus non-applicants. To our knowledge, this is the first paper that attempts to analyze the structure of export sales by innovative firms, captured by the prices charged and quantities sold across markets.

Our results show that patent applicants export more per product than non-applicants. Higher export values are primarily driven from higher export volumes, rather than increased pricing. To account for this evidence, we build a simple horizontally differentiated product model of trade, in which an innovative firm competes for market share against many non-innovative rivals. We show that as the competition among the exporters of the non-innovative product becomes more intense, the innovative firm will export more compared with its non-innovative rivals in more distant markets, a novel prediction that is robustly confirmed in our data.

It is worth noting that patents grant a monopoly over the invention for a limited period (typically covering 20 years from application date) in exchange for full disclosure.[23] An interesting extension would be to focus on the monopolistic rights implied by patenting and study whether patent rights, rather than patent filing, in selected destinations are related to the exporting margins at the firm level. For instance, firms might seek protection through patenting when the export share exceeds some threshold. An alternative use of our dataset could therefore exploit the within-firm variation between destinations and examine if, and how, the exporting behaviour across destinations at the firm level is affected by such monopolistic rights.[24]

Supporting information

Supporting information is available in the online version of this article.

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23 Hall and Harhoff (2012) review the literature on the economics of patents.

24 We thank a referee for pointing out to us this route of future research.

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