

THE IMPACTS OF COUNTERFEITING ON CORPORATE INVESTMENT*

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This study uses a unique international database on customs seizures between the years 2011 to 2013 and matched corporate statistics to study the impacts of counterfeiting on authentic corporations' investment and revenues. Applying the matched sampling combined with panel analyses, we attempt to estimate the effects counterfeit incidences have on corporate research investment and on firm sales and revenues ("sales displacement") in various industries. We find an overall negative effects on the R&D and net sales across various regression specifications, with a rare positive effect documented in the regression for the broad sector of tools, materials, and vehicles (HS code 8).

Keywords: Counterfeiting, International Customs Data, R&D Investments, Cross-industry

JEL Classification: F61, O34, K42

1. INTRODUCTION

With the rampant growth of counterfeiting in the global business, the impacts of counterfeiting on corporate investment thrusts to the forefront of world attention. Using a unique international database on customs seizures and matched corporate statistics, we isolate the effects counterfeit incidences have on corporate research investment from the effects counterfeit incidences may have on corporate sales and revenues ("sales displacement") in various industries. Conceptually, the (former) *net* investment effect

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may either be dominated by diminishing-revenues effect that could lead to declines in investment, or by competitive and stimulating (supposedly, positive) effects on investment due to the entry of counterfeit producers.

An empirical assessment of this net investment effect can help specify and account for some of the medium-term effects counterfeit entry has on market dynamics in different industries, as compared to the limited evidence previously available for policy and industry discussion and initiatives on static sales effects. Broadly speaking, given that the main function of IP rights is to provide incentives and safeguard investment of creators and inventors, it will be important to establish the concise level of investment “distortion” counterfeit entry and IP infringement introduces.

More specifically, as argued in the previous literature (Hui and Png, 2003; Bae and Choi, 2006; Yoon, 2007; Liebowitz, 2008; Hong, 2013; Belleflamme and Peitz, 2014; Aguiar and Waldfogel, 2018; Yang, 2019), displacement of sales by piracy commonly reduces financial resources available for corporate investment in future assets and increased productivity (for example, innovative products or improved quality of products/processes originating from R&D output). Innovation investment seldom relies on firm-external financing but cash flow (Hall and Lerner, 2010). However, promotional effects of counterfeits on authentic products may have compensating (positive) effect on sales and revenues reducing net displacement as evidenced in some industries. Moreover, entry of counterfeiters, even though not being based on legally authorized sales and thus eventually free-riding on resources committed by the original producers, may increase perceived competition levels in the industry and thus may induce additional investment in markets.

While the data is extensive and cover a wide range of countries and industries, a few concerns exist in the empirical estimation of counterfeiting effects. First, the data on counterfeits come exclusively from the customs confiscations. Counterfeiters usually infringe on more profitable corporations, and counterfeiting treatment is therefore unlikely to be randomly assigned across corporations. We apply the propensity score method combined with panel analyses to account for the endogeneity concern. Second, the data on counterfeits are at best a lower bound since these are the counterfeits discovered only at the customs. One could argue though that these could be considered as accurate measures (due to close examinations and tests at the customs office) of the relatively important counterfeits. We use both the amount of counterfeits confiscated at the respective customs office of a country and a dummy variable indicating the presence of counterfeits for the respective country, whenever positive amounts are reported by the customs office, as alternative measures for counterfeiting treatment. Results are robust that when sales are being displaced in product markets in the presence of counterfeiting, R&D investment decrease modestly. We also find evidence for weak impacts on R&D intensity in some industries. Counterfeit entry, notwithstanding its mostly negative static effect on sales and R&D, can also exhibit dynamic effects, making *specific* product markets more competitive in medium term.

The rest of the paper structures as follows. Section 2 reviews the existing literature

on counterfeit effects on corporate performance. Section 3 and 4 outline the data and the identification strategy. Sections 5 and 6 summarize and discuss our findings and conclude with policy implications.

2. LITERATURE REVIEW

IP rights, from an economic perspective, seek to remedy the failure of markets to provide for an efficient allocation of resources. However, infringement of IP rights persist even in the presence of IP laws, as evidenced by various IP litigations and, in our dataset, frequent confiscations of counterfeits. Using statistical inference on a dataset of German custom data in which each item seized is classified as being either authentic or counterfeit at the inspection, Cuntz (2016) estimates that the range of counterfeit goods in the German economy in 2010-2011 was ranging between a 9.5 and 22 percent of total import.

In the case of trademarks, there are two types of counterfeiting depending on whether consumers are deceived by the purchase of a fake good—in other words, whether they (mistakenly) believe that their acquired good is produced by the owner of the trademark. The likelihood of this deception clearly varies across products, depending on their physical properties and the nature of distribution channels. For example, consumers are usually unable to ascertain whether a pharmaceutical product contains the desired chemical ingredient, whereas most fashion shoppers can tell apart an original handbag from its fake clone. Prior literature has theorized the implications of deceptive and non-deceptive counterfeiting. This research is the first empirical study on the impacts of counterfeiting on firms' R&D investments, to our knowledge, and the first empirical study on counterfeiting cross-country and cross-industry.

Deceptive counterfeiting employs copied trademarks and designs to pass off as the legitimate product. This is called “primary market” counterfeiting by OECD (2008). Purchasers of a counterfeit product derive a value from the product which is below the price they paid for it as soon as they discover it is fake.¹ Rational consumers aware of the presence of fake goods on the market, though unable to distinguish them from the originals, will be unwilling to pay the full price of a high quality good. As a consequence, the incentive for producers to invest in higher quality is undermined and markets for high quality goods may not exist (Akerlof, 1970).

A more complex situation arises for products for which consumers are perfectly able to ascertain the quality attributes of a product at the moment of purchase, and therefore know whether they are buying a counterfeit. This situation is termed “secondary market” counterfeiting by OECD (2008). Counterfeiting of status goods may affect the prestige value that consumers derive from their purchases. Consumers might favor counterfeiting goods because of its social, functional and emotional benefits (Kalyoncuoglu et al.,

¹ See Liu et al. (2004) for a formal treatment.

2017; Wilcox et al., 2009).

In the international trade setting, Grossman and Shapiro (1988) theorize the effects of non-deceptive product counterfeiting. Producers and consumers of the genuine product are worse-off from counterfeits—largely because the greater club size reduces the status value of the genuine product. However, producers and consumers of the counterfeit product are better off. In particular, consumers of counterfeits can derive status value or try out a brand’s “personality” without paying the full price of the genuine product. The overall effect on social welfare depends on the values of the relevant market parameters and is thus an empirical question.

Qian (2008) utilizes a unique policy setting and Chinese dataset to identify the impacts of counterfeiting on a set of shoe brands’ marketing tactics. In particular, prices of authentic shoes increased significantly after entry by counterfeiters, albeit the initial drop, both due to the upgrades in authentic quality and price signaling to differentiate from the counterfeits. Here is evidence for innovation outcome, namely higher authentic quality, after the brands experienced counterfeit infringements. Our study has the advantage of detailed and reliable R&D expenditure data, and we are able to analyze the impacts on innovation inputs, which is a more direct measure of incentives to innovate, by counterfeiters.

Qian (2008) also found increases in vertical integration of authentic stores and other self-enforcement against counterfeits. These empirical findings are generalized in a theoretical framework (Qian, 2014), where two layers of asymmetric information are modeled for counterfeits: (1) counterfeiters fool buyers (see the discussion on deceptive counterfeiting above), and/or (2) buyers of counterfeits fool other peer consumers by signaling fake status.

In Qian (2014), quality was broadly measured by the cost of producing a good, which is a one-dimensional measure. In practice, quality can take on multiple dimensions. For instance, there are tangible, or “searchable”, elements of quality, such as the general appearance of shoes and other characteristics that are visible to consumers at the time of the purchase. There are also characteristics that consumers may not observe immediately, such as the technology that went into producing a pair of shoes. These functional features usually take time to experience and infer. Qian et al. (2015) study the effects of counterfeiter entry on decisions by original producers to upgrade the searchable and experiential dimensions of quality of the authentic incumbents. Building a vertical differentiation model with these two dimensions of quality, they find that entries by counterfeiters induce an authentic producer to invest more in improving visible quality and less in improving experiential quality, as compared to how that firm reacts to competition from legitimate, lower-quality entrants. They additionally show theoretically that visible quality can serve as a positive signal for the degree of experiential quality. Many of these theoretical predictions and findings are corroborated in several works (e.g. Berger et al., 2012; Li and Yi, 2017; Qian and Xie, 2016).

3. DATA

The data we deploy comes from two sources. A first dataset covers 427,389 customs seizures of goods and originates from various national customs authorities. It has been compiled by OECD/EUIPO (2016) for a recent update of their initiative on measuring the magnitude of global illicit trade.² The second source is the EC-JRC/OECD COR&DIP database (Dernis et al., 2015). The latter provides, among others, annual corporate accounts on sales performance, R&D investment, and IP activities.

3.1. Seizure Data

The OECD/EUIPO customs data reports individual-level seizures at national borders in the years between 2011 to 2013, including the year of seizures, reporting national custom authority, departure and destination economies, seized goods being imported or on transit, conveyance method, trade category/harmonized system (HS) of goods, name of the corporate IP right holder, and country of residence assigned via IP registration, registered name of the infringed IP (for example, name of the trademarked brand), quantity and estimated value³ of seizures as documented by customs' officers. Some of data provided to us on a confidential basis have been pre-cleaned, for example, as regards an attempt to standardize IP right holder names reported by customs officials. However, imputation and other data manipulations undertaken by OECD/EUIPO do not seem to affect the variables we deploy in the analysis. Moreover, as the data focuses on seized goods in trade only, notably, it excludes and does not record goods seized by offices or any other state authorities domestically (i.e. within borders).

A first look at the seizure data shows that the distributions of quantities and of value per customs seizure are highly skewed in 2011-13. The average (mean) quantity for each customs seizure listed in the OECD/EUIPO data contains 7,211 items, with a median value of only 3 items per seizure. The average (mean) value is 20,213 US dollars per seizure, with a median value of 400 US dollars. The average (mean) per-item value is 385 US dollars, with a median per-item value of 100 US dollars.

Second, more than 70% of border seizures infringe upon registered trademarks. Infringement of copyright, design, and utility model rights, geographical indications or

² The OECD/EUIPO dataset itself compiles three collections of data, namely subsamples of custom authorities in member states of the World Customs Organization (WCO), the European Commission's Directorate-General for Taxation and Customs Union (DG TAXUD) and US Customs and Border Protection (CBP).

³ In many instances value of seized goods is the transaction value appearing on accompanying invoices. This landed customs value includes the insurance and freight charges incurred. However, this documentation of values is not systematic and varies across national and regional jurisdictions and on custom officer levels. In the case of the DG TAXUD subset we will work with, declared rather than replacement values, i.e. prices of the authentic goods, are reported in the data.

patent rights is less commonly reported for goods being held in customs, together accounting for approximately 4 per cent of total seizures. The remainder of seizures does not hold information on the type of right infringed. However, it needs to be spelled out that cases infringing upon other rights may be per se harder to detect and assess for custom officials when compared to the ease of identification and burden of proof associated with infringing trademarks. In terms of seizure data quality, it should be noted that a certain amount of traded counterfeit goods may infringe upon rights other than trademark but is not seized at the borders and reported, and that there may be seizures recorded as trademark infringement that, unintentionally or on purpose, also infringe upon other rights. In that sense, the counterfeit measurement we capture here could be considered a lower-bound estimate. We also generate a dummy indicating counterfeit discovery/presence as an alternative treatment variable to test robustness of results in light of potential measurement errors. Moreover, the database contains close to 2,400 unique IP-right holders and for more than 70% of data-right holder information is available. Here, the average (mean) number of seizure listings per IP right holder is 128, with a median value of only 2 seizures.

