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Technical Barriers to Trade, Product Quality and Trade Margins: Firm-level Evidence*

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Abstract: *As tariffs have declined to a low level, the trade literature has paid increasing attention to the impact of non-tariff measures. Unlike tariffs, non-tariff measures could act as both a barrier to trade and a catalyst for quality upgrading. This study examines the effect of technical barriers to trade (TBTs) on trade margins and quality upgrading at the firm level. To do so, we utilise rich Chinese Customs data recording the universe of export transactions from 2000 to 2012, matched with the Annual Survey of Industrial Firms and the World Trade Organization's Specific Trade Concerns database. We find that TBTs are associated with higher probability to exit. Surviving exporters enjoy larger sales and charge higher export prices. We also find robust evidence for the quality upgrading effects of TBTs. Firms upgrade their product quality by expanding their research and development and investment and importing more intermediate inputs and capital goods. The positive impact of TBTs on quality upgrading offsets that on price increases, resulting in lower quality-adjusted export prices. This suggests the net welfare-enhancing effect of TBTs for the consumers of imported products. The results hold after controlling for potential endogeneity and across various specifications.*

Keywords: Non-tariff Measures, Technical Barrier to Trade, Trade Margins, Quality upgrading, Firm Heterogeneity, China
JEL classification: F13, F14, D22

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1. Introduction

Tariffs, as a traditional trade policy tool, have declined worldwide. The rise in the prevalence of non-tariff measures (NTMs), in particular technical standards such as sanitary and phytosanitary measures (SPSs) and technical barriers to trade (TBTs), has sparked off debates about the rationale of using NTMs.[1] NTMs are complex and cover a wide array of policy instruments with distinct objectives and designs. Their effects are ambiguous. On the one hand, NTMs represent added trade costs for exporters. They are associated with fixed costs: firms increase capital investment to conduct product and process innovation, to acquire necessary infrastructure such as storage and testing facilities, and the like. Standards could also raise variable costs through compliance with administrative procedure, adaptation of product labelling, a switch to more costly intermediate inputs, amongst others (Fugazza, 2013; Kee, Nicita, and Ollareaga, 2009; Fontagne et al., 2015; Hoekman and Nicita, 2011; Fugazza et al., 2018; Ing and Cadot, 2019; Nabeshima and Obashi, 2019). On the other hand, standards serve legitimate purposes: protection of consumers' health and safety, and the environment, for example. By setting requirements on products' attributes, standards induce quality upgrading (Ghodsi et al., 2020; Macedoni and Weinberger, 2021; Fiankor, Curzi and Olper, 2021).

Understanding the costs and benefits of NTMs facilitates policymaking. The existing literature, however, focuses primarily on the cost side. In addition, most studies are conducted at country-product level; firm-level studies are scarce. Our research attempts to fill these gaps by examining the impact of TBTs on trade margins and the quality of traded products at the firm-level. In particular, we address the following questions. First, does the enforcement of standards affect firms' entry and exit in the destination market, as well as export prices? Second, do firms upgrade their product quality in response to TBTs? Third, if quality upgrading is observed, what is the underlying mechanism?

[1] In this paper, NTMs and standards are used interchangeably.

We follow Khandelwal (2010) and Manova and Yu (2017) to derive product quality from the demand function. We consider various aspects of firms' heterogeneity, including size, ownership, initial product quality, trade status, differences between processing firms and ordinary firms, and the number of destinations served. To do so, we utilise rich, matched, firm-level production and trade data from China. We then combine this matched firm data with the World Trade Organisation's Specific Trade Concerns database covering 2000–12 using Harmonized System (HS) 4-digit product codes.

We find that TBTs are associated with a higher probability to exit. Surviving exporters enjoy larger sales and charge higher export prices. We also find supporting evidence for the quality upgrading effects of TBTs. Firms upgrade their product quality by raising their research and development (R&D) and investment and importing more intermediate inputs and capital goods. The positive impact of TBTs on quality upgrading offsets that on price increases, resulting in lower quality-adjusted export prices. This suggests the welfare-enhancing effect of TBTs for the imposing country. We note the differences in magnitude across different sub-groups of firms. The direction of impact, however, remains consistent. Our results are robust across various specifications, including endogeneity issues.