Third, the bulk of seizures (more than 30 per cent) is sent by mail or courier services, and more than 10 per cent of total seizures are shipped by airplane. Most goods are being imported to a country when seized in controls (again, around 30 per cent), while goods on transit, or those being exported, are less commonly held and reported by customs. For around 50% of total seizure records information on the former type of transport or on the latter direction of trade is not available.

Fourth, total seizures are highly concentrated in specific product/good categories (see Table A2 in the Appendix for a description of product categories). Goods from trade chapters 64 and 61 of the HS classification alone make up close to 40% of seizures listed in the data. These two categories contain footwear and clothing, knitted or crocheted, respectively. Goods from HS trade chapter 42 (articles of leather) and 85 (electrical machinery and equipment) each account for roughly 15% of listings. Chapters 90 (instruments, optical, medical etc.), 91 (watches) and 95 (toys) as well as 30 (pharmaceuticals) and 33 (perfumery and cosmetics) range around 3 to 10%.

Moreover, seizure data is not collected based on random sampling at borders, but authorities frequently rely on risk-profiling techniques as well as informational exchange and collaborations with IP right owners in industry when deciding to inspect shipments.⁴ In turn, this could bias present seizure activities towards certain product categories and provenance countries that were more likely to experience counterfeiting in the past as well as IP protected products where a collaboration of enforcement authorities and IP owners is in place (Cuntz, 2016). While the first source of bias is less relevant for

⁴ Typically, firms can decide to apply to customs authorities. The information they will provide includes, among other things, details on features of authentic products as well as unauthorized counterfeits, other information useful for risk profiling including trade routes and value chains, proof of validity of IP rights relating to the product etc.

disaggregate level of our analysis, the second source of bias may, however, become problematic. In this particular case, the level of firm-level counterfeiting based on custom seizures observed *ex post* would depend on *ex ante* collaboration being in place and tracing information being provided by companies to custom authorities.

Lastly, counterfeit producers may strategically respond to customs operations in order to not be detected and, for example, adjust counterfeit trade routes or opt for unauthorized copying of a different set of products accordingly. Moreover, certain products (categories) such as medicines and cosmetics will suffer from downward biases as they may be recorded by customs officers not as IP-infringing but hazardous goods in trade and therefore may not be included in the OECD/EUIPO database on IP-infringing seizures but elsewhere. We will address several of these limitations of seizure data at later stages of the analysis.

We also consider limiting our analysis to a subset of the total seizures, i.e. seizures submitted by custom authorities in the 28 EU member states, $N = 294,624$. This subset, accounting for close to 70 per cent of total seizures, has been gathered on a mandatory basis from member states by the European Commission's Directorate-General for Taxation and Customs Union (DG TAXUD). It feeds into an EU-wide information system that assures a similar level of information is available for customs' operations across Europe.⁵ We thus exclude two other subsets in the OECD data, one provided by the World Customs Organization (WCO) and one by US Customs and Border Protection (CBP). WCO data has been gathered on a voluntary basis only and reporting may be tilted towards dedicated and coordinated actions of custom authorities in regional or international enforcement operations as well as higher-value seizures.⁶ CBP data does not incorporate information on IP ownership, we will need to further process the data.

3.2. Firm-level Information and Data Matching Outcome

The EC-JRC/OECD COR&DIP database is an extension of the EU Industrial R&D Investment Scoreboard database. Both sources have been used in previous research (Cincera and Veugelers, 2014; Honore et al., 2015; García-Manjón and Romero-Merino 2012; Montresor and Vezzani, 2015). The Scoreboard data provides information on annual research and development (R&D) investment, net sales, operating profit, capital expenditure, and total employees of the top 2,000⁷ corporate R&D performers worldwide. The consolidated (ultimate parent) data is collected from firms' financial reports in 2009-2013 and accounts by the Bureau van Dijk. Accordingly, the R&D data

⁵ The so-called anti-counterfeit and anti-piracy information system (COPIS) is used for online information-sharing purposes by custom authorities in all European member states.

⁶ For a discussion of these biases see OECD/EUIPO (2016: 39ff).

⁷ Note that the 2013 series extended coverage of the database to an annual of 2,500 R&D performing companies. Moreover, for non-Euro area companies, the currency values are transformed in Euros by using the year-end closing exchange rate (2012).

captures (nominal) cash flow investment financed by the firms themselves, and it is subject to accounting definitions of R&D and their application.⁸ For example, the definition for “intangible assets” set out by International Accounting Standard (IAS) 38 is based on the OECD Frascati manual definitions of R&D.⁹ The data does not allow to locate where the reported R&D is performed. Most other data uses standard accounting definitions.¹⁰ The COR&DIP database enriches the Scoreboard data by linking to proxies of inventive and creative output: It identifies patent and trademark portfolios held by these firms in 2010-12.¹¹ IP-related information is taken from PATSTAT (Autumn, 2014) for patent families and from selected IP offices in the case of trademarks.¹² Moreover, the COR&DIP data not only contains information on top corporate R&D investors (ultimate owners), but also to account for “controlled”

⁸ In this way, R&D investment excludes contract research jointly conducted with public or private entities. It also excludes shares held in other companies or research investment in joint ventures.

⁹ According to these (IAS 38), on the one hand, “research” (R) is an “original and planned investigation undertaken with the prospect of gaining new scientific or technical knowledge and understanding.” In accounting practice, “expenditure on research is recognized as an expense when it is incurred.” On the other hand, “development” (D) is defined as an “application of research findings or other knowledge to a plan or design for the production of new or substantially improved materials, devices, products, processes, systems or services before the start of commercial production or use.” Accordingly, “development costs are capitalized when they meet certain criteria and when it can be demonstrated that the asset will generate probable future economic benefits. Where part or all of the R&D costs have been capitalized, additions to the appropriate intangible assets are included to calculate the cash investment and any amortization is eliminated.”

¹⁰ First, net sales exclude sales taxes and shares of sales of joint ventures and associates. Second, operating profit is calculated as profit (or loss) before taxation, plus net interest cost (or minus net interest income) minus government grants, less gains (or plus losses) arising from the sale/disposal of businesses or fixed assets. Third, capital expenditure is used to acquire or upgrade physical assets such as equipment, property, industrial buildings. In accounts capital expenditure is added to an asset account (i.e. capitalized), and thus increases the asset's base. It is disclosed as additions to tangible fixed assets in accounts. Finally, the number of total employees is the total consolidated average employees or year-end employee numbers.

¹¹ IP data were linked to enterprise data using the names of the top corporate R&D investors and of their subsidiaries and matching them to the applicants' names provided in patent and trademark documents. The linking was carried out for each country using a series of algorithms (Squicciarini and Dernis, 2013).

¹² The patent data covers applications filed at the five top IP offices (IP5) in the world, namely: EPO (European Patent Office), JPO (Japan Patent Office), KIPO (Korean Intellectual Property Office), SIPO (State Intellectual Property Office of the People's Republic of China), and USPTO (United States Patent and Trademark Office). Patent data relate to families of patent applications with members filed at least in one of the IP5, excluding single filings. This is done to identify patents of relatively higher and comparable value. Hence, applications filed only in one of the IP5 offices, i.e. EPO, JPO, KIPO, SIPO and USPTO, are considered only in so far as another family member has been filed in any other office worldwide (anywhere in the world, not necessarily at another IP5 office). The trademark data covers applications filed at the USPTO, OHIM (Office for Harmonization in the Internal Market) and IP AUS (IP Australia).

subsidiary structures of more than 50,000 entities (as of 2012).¹³

Table 1. Summary Table: Main Variables in Treated and Control Samples (COR&DIP Panel Companies W/O Recorded Customs Seizures), 2011-2013

Variable	obs.	mean	std. dev.	min	Max
<i>treated sample: companies with recorded seizures</i>					
total employees	497	70,564	93,351	174	572,800
net sales (million €)	556	22,273	33,676	33	354,000
operating profits (million €)	556	2,237	4,807	-23,013	48,539
research and development investment (million €)	556	1,074	1,747	20	11,743
COR&DIP rank by R&D investment	556	523	516	1	2,150
capital expenditure (million €)	513	1,270	2,560	1	25,975
total number of trademarks (1)	531	78	121	1	859
total number of patent families (2)	521	809	1,664	1	13,464
total number of patent families, restrictive (3)	510	800	1,660	1	13,453
<i>control sample: companies without recorded seizures</i>					
total employees	4,728	22,449	50,608	13	961,000
net sales (million €)	5,264	6,870	20,926	0	357,000
operating profits (million €)	5,291	661	2,703	-16,715	44,842
research and development investment (million €)	5,307	181	489	6	8,345
COR&DIP rank by R&D investment	5,311	1,051	571	2	2,473
capital expenditure (million €)	4,728	529	2,229	0	38,757
total number of trademarks (1)	3,691	16	29	1	638
total number of patent families (2)	4,080	169	587	1	13,464
total number of patent families, restrictive def. (3)	3,955	167	581	1	13,453

Note: (1) Counts cover trademark applications filed at the USPTO, OHIM and IP AUS offices.

(2) Counts based on patent families having family members filed at least in one of the IP5 offices (EPO, JPO, KIPO, SIPO, USPTO), excl. single filings.

(3) Counts based on patent families having family members filed in at least two of the IP5 offices.

When matching with names of IP right holders as listed in the OECD/EUIPO seizure data, we exploit subsidiary structures and, accordingly, the variety of applicant names recorded on US trademark filings registered either by the ultimate owner or by the subsidiary. We first run a fuzzy matching procedure using Stata's *matchit* package. We then continue by manually inspecting all cases/companies identified by the algorithm above a similarity score threshold of 0.85, resulting in 565 approved matches.¹⁴ Notably, these observations account for almost one third of total seizures where IP right holder information is available, or up to 100,000 seizures recorded in the data. Moreover, observations with customs seizures account for 11 per cent of total

¹³ COR&DIP considers entities as "controlled" only if subsidiary firms are owned for more than 50 per cent by the parent company.

¹⁴ For a documentation of the *matchit* package and details on abilities, please refer to <https://www.stata.com/meeting/switzerland16/slides/raffo-switzerland16.pdf>.

observations included in the COR&DIP panel of corporate R&D performers over the relevant period 2011-2013 where we can observe seizure activities (9 per cent or 492 cases, respectively, if only the DG TAXUD seizure population is used in the matching procedure).

In Tables 1 and 2, we compare firm characteristics and industry affiliation among observations in the matched sample (companies also recorded at least once in the seizure data) to those remaining unmatched in the COR&DIP panel. Descriptive results (Table 1) suggest that companies in the treated sample are, on average (mean), larger in terms of total employees, net sales and operating profit. Moreover, these companies are more heavily investing in R&D and have higher capital expenditure (CAPEX): The average company in the treated sample ranks 523rd among global R&D performers, while the average company in the control sample only ranks 1,051st. These companies are filing significantly larger numbers of trademarks and patent applications globally when their marketing and research effort is being IP-protected.

This already confirms economic intuition that infringing counterfeit producers frequently target companies with higher brand value and with greater research and innovation orientation, often serving larger markets and/or enabling to charge higher prices, by unauthorized copying of products and saving costs by free-riding on others' efforts. As companies in both samples operate in very similar industries, this suggests that the patterns we observe are not systematically biased by differences in industry composition (Table 2 and Table A1 in the Appendix for a description of industry codes).

Moreover, we inspect for and find no significant differences of seizures included in the matched sample when compared to the total seizure OECD/EUIPO data. With the exception of HS good chapter 91 (footwear), seizures in the sample are, again, highly concentrated in similar specific product categories (again, see Table A2 in the Appendix for category description).¹⁵ Accordingly, goods from trade chapter 85 alone (electrical machinery and equipment) account for slightly more than 30 per cent of total companies with seizures in 2011-2013. Goods from trade chapter 87 (vehicles other than railway, parts and accessories thereof) make up for roughly 15 per cent. Chapters 95 (toys), 84 (boilers, machinery and mechanical appliances; parts thereof), 61 (clothing, knitted or crocheted) and 42 (articles of leather) as well as 30 (pharmaceuticals) and 33 (perfumery and cosmetics) all range around 4 to 7 per cent.

Similar to the total seizure sample, distributions of quantities and of value per company's total seizures per year are, again, highly skewed. The average (mean) quantity seized per company and year contains 322,243 items, with a median value of 2,086 items. The average (mean) estimated value of annual seizures is 2,853,013 US dollars, with a median value of 35,462 US dollars. The average company in the matched sample has 176 seizures recorded annually (mean), with a median value of only 4 seizures.

¹⁵ We identify a unique harmonized system (HS) code per company, using only the most frequently cited hs code in all product seizures an individual firm experiences in the period 2011-13.

Table 2. Summary Table: Industry Classification Benchmark (ICB codes, 4-digit) Distributions for Treated and Control Samples (COR&DIP Panel Companies w/o Customs Seizures), 2011-2013

ICB description and code	obs.	p.c.	obs.	p.c.
	control sample: companies w/o customs seizures		treated sample: companies with customs seizures	
0530 Oil & Gas Producers	75	1.4	1	0.2
0570 Oil Equipment, Services and Distribution	41	0.8	0	0.0
0580 Alternative Energy	22	0.4	0	0.0
1350 Chemicals	332	6.3	17	3.1
1730 Forestry & Paper	27	0.5	0	0.0
1750 Industrial Metals & Mining	94	1.8	4	0.7
1770 Mining	29	0.5	0	0.0
2350 Construction & Materials	144	2.7	9	1.6
2710 Aerospace & Defense	123	2.3	13	2.3
2720 General Industrials	182	3.4	22	4.0
2730 Electronic & Electrical Equipment	482	9.1	37	6.7
2750 Industrial Engineering	494	9.3	32	5.8
2770 Industrial Transportation	26	0.5	0	0.0
2790 Support Services	56	1.1	1	0.2
3350 Automobiles & Parts	292	5.5	79	14.2
3530 Beverages	18	0.3	10	1.8
3570 Food Producers	139	2.6	12	2.2
3720 Household Goods & Home Construction	73	1.4	25	4.5
3740 Leisure Goods	59	1.1	42	7.6
3760 Personal Goods	65	1.2	43	7.7
3780 Tobacco	7	0.1	11	2.0
4530 Health Care Equipment & Services	235	4.4	9	1.6
4570 Pharmaceuticals & Biotechnology	581	10.9	42	7.6
5330 Food & Drug Retailers	9	0.2	0	0.0
5370 General Retailers	28	0.5	7	1.3
5550 Media	30	0.6	13	2.3
5750 Travel & Leisure	45	0.8	7	1.3
6530 Fixed Line Telecommunications	53	1.0	4	0.7
6570 Mobile Telecommunications	11	0.2	4	0.7
7530 Electricity	72	1.4	0	0.0
7570 Gas, Water & Multi-utilities	32	0.6	0	0.0
8350 Banks	73	1.4	5	0.9
8530 Nonlife Insurance	3	0.1	0	0.0
8570 Life Insurance	6	0.1	0	0.0
8630 Real Estate Investment & Services	5	0.1	0	0.0
8770 Financial Services	32	0.6	4	0.7
8980 Equity Investment Instruments	3	0.1	0	0.0
8990 Nonequity Investment Instruments	3	0.1	0	0.0
9530 Software & Computer Services	533	10.0	22	4.0
9570 Technology Hardware & Equipment	777	14.6	81	14.6
Total	5,311	100.0	556	100.0

4. IDENTIFICATION STRATEGY

Different from OECD's original approach on the data, we do not estimate total counterfeit trade based on value or volume records in the seizure data, but focus the analysis on firm-level sales performance and investment choices (outcomes) upon seizure incidences customs authorities are reporting to IP-right holding firms. Accordingly, we exploit variation in counterfeit seizure events, firms (i.e. the IP right holding entity) experience throughout the observation period 2011-2013 and create a binary counterfeit dummy equal to 1 if one or more incidences occur in a given year t , 0 otherwise. At this stage of the analysis, we neglect issues of scope, say, differences in firms' total number of annual seizures, and consider binary incidences (treatment) to fully reveal information and proxy to firms the presence of counterfeit activity in year t . At a first cut, this would also help us ward against potential measurement errors in the exact count of counterfeiting amount cross industry, as briefly discussed in the data section. The main focus of this paper is to analyze the impact of the presence of counterfeiting. We conduct robustness checks on the impacts of the amount of counterfeiting.

The immediate methodological challenge is to overcome the potential endogeneity of counterfeit activity due to active firm performance and investment choices. As the descriptive results from the previous section clearly demonstrate and as argued before, IP infringing producers typically target and have strong preferences for copying products and services by original producers with higher IP value and with greater research and innovation investment orientation, giving them maximum leeway to free-riding. Accordingly, we cannot expect counterfeit incidences to be randomly distributed among R&D performing companies in the COR&DIP panel. Rather, the treatment group (those with recorded customs seizure incidences) will systematically *ex ante* outperform corporate entities with no such incidences recorded in the observation period and the latter we would in principle consider for inclusion in the control group. In order to correct for this type of pretreatment selection bias, we deploy a propensity score matching (PSM) approach (Rosenbaum and Rubin, 1983; Qian, 2007). Ultimately, adjustments via propensity scores help balance treated and untreated samples. The propensity score is the conditional probability of assignment to the treatment, given observed covariates.

We use the Stata implemented PSCORE package¹⁶ to identify the total number of propensity score intervals (or blocks) it takes until, in all intervals, the treatment (counterfeit infringed) and control (un-infringed) groups of companies are comparable in all other aspects except the exposure to counterfeit infringements.

¹⁶ https://www.stata.com/meeting/italy14/abstracts/materials/it14_grotta.pdf and <https://www.bgsu.edu/content/dam/BGSU/college-of-arts-and-sciences/center-for-family-and-demographic-research/documents/Workshops/2013-workshop-PSA-brief-Stata-example.pdf>

Table 3. Estimation of Propensity Scores, Data Based on Pretreatment Values of Covariates and DG TAXUD Seizures Population Only.

DV: binary seizure incidences	Coef.	Std. Err.
log. total employees	-0.47	0.64
(log. total employees) ²	0.03	0.03
log. operating profits	0.42	0.30
(log. operating profits) ²	-0.01	0.02
log. total trademarks	0.53***	0.07
log. total patent fam. restrict.	0.19***	0.05
<i>ICB industry code, dum.</i>		
0530 Oil & Gas Producers	-4.20***	1.27
1350 Chemicals	-2.76***	0.77
1750 Industrial Metals & Mining	-1.41	0.92
2350 Construction & Materials	-1.92**	0.85
2710 Aerospace & Defense	-1.45*	0.78
2720 General Industrials	-0.93	0.73
2730 Electronic & Electrical Equipment	-1.39*	0.73
2750 Industrial Engineering	-0.99	0.72
3350 Automobiles & Parts	0.21	0.72
3530 Beverages	-0.38	0.82
3570 Food Producers	-1.68**	0.79
3720 Household Goods & Home Construction	-0.68	0.75
3740 Leisure Goods	1.02	0.75
3760 Personal Goods	0.68	0.75
3780 Tobacco	0.61	0.90
4530 Health Care Equipment & Services	-2.63***	0.80
4570 Pharmaceuticals & Biotechnology	-2.35***	0.73
5370 General Retailers	-0.18	0.93
5550 Media	-0.31	0.95
5750 Travel & Leisure	0.08	0.97
6530 Fixed Line Telecommunications	-2.77***	0.96
8350 Banks	-1.82*	0.97
9530 Software & Computer Services	-1.35*	0.76
9570 Technology Hardware & Equipment	-0.89	0.71
2011 year, dum.	-0.38**	0.17
2012 year, dum.	-0.18	0.16
unique company ident.	0.00	0.00
const.	-3.19	2.95
N	2783	
Prob > LR	0.00	
LR chi2	696.07	
Pseudo R2	0.32	

Note: * p<.05; ** p<.01; *** p<.001

This is achieved by matching on the expected probability of each respective observation unit (company entity in our case) (as denoted by $e(x)$) in the treated and

control groups so that the average $e(x)$ within each interval (or block) do not differ across treatment and control groups anymore and that there is no need to further split samples. Within each interval, the algorithm tests that the means of each characteristic do not systematically differ between the treated and control sample observations (Table A3 in Appendix). Upon careful inspections and using only the DG TAXUD recorded seizures, we select a set of covariates that could potentially correlate with both the counterfeit infringement probability and the sales and innovation outcomes, and hence could potentially cause biased coefficient estimates of the infringement effects in a regular regression model. We further include their non-linear transformations in estimating propensity scores based on pretreatment values (2009-2010)¹⁷ in a logistic model (Table 3 and Table A1 in Appendix for a description of industry codes).

5. RESULTS

5.1. Summary of Key Results

Table 4 presents results from regressions on main outcome variables, logged net sales and R&D investment. In the baseline specification (Column 1), we find no significant treatment effects for any of these outcomes. Hence we begin inspecting into product categories. For each product category as identified via HS trade chapters (Columns 2-9 in the Table 4 and Table A2 in the Appendix for a description of product categories), we run separate regressions estimating binary seizure treatment effect on outcomes. At large, infringing seizures treatment effects seem to be more pronounced for R&D outcome as compared to sales ones. Moreover, these effects are more commonly observed for higher HS chapters, higher chapters being associated with greater technological complexity and more sophisticated manufacturing and, arguably, product markets where research and innovation competition is more intense and product life cycles are shorter.

We find significant negative treatment effects on logged net sales in most product categories. However, in specific categories there is a positive sign, but effects render insignificant. For example, this applies to goods from HS chapter 8 such as metal-based machinery, electrical equipment, tools or vehicles. For R&D investment, we find similar patterns for treatment effects as regards direction, but on slightly higher significance levels. For R&D investment *net off* the effect of sales on R&D, these effects persist, while only the size of counterfeiting effects slightly decreases. Put differently, when controlling for the level of sales displacement, R&D investment decreases in most product categories as one would expect. However, for specific categories, effects are reversed and there is an increase in R&D levels.