Our study contributes to the emerging literature on firm-level impact of NTMs in several ways. First, our analysis proposes an important but underexplored channel through which trade-related policy could impact product quality. More importantly, we show that such policy results in a net welfare effect for consumers, justifying one of the key objectives of NTMs. Indeed, quality upgrading is particularly relevant for developing economies to enhance export competitiveness and move up the global value chain (Hallak and Schott, 2008; Amiti and Khandelwal, 2013). Producers of high-quality products are more successful: they are more productive, get access to more export markets, and earn higher revenue and larger global sales (Verhoogen, 2008; Manova and Zhang, 2012; Crozet, Head, and Mayer, 2012). Studies on firms' response to tariff liberalisation have found abundant evidence of quality upgrading (Amiti and Khandelwal, 2013; Fan, Li and Yeaple, 2015; Bas and Strauss-Kahn, 2015; Manova and Yu, 2017; Fernandes and Paunov, 2013). However, related literature on non-tariff measures remains scarce

(Movchan, Shepotylo, and Vakhitov, 2020; Disdier, Gaigné, and Herghelegiu, 2018; Curzi et al., 2020). As such, our study makes an important contribution to this line of research.

Furthermore, our work is novel in addressing the underlying mechanism of quality upgrading. Ing et al. (2016) proposed two types of adjustments: process adaptation costs and sourcing costs.[2] Process adaptation costs refer to firms' capital investment to adjust their production to purchase new equipment, and with that to hire more skilled employees or to train current employees to operate. Sourcing costs accrue when firms must change the amount, type, or composition of imported intermediate inputs to comply with a newly introduced standard. For instance, a ban on the use of dangerous chemicals in manufacture of clothing forces firms to seek a less harmful substitute.[3] The availability of matched customs-production data allows us to observe firms' various adjustments to improve their product quality.

Contrary to a few existing studies with a narrow focus on products, markets, or regulations,[4] our study offers a comprehensive analysis covering all traded products from China to the global market using highly disaggregated firm-trade data. Since the decision of what and how to produce and to trade is taken by individual firms, analysis at aggregate level masks substantial differences across firms. Indeed, trade literature since Melitz (2003) has found overwhelming evidence of heterogeneity in firms' response to tariff changes (Bernard et al., 2007; Wagner, 2012). By working at the firm level across different products, destinations and standards, our analysis could demonstrate the heterogeneous effects of NTMs across exporters with different characteristics. We focus on China, the world's

[2] The third component, enforcement costs, represents firms' administrative efforts to comply with the new requirement. For example, firms will need more staff to handle paperwork, prepare for inspections from government officials. This category is less relevant for quality upgrading. As a result, we exclude them from the discussion.

[3] Empirically, Chakraborty (2017) showed that Germany's ban on an input (Azo dyes) used by Indian textile and leather producers led to investment in high-quality imported raw materials and technology by these firms. In a related study, Chakraborty and Chatterjee (2017) showed a similar finding for dye-makers, who increased technology transfer in response to the ban.

[4] See, for example, Curzi et al. (2020), and Olper, Curzi, and Pacca (2014) on food standards. For studies using Chinese transaction-level data, see Beestermöller, Disdier, and Fontagné (2018) on agri-food exports, and Hu et al. (2019) on cigarette lighter exports to the European Union. Chakraborty and Chatterjee (2017) and Chakraborty (2017) focused on one single environmental regulation on dyes.

largest goods trader. China provides an interesting setting for our analysis. The spectacular rise of China as the global leading exporter has raised serious concerns to some policymakers. Various studies have documented the detrimental impact of Chinese imports on employment and growth, especially after the country's entry to the World Trade Organization (WTO) (Autor, Dorn and Hanson, 2013; Pierce and Schott, 2016; Álvarez and Claro, 2009). To counterbalance the loss for domestic producers and workers, policymakers may resort to trade policy instruments. The imposition of restrictive NTMs could be amongst them. On the other hand, since China is a developing country where the regulatory framework may not meet developed countries' standards, with a diverse and expanding global trade network, it is also more likely to encounter NTM challenges.

Our study informs policymakers about the firms' adjustments to standards at the export market. By showing the welfare-improving effect of standards, we challenge the common perception amongst policymakers that NTMs are bad and should be eliminated. Indeed, our findings highlight the neutrality and complexity of NTMs: they serve legitimate public policy goals, yet they can be trade-restrictive. For effective policy intervention, it is crucial to weigh both the costs and benefits.