¹⁷ One exception is the IP related data we use. Reference year (application year) for trademark and patent family data is 2010.

Table 4. OLS Regression Results for Binary Seizure Dummy Variable Based on Separately Run Regressions by Outcome Variables (Logged Net Sales, Logged R&D Investment) and By Good Category (Harmonized System Trade Chapter), DG TAXUD Seizures Population Only, 2011-2013

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
seizure incidences, dum.	0.10 (0.08)	-1.33 (1.01)	-3.21*** (0.52)	-0.12 (0.15)	-0.15 (0.22)	1.37 (1.01)	-0.69*** (0.19)	0.35*** (0.09)	-0.94*** (0.16)
propensity score	3.89*** (0.14)	4.91*** (0.19)	4.81*** (0.19)	4.20*** (0.18)	4.74*** (0.18)	4.92*** (0.19)	4.62*** (0.18)	4.85*** (0.15)	4.56*** (0.17)
const.	4.38*** (0.03)	4.23*** (0.03)	4.24*** (0.03)	4.31 (0.03)	4.24 (0.03)	4.23*** (0.03)	4.25 (0.03)	4.28 (0.02)	4.26 (0.03)
N	2,783	2,176	2,179	2,290	2,227	2,176	2,215	2,474	2,257
adj. R ²	0.31	0.24	0.23	0.24	0.25	0.24	0.23	0.37	0.24
DV: logged net sales									
seizure incidences, dum.	0.13 (0.09)	1.58 (1.27)	-1.35* (0.65)	-0.30 (0.18)	-0.13 (0.27)	1.71 (1.27)	-0.59* (0.24)	0.16 (0.11)	-0.64** (0.20)
propensity score	4.36*** (0.15)	5.89*** (0.24)	5.83*** (0.24)	5.16*** (0.21)	5.70*** (0.22)	5.90*** (0.24)	5.48*** (0.23)	5.40*** (0.19)	5.15*** (0.22)
const.	7.54*** (0.03)	7.37*** (0.03)	7.37*** (0.03)	7.44*** (0.03)	7.39*** (0.03)	7.37*** (0.03)	7.40*** (0.03)	7.43*** (0.03)	7.43*** (0.03)
N	2,776	2,169	2,172	2,283	2,220	2,169	2,208	2,467	2,250
adj. R ²	0.31	0.22	0.22	0.24	0.24	0.22	0.21	0.31	0.21
DV: logged R&D									
logged net sales	0.50*** (0.01)	0.40*** (0.01)	0.40*** (0.01)	0.44*** (0.01)	0.41*** (0.01)	0.40*** (0.01)	0.42*** (0.01)	0.43*** (0.01)	0.42*** (0.01)
seizure incidences, dum.	0.03 (0.06)	-1.97* (0.88)	-2.67*** (0.45)	0.01 (0.13)	-0.09 (0.19)	0.68 (0.87)	-0.44** (0.17)	0.28*** (0.08)	-0.67*** (0.13)
propensity score	1.71*** (0.13)	2.54*** (0.19)	2.45*** (0.18)	1.90*** (0.17)	2.39*** (0.18)	2.54*** (0.18)	2.34*** (0.18)	2.52*** (0.15)	2.41*** (0.17)
const.	0.62*** (0.11)	1.28*** (0.11)	1.26*** (0.11)	1.01*** (0.11)	1.21*** (0.11)	1.27*** (0.11)	1.18*** (0.11)	1.07*** (0.11)	1.17*** (0.11)
N	2,776	2,169	2,172	2,283	2,220	2,169	2,208	2,467	2,250
adj. R ²	0.53	0.43	0.43	0.45	0.44	0.43	0.44	0.54	0.45

Note: s.e. in parentheses. legend: * p<.05; ** p<.01; *** p<.001

Counterfeit entry, notwithstanding its mostly negative static effect on sales, might exhibit positive dynamic effects there, making *specific* product markets more competitive in medium term. Further research with a longer panel data are needed to confirm this which would further enable us to control for potential time lags in responses. Counterfeit effects on sales and R&D become very small or even render insignificant once we deploy the total number of annual seizures as an alternative dependent variable. Tobit, fixed effect (FE) Poisson and quasi maximum likelihood (QML) panel models presented in Tables A4, A5 and A6 in the Appendix aim to capture these effects.

We run several robustness checks to confirm main results: First, results do not seem to depend on selection of the underlying sample of seizures, i.e. whether we also include data from WCO sources (see Table A7 in the Appendix). Second, OLS regression for winsorized outcomes based on 99 percentile cutoff values yields very similar results (see Table A8). Similarly, results continue to hold when we exclude propensity score intervals 7 and 8 from the overall sample (see Table A9). Both checks suggest that the analysis is not sensitive to outliers in the data. Third, by introducing sales as an independent variable, estimates might be subject to bias, as sales and R&D investment seem simultaneously defined. We address these concerns by using an instrumental variable (IV) approach. Table A10 in the Appendix presents findings where the IV is the net sales at time (t-2). Estimates are very similar to those in our baseline models.

Several arguments can be put forward to explain *heterogeneous* product category sales and R&D effects we observe. First, rates of substitutability between authentic and counterfeit products may differ from one category to the other and, in turn, would impose different levels of sales displacement (or extension) on original producers.

Second, elasticities of revenues from sales and R&D investment may differ for average companies in one product market to another. Put differently, any sudden decline (or increase) in available corporate cash flow from displaced or promoted net sales will not necessarily translate into one-to-one changes in the level of investment. Analogously, there is an extensive literature on elasticities in the context of R&D tax credit and similar tax instruments, i.e. looking into corporate R&D investment responses to changes in taxable income (often referred to as “input additionality”). Here, similarly, industries (and, likely, product markets) show heterogeneous effects with variation of income, with the strongest effects of tax policy coming from those sectors that are more intensive in R&D and patents (for example, Dechezleprêtre et al., 2016; Rao 2016).

Third, as discussed in previous research (Qian, 2014; Qian et al., 2015) product markets with asymmetric information may differ by the amount of deceptive and non-deceptive counterfeiting, each having separate implications for the expected direction of effects on sales.¹⁸ In the case of deceptive counterfeiting, demand

¹⁸ Based on the data available to us, however, we cannot distinguish deceptive from non-deceptive counterfeiting, nor can we credibly establish market-specific rates of substitutability. Moreover, we cannot provide evidence on (nor identify) possible firm strategies underlying the sales and R&D effects we observe. If applicable, any effects incorporating original producer's set of strategic responses would be conditional on

deteriorates as some rational consumer aware of counterfeiters withdraw from markets entirely, leading to a decline in sales which is in line with some of the negative sales effects we observe across product categories.

In the case of non-deceptive counterfeiting, however, pricing and net sales effects render ambiguous. On the one hand, original producers upgrade product quality and increase prices in order to recover costs under specific circumstances (Qian, 2008) or send costly (higher) price signals, both enabling consumers to distinguish types and quality (Akerlof 1970). The positive sign for sales as well as the robust positive and significant effect on R&D in HS chapter 8 provide some product-specific evidence for this line of the argument. On the other hand, counterfeiters can also increase price competition levels, their market presence lowering average prices that can be commanded by original producers accordingly, or inducing original producers to choose “predatory” pricing strategies. Ultimately, the latter strategies deter entry of (additional) counterfeiters, by also lowering prices below marginal costs. Here again, forgone sales from lowering prices may explain some of the declining sales effects we observe across many product categories.

Fourth, positive sales effect can also, as discussed above, emerge from promotional effects generated by the presence of counterfeit goods, in particular in low-IP equilibrium industries with status-conferring goods such as global fashion (Raustiala and Sprigman, 2006). The positive sales sign we observe in HS Chapter 8, however, does not corroborate this last line of argument as the HS category mostly does not include such type of goods and is among the ones being considered IP-right intensive. Moreover, for global fashion and artistic industries which are most prominent in HS good Chapters 6 and 9 we find negative sales effects.

4.1. Checking Potential Biases due to Omitted Variables

We conduct statistical analyses following Rosenbaum (1999, 2002) to check how sensitive the effect estimates of counterfeit infringements are to other potential variables we do not observe. The estimates in this study are robust. Such sensitivity analysis as proposed by Rosenbaum are commonly applied (DiPrete and Gangl, 2004; Becker and Caliendo, 2007). It addresses the following concern: after matching on the observed firm characteristics, how large must the residual departure from random assignment be before the qualitative conclusions are altered. We check the range of point estimates for the counterfeit impacts in our study against the standard sensitivity range listed in Rosenbaum (2002). The estimates in this study are shown to be insensitive to hidden biases due to unobserved covariates. Details are available upon request.

one or more (ideal) escalation stages of the counterfeiting phenomena. Stages and sales at risk are likely specific to product markets at time t : prevention (strategies deterring entry), presence (product differentiation and competitive strategies), dominance (demand deterioration and, possibly, market exit).

5. DISCUSSION AND LIMITATIONS OF THE APPROACH

The results shed lights to the following implications and interpretations. First, although counterfeit infringement incidences exhibit an overall negative effects on the R&D and net sales across various regression specifications, with a rare positive effect documented in the regression for the tools, materials, and vehicles sector (HS 8), the magnitudes and significances of such impacts seem to vary across industries. The broadly negative effects on R&D investment convey potential discouragement of counterfeit infringements for innovative incentives for the sectors where we observed significantly negative effect estimates. Arguably, positive or negative R&D effects could also reflect changing appropriability conditions on future assets, for example, more or less effective public and private enforcement institutions (qualitatively), or more or less extensive activities (quantitatively). In that case, it would seem most industries in our sample were downgrading their expectations and depreciating future assets in 2011-13. This scenario we consider as the most unlikely as we would expect firm-level management (and risk management in particular) to rationally respond to the risk posed by sales-displacing counterfeits, and, arguably, early indication signaled via recorded customs seizures should have informational value to management.¹⁹ Rather than mere admittance, with expectations dampening, management should reallocate investment to a set of less risky business activities with higher expected profits. These reallocations have implications for changes in, both, the direction but also the total amount of R&D invested. While we are unable to monitor changes in the direction of R&D undertaken, we can observe changes in total investment.

It is worth acknowledging that, even though the firm sample we deploy puts an emphasis on heavy R&D spenders (and, plausibly, frequent innovators), we cannot distinguish sales generated from innovative products and services from sales generated from other sources. However, counterfeit effects on sales may differ in these two categories, for example, say more technically advanced, innovative solutions being harder copy and, thus, less frequently sales being displaced. Similarly, distinct sales effects also imply different and preventive research investment choices: assuming research investment makes future sales (generated by innovative products) more resilient to counterfeiting may induce additional investment upfront. Accordingly, future research on counterfeiting and R&D dynamics might be using additional sales and investment information, accounting and testing for specific effects as regards sales from innovative products and services versus sales from any other sources.