The rest of our paper is structured as follows. Section 2 presents methodology and data. Section 3 reports empirical results. Section 4 concludes and discusses policy implications.

2. Empirical Strategy

2.1. Data

The Specific Trade Concerns database

We employ three key data sources. The first data source is WTO's Specific Trade Concerns (STC) database.[5] While NTMs cover a broad array of commercial and public policy instruments with diverse impact, we only focus on standards that are viewed as trade barriers. According to the WTO's commitments, members are expected to apply SPS and TBTs as per the provisions specified in the respective

[5] The dataset in Excel format can be downloaded from https://www.wto.org/english/res_e/publications_e/wtr12_dataset_e.htm.

agreements. In particular, SPS and TBTs should follow international standards, be implemented in a non-discriminatory manner, and not be overly restrictive. In case a measure is deemed more restrictive than necessary and generates noticeable loss to the exporting countries, the affected member(s) can raise a concern to the responsible committee, i.e. the SPS or TBT committee, in the WTO. As trade-intensive products are more likely to be targeted by restrictive regulations, the focus of this data on such regulations suggests endogeneity could be a problem (Fontagne et al., 2015). We will address this issue in detail in the methodology section.

We extract from the STC database information about maintaining members, i.e. countries who impose the TBTs under consideration, the member(s) raising the concerns, affected products coded at HS 4-digit level, the year when the concern was first raised, and whether it has been resolved. We keep TBTs concerns raised by China as the country affected, i.e. the exporting country.[6] Over the 2000–12 period, approximately 49% of concerns raised by China were resolved or partially resolved, as reported by WTO members to the TBT Committee. The average duration between when the concern was first raised and its resolution is 4.5 years. Table A1 in the Appendix gives an example of TBT concerns raised by China.

Table 1 reports the number of TBT concerns by imposing countries in each year from 1999 to 2011.[7] Even though our data record 73 export destinations, TBT concerns concentrate on few large trading partners. Of 979 concerns raised during the period, the European Union (EU) and the Republic of Korea (henceforth, Korea) accounted for one-third each, followed by the United States (US). It should be noted that the absence of concerns toward small export markets does not necessarily mean that these markets are free from restrictive NTMs. As bringing the issue to the WTO's dispute settlement is a costly process, countries tend to be selective about raising concerns. Intuitively, priority is given to important export markets due to the potentially larger loss. As shown in Figure 1, the top countries imposing restrictive TBTs (highlighted in red) are also the most attractive markets for Chinese exporters. Moreover, developed countries tend to apply more stringent

[6] Although the STC database covers both SPSs and TBTs, few SPS concerns were raised by China during the period. Therefore, we focus our analysis on TBTs.

[7] Some concerns were first raised by other WTO members before China gained WTO membership. China joined later as a complainant.

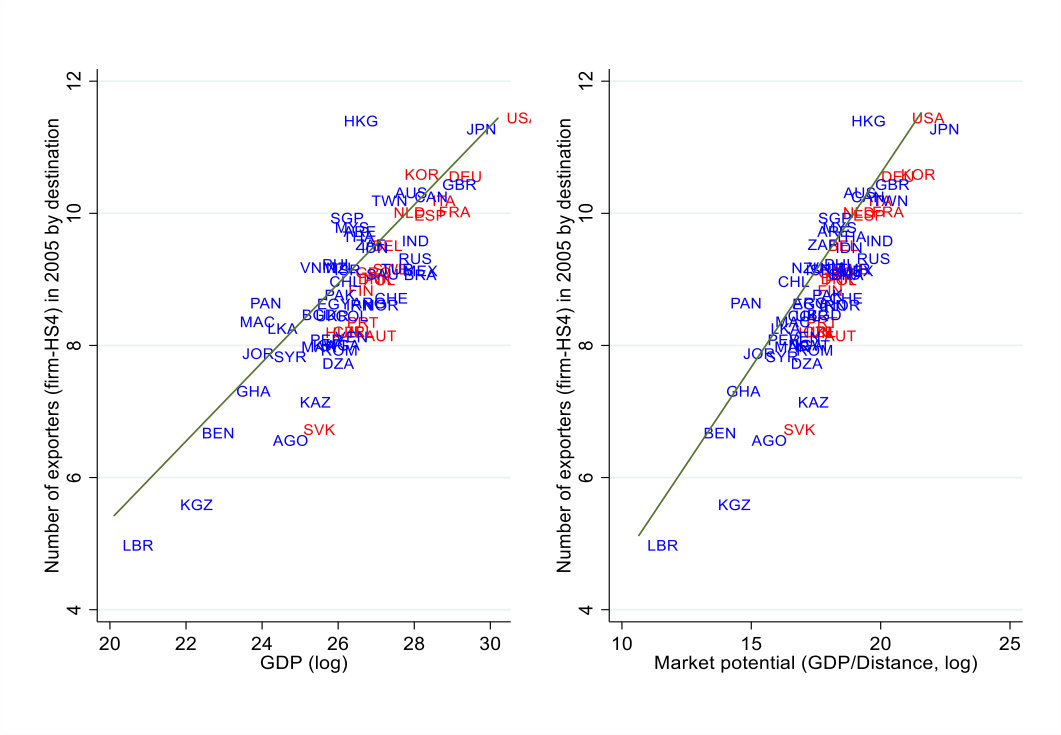
standards to ensure product safety and quality, resulting in a larger number of concerns against them.

Table 1: Number of TBT Concerns, by Maintaining Members

Year	Australia	Brazil	European Union	India	Japan	Rep. of Korea	United States	Total
1999	0	0	63	0	0	0	0	63
2000	0	0	3	0	0	0	0	3
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	25	25
2003	0	0	178	0	0	0	167	345
2004	0	0	0	0	0	0	1	1
2005	0	0	9	0	0	10	1	20
2006	0	0	46	0	18	0	8	72
2007	0	0	21	0	0	0	46	67
2008	0	3	11	0	0	0	1	15
2009	0	0	0	4	0	161	1	166
2010	0	0	18	0	0	0	4	22
2011	2	0	0	0	0	178	0	180
Total	**2**	**3**	**349**	**4**	**18**	**349**	**254**	**979**

TBT = Technical barrier to trade.
Notes:
1/ "Year" records the year a concern was first raised to the TBT committee.
2/ "Maintaining members" refer to WTO members who impose the TBT under consideration.
3/ Only concerns of which China is a complainant are included.
Source: Authors' own compilation based on TBT-Specific Trade Concerns Database, World Trade Organization.

Figure 1: Number of Exporters and GDP/Distance in Destinations (2005)



GDP = gross domestic product.
Note: See Table A2 for the list of countries and regions.
Source: Authors' calculation.

Table 2 shows the cumulative number of TBT concerns, measured as the total number of concerns that were raised and have not been resolved throughout the years. For example, in 2006, China raised 18 concerns against Japan, eight of which were resolved within 1 year, and the rest had been resolved by 2008. If a concern was raised in the early years and stayed until the end, the cumulative number will be large. The EU stands out amongst the maintaining countries, contributing to approximately two-thirds of all the concerns raised by China. Korea and the US account for about 20% and 10%, respectively.