Second, indirect competition biases results on sales and R&D effects, for example, as has been previously argued in the economic literature, counterfeiters' technologies may be scalable in specific industries (Belleflamme and Picard, 2007). Arguably,

¹⁹ Another argument in this line of "non-strategic" reasoning is to consider counterfeit entry to generate neck-to-neck competition among incumbents, possibly, leading to biased investment behavior (for example, Cantner et al. 2009) and increases in R&D.

counterfeit entry and sales may discourage average R&D investment more rapidly among competitors than investment effort by the original producer, i.e. the one whose products are being infringed in a specific good categories or industry (i.e. indirect effect > direct effect). In turn, the positive effects on R&D investment we observe would be a mere artefact of the changes in competitors' investment levels. While we fully subscribe to the argument on (indirect) competition due to counterfeit entry, we object the idea of indirect sales or R&D effects outweighing any direct ones, partially because strategic firm responses rely on exclusive information sharing with customs. Rather, it seems likely that we underestimate any sales and R&D displacement effect, positive as well as negative ones (downward biasing our results, i.e. direct effect > indirect effect). Again, future research in this area may want to isolate out and separately study effects of counterfeit entry on original producers and on competitor firms.

Third, effects on R&D display pure strategic firm responses to counterfeit incidences. While we consider this interpretation as the most credible one based on the data and results we have obtained, certain caveats still apply: Certain R&D investment may constitute "sticky or slack" resources that cannot be immediately traded, requiring long-term orientation and commitment and therefore it will be harder (or sometimes impossible) to reallocate these, for example, multi-annual investment in lab facilities in a specific location. Moreover, there is a plethora of alternative strategic responses to counterfeit seizure incidences (other than investment in research) available such as investment in private or public-private IP enforcement initiatives, relocation of manufacturing sites, changes of suppliers or distribution channels in due course, all expected to lower the risk of informational leakages and unauthorized copying on future assets. Lastly, it is hard to assess the concise quality, value and timeliness of customs information on seizures to firms' management decisions, not only because detection of goods is limited to those traded. However, we trust that seizures can serve as a credible signal and important cue for the presence of counterfeiters and riskiness of investment choices.

Fourth, using investment on R&D on a sample of companies with seizures mainly infringing upon trademarks may come with some loss of precision, R&D investment being typically associated with other IP protection such as patenting. Rather, one would want to use investment measures more closely tied to brand value and trademarks such as specific investment in marketing or advertising campaigns. However, as noted above, seizures recorded as infringing by customs officials may often not solely infringe upon trademarks but involve counterfeiting of underlying technologies that may be patent protected but are not adequately recorded by officials as harder to detect. Moreover, previous research suggests that brand-intensive firms also tend to be more patent-intensive (Graevenitz and Sandner, 2009; WIPO, 2013).

6. CONCLUSIONS

Counterfeit and pirated products are prevalent across the world and in all industry sectors. The impacts of counterfeiting on corporate R&D investment and sales is at the heart of much economics and policy debates. Two decades of IO literature attempt to reconcile two strands of theories on how market structure affects innovative incentives. While Schumpeter considers monopoly as most conducive to stimulating innovations, enabling sufficient profitability to recoup innovative costs and hence secure incentives to innovate. Arrow, on the other hand, argues that perfect competition expels idleness and stimulates innovation. Later theory and empirical analyses show an inverted-U relationship between competition and innovation (Aghion et. al., 2005). Counterfeits have been treated in the literature as illegal and inferior competitors (Grossman and Shapiro, 1988; Qian, 2014, Qian et al., 2015). Theories have proposed heterogeneous effects counterfeiters could have on the authentic firms, depending on the product categories (Qian et. al., 2015). This research provides one of the first empirical analyses on the international customs data on counterfeiting by each product category.

Utilizing a unique international customs dataset matched with company statistics, we are able to track the sampled corporations' R&D investments and performances before and after being infringed by counterfeiters. We take the approach of propensity score method combined with panel analyses to account for the potential endogeneity of counterfeiting infringement. We identified mostly negative impacts counterfeiting has on R&D investments, sales, and revenue across industries, with heterogeneous magnitudes and statistical significances. While most specifications show negative impacts on R&D investments, sales, and firm revenue, R&D intensity increased for certain sectors (broadly categorized as the tools and vehicles sector). This implies that enforcement priorities could be directed to the sectors that suffered negative consequences from the counterfeiting most and depending on where social pay-off from enforcement is highest, since enforcement resources are constrained even in the most resourceful nations (Fink et al., 2016).

Given the scope of the data available, longer term impacts of counterfeiting are yet to be explored. It would be desirable to obtain counterfeit statistics outside the exporting and importing context in the domestic market, and to enlarge sample size in some of the industries. Data on different types of counterfeits, when could be made available, would also be helpful to further test the mechanisms of the underlying effects on innovative incentives and other firm outcomes. Nonetheless, this study serves as a first step to explore many interesting topics on counterfeiting in the international market.

APPENDIX

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description

Sector	Subsector	Definition
0530 Oil & Gas Producers	0533 Exploration & Production	Companies engaged in the exploration for and drilling, production, refining and supply of oil and gas products.
	0537 Integrated Oil & Gas	Integrated oil and gas companies engaged in the exploration for and drilling, production, refining, distribution and retail sales of oil and gas products.
0570 Oil Equipment, Services & Distribution	0573 Oil Equipment & Services	Suppliers of equipment and services to oil fields and offshore platforms, such as drilling, exploration, seismic-information services and platform construction.
	0577 Pipelines	Operators of pipelines carrying oil, gas or other forms of fuel. Excludes pipeline operators that derive the majority of their revenues from direct sales to end users, which are classified under Gas Distribution.
0580 Alternative Energy	0583 Renewable Energy Equipment	Companies that develop or manufacture renewable energy equipment utilizing sources such as solar, wind, tidal, geothermal, hydro and waves.
	0587 Alternative Fuels	Companies that produce alternative fuels such as ethanol, methanol, hydrogen and bio-fuels that are mainly used to power vehicles, and companies that are involved in the production of vehicle fuel cells and/or the development of alternative fueling infrastructure.
1350 Chemicals	1353 Commodity Chemicals	Producers and distributors of simple chemical products that are primarily used to formulate more complex chemicals or products, including plastics and rubber in their raw form, fiberglass and synthetic fibers.
	1357 Specialty Chemicals	Producers and distributors of finished chemicals for industries or end users, including dyes, cellular polymers, coatings, special plastics and other chemicals for specialized applications. Includes makers of colorings, flavors and fragrances, fertilizers, pesticides, chemicals used to make drugs, paint in its pigment form and glass in its unfinished form. Excludes producers of paint and glass products used for construction, which are classified under Building Materials & Fixtures.
1730 Forestry & Paper	1733 Forestry	Owners and operators of timber tracts, forest tree nurseries and sawmills. Excludes providers of finished wood products such as wooden beams, which are classified under Building Materials & Fixtures.
	1737 Paper	Producers, converters, merchants and distributors of all grades of paper. Excludes makers of printed forms, which are classified under Business Support Services, and manufacturers of paper items such as cups and napkins, which are classified under Nondurable Household Products.
1750 Industrial Metals & Mining	1753 Aluminum	Companies that mine or process bauxite or manufacture and distribute aluminum bars, rods and other products for use by other industries. Excludes manufacturers of finished aluminum products, such as siding, which are categorized according to the type of end product.
	1755 Nonferrous Metals	Producers and traders of metals and primary metal products other than iron, aluminum and steel. Excludes companies that make finished products, which are categorized according to the type of end product.
	1757 Iron & Steel	Manufacturers and stockholders of primary iron and steel products such as pipes, wires, sheets and bars, encompassing all processes from smelting in blast furnaces to rolling mills and foundries. Includes companies that primarily mine iron ores.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
1770 Mining	1771 Coal	Companies engaged in the exploration for or mining of coal.
	1773 Diamonds & Gemstones	Companies engaged in the exploration for and production of diamonds and other gemstones.
	1775 General Mining	Companies engaged in the exploration, extraction or refining of minerals not defined elsewhere within the Mining sector.
	1777 Gold Mining	Prospectors for and extractors or refiners of gold-bearing ores.
	1779 Platinum & Precious Metals	Companies engaged in the exploration for and production of platinum, silver and other precious metals not defined elsewhere.
2350 Construction & Materials	2353 Building Materials & Fixtures	Producers of materials used in the construction and refurbishment of buildings and structures, including cement and other aggregates, wooden beams and frames, paint, glass, roofing and flooring materials other than carpets. Includes producers of bathroom and kitchen fixtures, plumbing supplies and central air-conditioning and heating equipment. Excludes producers of raw lumber, which are classified under Forestry.
	2357 Heavy Construction	Companies engaged in the construction of commercial buildings, infrastructure such as roads and bridges, residential apartment buildings, and providers of services to construction companies, such as architects, masons, plumbers and electrical contractors.
2710 Aerospace & Defense	2713 Aerospace	Manufacturers, assemblers and distributors of aircraft and aircraft parts primarily used in commercial or private air transport. Excludes manufacturers of communications satellites, which are classified under Telecommunications Equipment.
	2717 Defense	Producers of components and equipment for the defense industry, including military aircraft, radar equipment and weapons.
2720 General Industrials	2723 Containers & Packaging	Makers and distributors of cardboard, bags, boxes, cans, drums, bottles and jars and glass used for packaging.
	2727 Diversified Industrials	Industrial companies engaged in three or more classes of business within the Industrial industry that differ substantially from each other.
2730 Electronic & Electrical Equipment	2733 Electrical Components & Equipment	Makers and distributors of electrical parts for finished products, such as printed circuit boards for radios, televisions and other consumer electronics. Includes makers of cables, wires, ceramics, transistors, electric adapters and security cameras.
	2737 Electronic Equipment	Manufacturers and distributors of electronic products used in different industries. Includes makers of lasers, smart cards, bar scanners, fingerprinting equipment and other electronic factory equipment.
2750 Industrial Engineering	2753 Commercial Vehicles & Trucks	Manufacturers and distributors of commercial vehicles and heavy agricultural and construction machinery, including rail cars, tractors, bulldozers, cranes, buses and industrial lawn mowers. Includes non-military shipbuilders, such as builders of cruise ships and ferries.
	2757 Industrial Machinery	Designers, manufacturers, distributors and installers of industrial machinery and factory equipment, such as machine tools, lathes, presses and assembly line equipment. Includes makers of pollution control equipment, castings, pressings, welded shapes, structural steelwork, compressors, pumps, bearings, elevators and escalators.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
2770 Industrial Transportation	2771 Delivery Services	Operators of mail and package delivery services for commercial and consumer use. Includes courier and logistic services primarily involving air transportation.
	2773 Marine Transportation	Providers of on-water transportation for commercial markets, such as container shipping. Excludes ports, which are classified under Transportation Services, and shipbuilders, which are classified under Commercial Vehicles & Trucks.
	2775 Railroads	Providers of industrial railway transportation and railway lines. Excludes passenger railway companies, which are classified under Travel & Tourism, and manufacturers of rail cars, which are classified under Commercial Vehicles & Trucks.
	2777 Transportation Services	Companies providing services to the Industrial Transportation sector, including companies that manage airports, train depots, roads, bridges, tunnels, ports, and providers of logistic services to shippers of goods. Includes companies that provide aircraft and vehicle maintenance services.
	2779 Trucking	Companies that provide commercial trucking services. Excludes road and tunnel operators, which are classified under Transportation Services, and vehicle rental and taxi companies, which are classified under Travel & Tourism.
2790 Support Services	2791 Business Support Services	Providers of nonfinancial services to a wide range of industrial enterprises and governments. Includes providers of printing services, management consultants, office cleaning services, and companies that install, service and monitor alarm and security systems.
	2793 Business Training & Employment Agencies	Providers of business or management training courses and employment services.
	2795 Financial Administration	Providers of computerized transaction processing, data communication and information services, including payroll, bill payment and employee benefit services.
	2797 Industrial Suppliers	Distributors and wholesalers of diversified products and equipment primarily used in the commercial and industrial sectors. Includes builders merchants.
	2799 Waste & Disposal Services	Providers of pollution control and environmental services for the management, recovery and disposal of solid and hazardous waste materials, such as landfills and recycling centers. Excludes manufacturers of industrial air and water filtration equipment, which are classified under Industrial Machinery.
3350 Automobiles & Parts	3353 Automobiles	Makers of motorcycles and passenger vehicles, including cars, sport utility vehicles (SUVs) and light trucks. Excludes makers of heavy trucks, which are classified under Commercial Vehicles & Trucks, and makers of recreational vehicles (RVs and ATVs), which are classified under Recreational Products.
	3355 Auto Parts	Manufacturers and distributors of new and replacement parts for motorcycles and automobiles, such as engines, carburetors and batteries. Excludes producers of tires, which are classified under Tires.
	3357 Tires	Manufacturers, distributors and retreaders of automobile, truck and motorcycle tires.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
3530 Beverages	3533 Brewers	Manufacturers and shippers of cider or malt products such as beer, ale and stout.
	3535 Distillers & Vintners	Producers, distillers, vintners, blenders and shippers of wine and spirits such as whisky, brandy, rum, gin or liqueurs.
	3537 Soft Drink	Manufacturers, bottlers and distributors of non-alcoholic beverages, such as soda, fruit juices, tea, coffee and bottled water.
3570 Food Producers	3573 Farming, Fishing & Plantation	Companies that grow crops or raise livestock, operate fisheries or own nontobacco plantations. Includes manufacturers of livestock feeds and seeds and other agricultural products but excludes manufacturers of fertilizers or pesticides, which are classified under Specialty Chemicals.
	3577 Food Products	Food producers, including meatpacking, snacks, fruits, vegetables, dairy products and frozen seafood. Includes producers of pet food and manufacturers of dietary supplements, vitamins and related items. Excludes producers of fruit juices, tea, coffee, bottled water and other non-alcoholic beverages, which are classified under Soft Drinks.
3720 Household Goods & Home Construction	3722 Durable Household Products	Manufacturers and distributors of domestic appliances, lighting, hand tools and power tools, hardware, cutlery, tableware, garden equipment, luggage, towels and linens.
	3724 Nondurable Household Products	Producers and distributors of pens, paper goods, batteries, light bulbs, tissues, toilet paper and cleaning products such as soaps and polishes.
	3726 Furnishings	Manufacturers and distributors of furniture, including chairs, tables, desks, carpeting, wallpaper and office furniture.
	3728 Home Construction	Constructors of residential homes, including manufacturers of mobile and prefabricated homes intended for use in one place.
3740 Leisure Goods	3743 Consumer Electronics	Manufacturers and distributors of consumer electronics, such as TVs, VCRs, DVD players, audio equipment, cable boxes, calculators and camcorders.
	3745 Recreational Product	Manufacturers and distributors of recreational equipment. Includes musical instruments, photographic equipment and supplies, RVs, ATVs and marine recreational vehicles such as yachts, dinghies and speedboats.
	3747 Toys	Manufacturers and distributors of toys and video/computer games, including such toys and games as playing cards, board games, stuffed animals and dolls.
3760 Personal Goods	3763 Clothing & Accessories	Manufacturers and distributors of all types of clothing, jewelry, watches or textiles. Includes sportswear, sunglasses, eyeglass frames, leather clothing and goods, and processors of hides and skins.
	3765 Footwear	Manufacturers and distributors of shoes, boots, sandals, sneakers and other types of footwear.
	3767 Personal Products	Makers and distributors of cosmetics, toiletries and personal-care and hygiene products, including deodorants, soaps, toothpaste, perfumes, diapers, shampoos, razors and feminine-hygiene products. Includes makers of contraceptives other than oral contraceptives, which are classified under Pharmaceuticals.
3780 Tobacco	3785 Tobacco	Manufacturers and distributors of cigarettes, cigars and other tobacco products. Includes tobacco plantations.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
4530 Health Care Equipment & Services	4533 Health Care Providers	Owners and operators of health maintenance organizations, hospitals, clinics, dentists, opticians, nursing homes, rehabilitation and retirement centers. Excludes veterinary services, which are classified under Specialized Consumer Services.
	4535 Medical Equipment	Manufacturers and distributors of medical devices such as MRI scanners, prosthetics, pacemakers, X-ray machines and other non-disposable medical devices.
	4537 Medical Supplies	Manufacturers and distributors of medical supplies used by health care providers and the general public. Includes makers of contact lenses, eyeglass lenses, bandages and other disposable medical supplies.
4570 Pharmaceuticals & Biotechnology	4573 Biotechnology	Companies engaged in research into and development of biological substances for the purposes of drug discovery and diagnostic development, and which derive the majority of their revenue from either the sale or licensing of these drugs and diagnostic tools.
	4577 Pharmaceuticals	Manufacturers of prescription or over-the-counter drugs, such as aspirin, cold remedies and birth control pills. Includes vaccine producers but excludes vitamin producers, which are classified under Food Products.
5330 Food & Drug Retailers	5333 Drug Retailers	Operators of pharmacies, including wholesalers and distributors catering to these businesses.
	5337 Food Retailers & Wholesalers	Supermarkets, food-oriented convenience stores and other food retailers and distributors. Includes retailers of dietary supplements and vitamins.
5370 General Retailers	5371 Apparel Retailers	Retailers and wholesalers specializing mainly in clothing, shoes, jewelry, sunglasses and other accessories.
	5373 Broadline Retailers	Retail outlets and wholesalers offering a wide variety of products including both hard goods and soft goods.
	5375 Home Improvement Retailers	Retailers and wholesalers concentrating on the sale of home improvement products, including garden equipment, carpets, wallpaper, paint, home furniture, blinds and curtains, and building materials.
	5377 Specialized Consumer Services	Providers of consumer services such as auction houses, day-care centers, dry cleaners, schools, consumer rental companies, veterinary clinics, hair salons and providers of funeral, lawn-maintenance, consumer-storage, heating and cooling installation and plumbing services.
	5379 Specialty Retailers	Retailers and wholesalers concentrating on a single class of goods, such as electronics, books, automotive parts or closeouts. Includes automobile dealerships, video rental stores, dollar stores, duty-free shops and automotive fuel stations not owned by oil companies.
5550 Media	5553 Broadcasting & Entertainment	Producers, operators and broadcasters of radio, television, music and filmed entertainment. Excludes movie theatres, which are classified under Recreational Services.
	5555 Media Agencies	Companies providing advertising, public relations and marketing services. Includes billboard providers and telemarketers.
	5557 Publishing	Publishers of information via printed or electronic media.
5750 Travel & Leisure	5751 Airlines	Companies providing primarily passenger air transport. Excludes airports, which are classified under Transportation Services.
	5752 Gambling	Providers of gambling and casino facilities. Includes online casinos, racetracks and the manufacturers of pachinko machines and casino and lottery equipment.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
5750 Travel & Leisure	5753 Hotels	Operators and managers of hotels, motels, lodges, resorts, spas and campgrounds.
	5755 Recreational Services	Providers of leisure facilities and services, including fitness centers, cruise lines, movie theatres and sports teams.
	5757 Restaurants & Bars	Operators of restaurants, fast-food facilities, coffee shops and bars. Includes integrated brewery companies and catering companies.
	5759 Travel & Tourism	Companies providing travel and tourism related services, including travel agents, online travel reservation services, automobile rental firms and companies that primarily provide passenger transportation, such as buses, taxis, passenger rail and ferry companies.
6530 Fixed Line Telecommunications	6535 Fixed Line Telecommunications	Providers of fixed-line telephone services, including regional and long-distance. Includes companies that primarily provides telephone services through the internet. Excludes companies whose primary business is Internet access, which are classified under Internet.
6570 Mobile Telecommunications	6575 Mobile Telecommunications	Providers of mobile telephone services, including cellular, satellite and paging services. Includes wireless tower companies that own, operate and lease mobile site towers to multiple wireless service providers.
7530 Electricity	7535 Conventional Electricity	Companies generating and distributing electricity through the burning of fossil fuels such as coal, petroleum and natural gas, and through nuclear energy.
	7537 Alternative Electricity	Companies generating and distributing electricity from a renewable source. Includes companies that produce solar, water, wind and geothermal electricity.
7570 Gas, Water & Multi-utilities	7573 Gas Distribution	Distributors of gas to end users. Excludes providers of natural gas as a commodity, which are classified under the Oil & Gas industry.
	7575 Multi-utilities	Utility companies with significant presence in more than one utility.
	7577 Water	Companies providing water to end users, including water treatment plants.
8350 Banks	8355 Banks	Banks providing a broad range of financial services, including retail banking, loans and money transmissions.
8530 Nonlife Insurance	8532 Full Line Insurance	Insurance companies with life, health, property & casualty and reinsurance interests, no one of which predominates.
	8534 Insurance Brokers	Insurance brokers and agencies.
	8536 Property & Casualty Insurance	Companies engaged principally in accident, fire, automotive, marine, malpractice and other classes of nonlife insurance.
	8538 Reinsurance	Companies engaged principally in reinsurance.
8570 Life Insurance	8575 Life Insurance	Companies engaged principally in life and health insurance.
8630 Real Estate Investment & Services	8633 Real Estate Holding & Development	Companies that invest directly or indirectly in real estate through development, investment or ownership. Excludes real estate investment trusts and similar entities, which are classified as Real Estate Investment Trusts.
	8637 Real Estate Services	Companies that provide services to real estate companies but do not own the properties themselves. Includes agencies, brokers, leasing companies, management companies and advisory services. Excludes real estate investment trusts and similar entities, which are classified as Real Estate Investment Trusts.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
8670 Real Estate Investment Trusts	8671 Industrial & Office REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that primarily invest in office, industrial and flex properties.
	8672 Retail REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that primarily invest in retail properties. Includes malls, shopping centers, strip centers and factory outlets.
	8673 Residential REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that primarily invest in residential home properties. Includes apartment buildings and residential communities.
	8674 Diversified REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that invest in a variety of property types without a concentration on any single type.
	8675 Specialty REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that invest in self-storage properties, properties in the health care industry such as hospitals, assisted living facilities and health care laboratories, and other specialized properties such as auto dealership facilities, timber properties and net lease properties.
	8676 Mortgage REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that are directly involved in lending money to real estate owners and operators or indirectly through the purchase of mortgages or mortgage backed securities.
8770 Financial Services	8677 Hotel & Lodging REITs	Real estate investment trusts or corporations (REITs) or listed property trusts (LPTs) that primarily invest in hotels or lodging properties.
	8771 Asset Managers	Companies that provide custodial, trustee and other related fiduciary services. Includes mutual fund management companies.
	8773 Consumer Finance	Credit card companies and providers of personal finance services such as personal loans and check cashing companies.
	8775 Specialty Finance	Companies engaged in financial activities not specified elsewhere. Includes companies not classified under Equity Investment Instruments or Nonequity Investment Instruments engaged primarily in owning stakes in a diversified range of companies.
	8777 Investment Services	Companies providing a range of specialized financial services, including securities brokers and dealers, online brokers and security or commodity exchanges.
8980 Equity Investment Instruments	8779 Mortgage Finance	Companies that provide mortgages, mortgage insurance and other related services.
	8985 Equity Investment Instruments	Corporate closed-ended investment entities identified under distinguishing legislation, such as investment trusts and venture capital trusts.
8990 Nonequity Investment Instruments	8995 Nonequity Investment Instruments	Cash shells, Special Purpose Acquisition Company (SPACs), Noncorporate, open-ended investment instruments such as open-ended investment companies and funds, unit trusts, ETFs and currency funds and split capital trusts.
9530 Software & Computer Services	9533 Computer Services	Companies that provide consulting services to other businesses relating to information technology. Includes providers of computer-system design, systems integration, network and systems operations, data management and storage, repair services and technical support.
	9535 Internet	Companies providing Internet-related services, such as Internet access providers and search engines and providers of Web site design, Web hosting, domain-name registration and e-mail services.
	9537 Software	Publishers and distributors of computer software for home or corporate use. Excludes computer game producers, which are classified under Toys.

Table A1. Industry Classification Benchmark (ICB) Sectors, Subsectors and Description (con't)

Sector	Subsector	Definition
9570 Technology Hardware & Equipment	9572 Computer Hardware	Manufacturers and distributors of computers, servers, mainframes, workstations and other computer hardware and subsystems, such as mass-storage drives, mice, keyboards and printers.
	9574 Electronic Office Equipment	Manufacturers and distributors of electronic office equipment, including photocopiers and fax machines.
	9576 Semiconductors	Producers and distributors of semiconductors and other integrated chips, including other products related to the semiconductor industry, such as semiconductor capital equipment and motherboards. Excludes makers of printed circuit boards, which are classified under Electrical Components & Equipment.
	9578 Telecommunications Equipment	Makers and distributors of high-technology communication products, including satellites, mobile telephones, fibers optics, switching devices, local and wide-area networks, teleconferencing equipment and connectivity devices for computers, including hubs and routers.

Source: FTSE Russell

Table A2. Harmonized System (HS) Product Code and Description

HS code	Product Code	Product Description
0	01	live animals
	02	meat and edible meat offal
	03	fish and crustaceans, molluscs and other aquatic invertebrates
	04	dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included
	05	products of animal origin, not elsewhere specified or included
	06	live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage
	07	edible vegetables and certain roots and tubers
	08	edible fruit and nuts; peel of citrus fruit or melons
	09	coffee, tea, maté and spices
1	10	Cereals
	11	products of the milling industry; malt; starches; inulin; wheat gluten
	12	oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medicinal plants; straw and fodder
	13	lac; gums, resins and other vegetable saps and extracts
	14	vegetable plaiting materials; vegetable products not elsewhere specified or included
	15	animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
	16	preparations of meat, of fish or of crustaceans, molluscs or other aquatic invertebrates
	17	sugars and sugar confectionery
	18	cocoa and cocoa preparations
19	preparations of cereals, flour, starch or milk; pastrycooks' products	

Table A2. Harmonized System (HS) Product Code and Description (con't)

HS code	Product Code	Product Description
2	20	preparations of vegetables, fruit, nuts or other parts of plants
	21	miscellaneous edible preparations
	22	beverages, spirits and vinegar
	23	residues and waste from the food industries; prepared animal fodder
	24	tobacco and manufactured tobacco substitutes
	25	salt; sulphur; earths and stone; plastering materials, lime and cement
	26	ores, slag and ash
	27	mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes
	28	inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes
	29	organic chemicals
3	30	pharmaceutical products
	31	Fertilisers
	32	tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints and varnishes; putty and other mastics; inks
	33	essential oils and resinoids; perfumery, cosmetic or toilet preparations
	34	soap, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, polishing or scouring preparations, candles and similar articles, modelling pastes, 'dental waxes' and dental preparation
	35	albuminoidal substances; modified starches; glues; enzymes
	36	explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations
	37	photographic or cinematographic goods
	38	miscellaneous chemical products
	39	plastics and articles thereof
4	40	rubber and articles thereof
	41	raw hides and skins (other than furskins) and leather
	42	articles of leather; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silkworm gut)
	43	furskins and artificial fur; manufactures thereof
	44	wood and articles of wood; wood charcoal
	45	cork and articles of cork
	46	manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork
	47	pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard
	48	paper and paperboard; articles of paper pulp, of paper or of paperboard
	49	printed books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans
5	50	Silk
	51	wool, fine or coarse animal hair; horsehair yarn and woven fabric
	52	Cotton
	53	other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
	54	man-made filaments; strip and the like of man-made textile materials
	55	man-made staple fibres

Table A2. Harmonized System (HS) Product Code and Description (con't)

HS code	Product Code	Product Description
5	56	wadding, felt and nonwovens; special yarns; twine, cordage, ropes and cables and articles thereof
	57	carpets and other textile floor coverings
	58	special woven fabrics; tufted textile fabrics; lace; tapestries; trimmings; embroidery
	59	impregnated, coated, covered or laminated textile fabrics; textile articles of a kind suitable for industrial use
6	60	knitted or crocheted fabrics
	61	articles of apparel and clothing accessories, knitted or crocheted
	62	articles of apparel and clothing accessories, not knitted or crocheted
	63	other made-up textile articles; sets; worn clothing and worn textile articles; rags
	64	footwear, gaiters and the like; parts of such articles
	65	headgear and parts thereof
	66	umbrellas, sun umbrellas, walking sticks, seat-sticks, whips, riding-crops and parts thereof
	67	prepared feathers and down and articles made of feathers or of down; artificial flowers; articles of human hair
	68	articles of stone, plaster, cement, asbestos, mica or similar materials
69	ceramic products	
7	70	glass and glassware
	71	natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal, and articles thereof; imitation jewelry; coin
	72	iron and steel
	73	articles of iron or steel
	74	copper and articles thereof
	75	nickel and articles thereof
	76	aluminum and articles thereof
	78	lead and articles thereof
	79	zinc and articles thereof
8	80	tin and articles thereof
	81	other base metals; cermets; articles thereof
	82	tools, implements, cutlery, spoons and forks, of base metal; parts thereof of base metal
	83	miscellaneous articles of base metal
	84	nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
	85	electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles
	86	railway or tramway locomotives, rolling stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electromechanical) traffic signaling equipment of all kinds
	87	vehicles other than railway or tramway rolling stock, and parts and accessories thereof
	88	aircraft, spacecraft, and parts thereof
89	ships, boats and floating structures	

Table A2. Harmonized System (HS) Product Code and Description (con't)

HS code	Product Code	Product Description
9	90	optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof
	91	clocks and watches and parts thereof
	92	musical instruments; parts and accessories of such articles
	93	arms and ammunition; parts and accessories thereof
	94	furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, not elsewhere specified or included; illuminated signs, illuminated nameplates and the like; prefabricated buildings
	95	toys, games and sports requisites; parts and accessories thereof
	96	miscellaneous manufactured articles
	97	works of art, collectors' pieces and antiques

Source: World Bank

Table A3. Covariate Balance Table

Variable	Un/matched		Mean		% reduct in		t-test	
	Status	Treated	Control	% bias	bias	t	p>t	
total employees	U	72784	22893	66.5		17.67	0.000	
	M	72784	60013	17	74.4	1.74	0.082	
net sales (million	U	23816	6936.4	58.3		15.84	0.000	
	M	23816	16887	24	59	2.63	0.009	
operating profits (million €)	U	2337	672.84	41.1		11.81	0.000	
	M	2337	1918.2	10.3	74.8	1.11	0.268	
R&D investment (million €)	U	1105.1	189.75	69.6		26.98	0.000	
	M	1105.1	839.33	20.2	71	1.94	0.053	
COR&DIP rank by R&D	U	521.03	1043.9	-95.9		-19.35	0.000	
	M	521.03	532.46	-2.1	97.8	-0.27	0.787	
capital expenditure (million €)	U	1350.7	531.17	33.6		7.33	0.000	
	M	1350.7	1026.9	13.3	60.5	1.50	0.134	
total number of trademarks (1)	U	79.807	17.27	70.5		24.94	0.000	
	M	79.807	48.876	34.9	50.5	3.50	0.001	
total number of patent families (2)	U	859.03	173.42	52.6		17.70	0.000	
	M	859.03	645.64	16.4	68.9	1.62	0.105	
total num. patent families, restr. (3)	U	851.61	170.87	52.4		17.44	0.000	
	M	851.61	622.37	17.6	66.3	1.75	0.080	

Note: * if variance ratio outside [0.84; 1.19] for U and [0.84; 1.19] for M.

(1) Counts cover trademark applications filed at the USPTO, OHIM and IP AUS offices.

(2) Counts based on patent families having family members filed at least in one of the IP5 offices (EPO, JPO, KIPO, SIPO, USPTO), excl. single filings.

(3) Counts based on patent families having family members filed in at least two of the IP5 offices.

Sample	Ps R ²	LR chi2	p>chi2	Mean Bias	Med Bias	B	R	% Var
Unmatched	0.209	448.08	0	60.1	58.3	109.1*	4.64*	100
Matched	0.053	37.59	0	17.3	17	54.7*	1.98	89

Note: * if B>25%, R outside [0.5; 2]

Table A4. Tobit Results for Total Annual Number of Seizure Incidences Variable by Good Category
(Harmonized System Trade Chapter). DG TAXUD Seizures Population Only, 2011-2013.

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
logged net sales	0.50***	0.40***	0.41***	0.44***	0.41***	0.40***	0.42***	0.43***	0.42***
seizure incidences, total annual number	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	-0.01***	-1.97*	-0.47***	0.01**	-0.01***	0.68	-0.01***	0.01	-0.01
propensity score	0.01	0.88	0.11	0.01	0.01	0.87	0.01	0.01	0.01
	1.86***	2.54***	2.35***	1.83***	2.53***	2.54***	2.35***	2.71***	2.15***
const.	0.12	0.18	0.18	0.15	0.17	0.18	0.17	0.14	0.16
	0.63***	1.28***	1.25***	1.01***	1.23***	1.27***	1.18***	1.06***	1.15***
var(e.log R&D)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	0.88***	0.77***	0.77***	0.83***	0.77***	0.76***	0.76***	0.78***	0.79***
	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N	2776	2169	2172	2283	2220	2169	2208	2467	2250
AIC	7523.62	5588.74	5616.66	6061.02	5732.3	5578.39	5676.01	6383.22	5860.27
BIC	7553.27	5617.15	5645.08	6089.69	5760.83	5606.8	5704.51	6412.27	5888.87

Note: s.e. in parentheses. Legend: * p<.05; ** p<.01; *** p<.001.

Table A5. FE Poisson Panel Results for Total Annual Number of Seizure Incidences Variable, by Good Category
(Harmonized System Trade Chapter). DG TAXUD Seizures Population Only, 2011-2013.

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
logged net sales	0.05*	0.05*	0.05*	0.05	0.05*	0.05	0.05*	0.05*	0.05
	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.03
seizure incidences, total annual number	0.01	0.01**	0.01	0.01	0.01	-0.01	0.01	0.01	-0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
propensity score	0.07*	0.14*	0.15**	0.09**	0.14*	0.14*	0.13**	0.09	0.12**
	0.03	0.06	0.05	0.04	0.06	0.06	0.04	0.05	0.05
N	2776	2169	2172	2283	2220	2169	2208	2467	2250

Note: s.e. in parentheses. Legend: * p<.05; ** p<.01; *** p<.001.

Table A6. QML Panel Regressions Results for Total Annual Number of Seizure Incidences Variable, by Good Category (Harmonized System Trade Chapter). DG TAXUD Seizures Population Only, 2011-2013.

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
logged net sales	0.05**	0.05*	0.05*	0.05**	0.05*	0.05*	0.05*	0.05**	0.05**
seizure incidences, total annual number	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
propensity score	0.01	0.01***	0.01	0.01	0.01**	-0.01	0.01	0.01**	-0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.07*	0.14*	0.15**	0.09*	0.14**	0.14*	0.13*	0.09*	0.12*
	0.03	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.05
N	2776	2169	2172	2283	2220	2169	2208	2467	2250
chi2	15.62	1.13E+08	15.19	12.96	5691.48	5.37E+09	17.57	80.79	14.62
df_m	3	3	3	3	3	3	3	3	3
p	0	0	0	0	0	0	0	0	0

Note: s.e. in parentheses. Legend: * p<.05; ** p<.01; *** p<.001.

Table A7. OLS Results Based on Separately Run Regressions by Outcome Variables (Logged Net Sales, Logged R&D Investment) and by Good Category (Harmonized System Trade Chapter). WCO and DG TAXUD Seizures Population, 2011-2013.

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
seizure incidences, dum.	0.12	(omitted)	-2.67***	-0.06	-0.26	1.43	-0.60**	0.39***	-0.86***
	0.07		0.49	0.14	0.21	0.98	0.19	0.08	0.14
propensity score	3.90***	4.69***	4.62***	4.09***	4.60***	4.70***	4.51***	4.66***	4.45***
	0.13	0.17	0.17	0.16	0.16	0.17	0.16	0.14	0.16
const.	4.29***	4.17***	4.17***	4.24***	4.18***	4.17***	4.19***	4.20***	4.19***
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N	2579	2004	2010	2115	2055	2007	2046	2285	2085
adj. R ²	0.36	0.28	0.28	0.3	0.3	0.28	0.27	0.41	0.29

Table A7. OLS Results Based on Separately Run Regressions by Outcome Variables (Logged Net Sales, Logged R&D Investment) and by Good Category (Harmonized System Trade Chapter), WCO and DG TAXUD Seizures Population, 2011-2013 (Con't)

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged net sales									
seizure incidences, dum.	0.11	(omitted)	-0.57	-0.36*	-0.22	1.78	-0.41	0.18	-0.47*
	0.08		0.63	0.17	0.26	1.25	0.24	0.1	0.18
propensity score	4.20***	5.28***	5.24***	4.73***	5.18***	5.29***	5.04***	5.05***	4.75***
	0.15	0.21	0.21	0.19	0.2	0.21	0.21	0.17	0.2
const.	7.48***	7.34***	7.34***	7.39***	7.35***	7.34***	7.36***	7.38***	7.39***
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N	2575	2000	2006	2111	2051	2003	2042	2281	2081
adj. R ²	0.33	0.23	0.23	0.26	0.25	0.23	0.23	0.34	0.23
DV: logged R&D									
logged net sales	0.47***	0.37***	0.37***	0.41***	0.38***	0.37***	0.38***	0.41***	0.39***
	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
seizure incidence, dum.	0.07	(omitted)	-2.45***	0.08	-0.17	0.77	-0.44**	0.32***	-0.68***
	0.06		0.43	0.12	0.18	0.86	0.16	0.07	0.13
propensity score	1.92***	2.72***	2.66***	2.16***	2.63***	2.72***	2.56***	2.60***	2.60***
	0.12	0.17	0.17	0.16	0.16	0.17	0.16	0.14	0.15
const.	0.78***	1.45***	1.44***	1.24***	1.40***	1.44***	1.36***	1.20***	1.33***
	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11
N	2575	2000	2006	2111	2051	2003	2042	2281	2081
adj. R ²	0.55	0.44	0.44	0.47	0.46	0.44	0.45	0.56	0.46

Notes: Remark: Compared to the exercise based on DG TAXUD population only, here the selection of covariates for the propensity score matching differs only by inclusion of CAPEX and transformed (CAPEX)². s.e. in parentheses. legend: * p<.05; ** p<.01; *** p<.001

Table A8. OLS Regression Results (for Winsorized Outcomes, 99 Percentile Cutoff Values) by Outcome Variables (Logged Net Sales, Logged R&D Investment) and by Good Category (Harmonized System Trade Chapter).

		DG TAXUD Seizure Population Only, 2011-13.								
Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9	
DV: logged R&D										
seizure incidences, dum.	0.1	-1.33	-3.20***	-0.14	-0.16	1.37	-0.68***	0.34***	-0.96***	
	0.08	1.01	0.51	0.15	0.22	1.01	0.19	0.09	0.16	
propensity score	3.81***	4.88***	4.79***	4.17***	4.72***	4.90***	4.60***	4.76***	4.51***	
	0.14	0.19	0.19	0.18	0.18	0.19	0.18	0.15	0.17	
const.	4.38***	4.23***	4.24***	4.31***	4.25***	4.23***	4.26***	4.28***	4.26***	
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	
N	2783	2176	2179	2290	2227	2176	2215	2474	2257	
adj. R ²	0.3	0.24	0.23	0.24	0.25	0.24	0.22	0.36	0.24	
DV: logged net sales										
seizure incidences, dum.	0.13	1.59	-1.34*	-0.3	-0.13	1.71	-0.59*	0.14	-0.68***	
	0.09	1.24	0.63	0.18	0.27	1.24	0.24	0.11	0.19	
propensity score	4.34***	5.90***	5.84***	5.17***	5.71***	5.91***	5.49***	5.35***	5.17***	
	0.15	0.23	0.23	0.21	0.21	0.23	0.23	0.18	0.21	
const.	7.54***	7.36***	7.37***	7.43***	7.38***	7.36***	7.39***	7.43***	7.43***	
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
N	2776	2169	2172	2283	2220	2169	2208	2467	2250	
adj. R ²	0.31	0.23	0.23	0.26	0.25	0.23	0.22	0.32	0.22	
DV: logged R&D										
logged net sales	0.50***	0.40***	0.40***	0.44***	0.41***	0.40***	0.42***	0.43***	0.42***	
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
seizure incidence, dum.	0.03	-1.97*	-2.66***	-0.01	-0.11	0.68	-0.43**	0.28***	-0.69***	
	0.06	0.87	0.44	0.13	0.19	0.87	0.17	0.08	0.13	
propensity score	1.64***	2.52***	2.43***	1.88***	2.37***	2.51***	2.31***	2.43***	2.37***	
	0.13	0.18	0.18	0.17	0.17	0.18	0.18	0.15	0.17	
const.	0.64***	1.29***	1.27***	1.02***	1.21***	1.27***	1.18***	1.08***	1.18***	
	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	
N	2776	2169	2172	2283	2220	2169	2208	2467	2250	
adj. R ²	0.52	0.43	0.43	0.45	0.44	0.43	0.44	0.54	0.45	

Note: s.e. in parentheses. legend: * p<.05; ** p<.01; *** p<.001.

Table A9. OLS Regression Results (Excl. All Obs. from Propensity Score Blocks/Intervals 7 and 8 from the Sample) by Outcome Variables (Logged Net Sales, Logged R&D Investment) and by Good Category (Harmonized System Trade Chapter).

Variable	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
DV: logged R&D									
seizure incidences, dum.	0.05	-1.38	-3.47***	0.30	0.00	1.32	-0.54**	0.32***	-0.87***
	0.08	1.02	0.52	0.17	0.25	1.02	0.21	0.09	0.17
propensity score	4.79	5.33	5.29	5.16	5.40	5.35	5.14	5.40	4.98
	0.18	0.23	0.22	0.22	0.22	0.23	0.22	0.19	0.21
const.	4.34	4.23	4.24	4.27	4.23	4.23	4.25	4.27	4.26
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N	2538	2023	2025	2111	2066	2023	2057	2285	2088
adj. R ²	0.27	0.22	0.22	0.25	0.24	0.22	0.21	0.30	0.21
DV: logged net sales									
seizure incidences, dum.	0.07	1.51	-1.73**	-0.02	-0.09	1.62	-0.58*	0.1	-0.28
	0.09	1.24	0.63	0.2	0.3	1.24	0.25	0.11	0.21
propensity score	5.36***	6.56***	6.54***	6.26***	6.51***	6.56***	6.15***	6.10***	6.02***
	0.2	0.28	0.27	0.26	0.26	0.28	0.27	0.23	0.26
const.	7.52***	7.38***	7.38***	7.42***	7.39***	7.38***	7.41***	7.44***	7.43***
	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N	2531	2016	2018	2104	2059	2016	2050	2278	2081
adj. R ²	0.27	0.22	0.22	0.25	0.23	0.22	0.21	0.27	0.21
logged net sales									
	0.48***	0.40***	0.41***	0.43***	0.41***	0.41***	0.42***	0.43***	0.42***
seizure incidence, dum.	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.01	-1.99*	-2.76***	0.31*	0.03	0.66	-0.29	0.27***	-0.75***
propensity score	0.07	0.89	0.45	0.15	0.21	0.89	0.18	0.08	0.15
	2.21***	2.67***	2.63***	2.45***	2.73***	2.67***	2.57***	2.75***	2.45***
const.	0.17	0.22	0.22	0.21	0.21	0.22	0.21	0.19	0.21
	0.72***	1.25***	1.24***	1.07***	1.21***	1.24***	1.17***	1.05***	1.15***
	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
N	2531	2016	2018	2104	2059	2016	2050	2278	2081
adj. R ²	0.48	0.41	0.41	0.44	0.42	0.41	0.42	0.49	0.41

Note: s.e. in parentheses. legend: * p<.05; ** p<.01; *** p<.001.

Table A10. IV Regression Results (Instrumental Variable Is Logged Net Sales, t-2).
DG TAXUD Seizure Population Only, 2011-2013.

DV: logged R&D	base	HS 0	HS 2	HS 3	HS 4	HS 5	HS 6	HS 8	HS 9
logged net sales, t = logged net sales, t-2	0.51 ***	0.40 ***	0.41 ***	0.45 ***	0.42 ***	0.41 ***	0.42 ***	0.44 ***	0.42 ***
	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
seizure incidences, dum.	0.03	-1.98 *	-2.66 ***	0.02	-0.09	0.67	-0.44 **	0.28 ***	-0.66 ***
	0.06	0.88	0.45	0.13	0.19	0.87	0.17	0.08	0.13
propensity score	1.67 ***	2.52 ***	2.43 ***	1.86 ***	2.36 ***	2.51 ***	2.31 ***	2.49 ***	2.38 ***
	0.13	0.19	0.19	0.17	0.18	0.19	0.18	0.15	0.17
const.	0.55 ***	1.25 ***	1.23 ***	0.96* **	1.17 ***	1.24 ***	1.15* **	1.04 ***	1.13 ***
	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
N	2771	2164	2167	2278	2215	2164	2203	2462	2245
adj. R2	0.53	0.43	0.43	0.45	0.44	0.43	0.44	0.55	0.45

Note: s.e. in parentheses. legend: * p<.05; ** p<.01; *** p<.001.

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