Table 2: Cumulative Number of TBT Concerns, by Maintaining Members

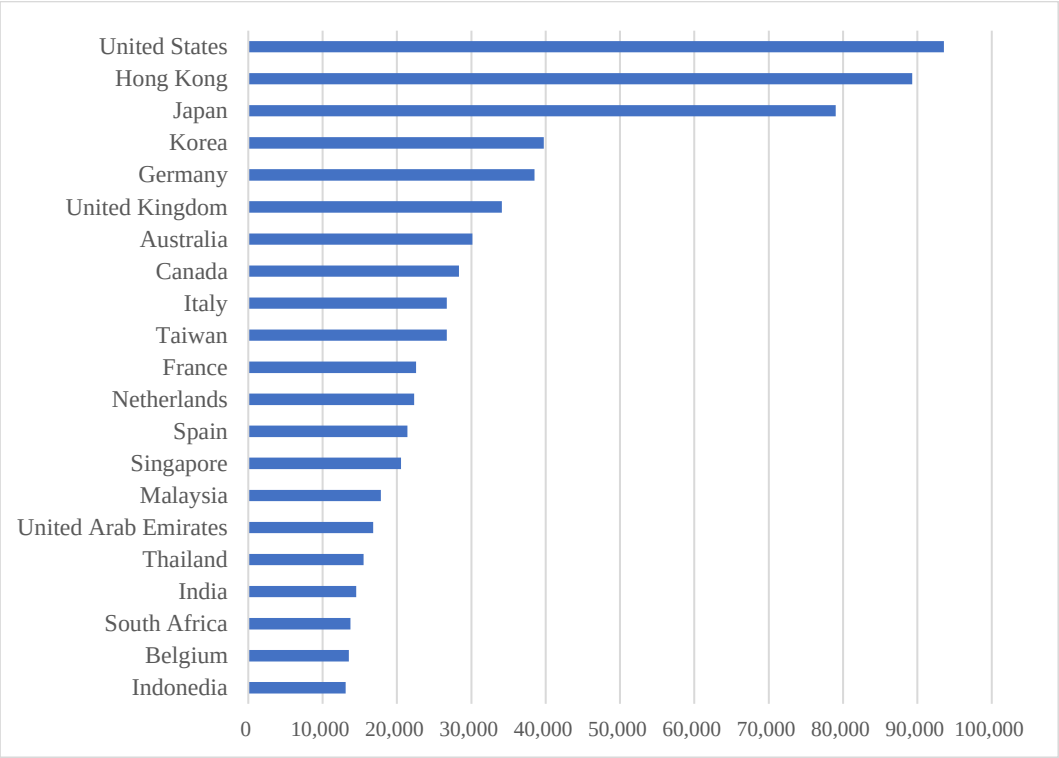
Year	Australia	Brazil	European Union	India	Japan	Rep. of Korea	United States	Total
1999	0	0	63	0	0	0	0	63
2000	0	0	63	0	0	0	0	63
2001	0	0	63	0	0	0	0	63
2002	0	0	63	0	0	0	20	83
2003	0	0	237	0	0	0	167	404
2004	0	0	237	0	0	0	21	258
2005	0	0	238	0	0	10	22	270
2006	0	0	241	0	10	10	28	289
2007	0	0	256	0	10	10	66	342
2008	0	3	256	0	10	0	66	335
2009	0	3	253	4	0	160	22	442
2010	0	0	255	4	0	160	5	424
2011	2	0	255	0	0	324	5	586
2012	2	0	1	0	0	164	3	170
Total	**4**	**6**	**2,418**	**8**	**30**	**838**	**425**	**3,729**

TBT = Technical barrier to trade.
Notes:
1/ "Year" records the year a concern was first raised to the TBT committee.
2/ "Maintaining members" refer to WTO members who impose the TBT under consideration.
3/ Only concerns of which China is a complainant are included.
Source: Authors' own compilation based on TBT-Specific Trade Concerns Database, World Trade Organization.

Figure 2 further highlights the importance of those markets against whom the concerns are raised. At product-destination level, approximately 93,000 Chinese exporters participated in the US markets. Hong Kong and Japan follow closely with slightly more than 70,000 exporters each. Five EU countries, namely Germany, Italy, France, Spain, and Belgium, as well as the United Kingdom (UK), Korea, and Australia are also amongst the top 21 export markets.[8]

[8] It is worth noting that this study utilizes data until 2012 when the UK was still a member of the EU. Therefore, in our empirical model, we include the UK in the EU sample.

Figure 2: Number of Exporters (Top 21 HS4-Destination Market Combination) in 2005



Source: Authors' calculation.

Table 3 depicts the distribution of TBT concerns at the product level. Of the HS 2-digit sectors, 46% have at least one HS 4-digit product subject to TBT concerns. At HS 4-digit level, 43% of products are subject to TBTs in the period studied. TBTs are more prevalent on agriculture and food products, raw materials, chemicals, and machinery, which are major exports of China. The concentration of TBTs in these sectors mirrors the pattern observed elsewhere in the world, where these sectors are heavily regulated by NTMs (UNCTAD, 2019; Doan and Rosenow, 2019).

Table 3: Distribution of Affected Products by TBT Concerns

HS2 code	HS2 description	TBT
01	Animals; live	1
02	Meat and edible meat offal	1
03	Fish and crustaceans, molluscs and other aquatic invertebrates	1
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included	1
05	Animal originated products; not elsewhere specified or included	0
06	Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage	0
07	Vegetables and certain roots and tubers; edible	1
08	Fruit and nuts, edible; peel of citrus fruit or melons	1
09	Coffee, tea, mate and spices	1
10	Cereals	1
11	Products of the milling industry; malt, starches, inulin, wheat gluten	1
12	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit, industrial or medicinal plants; straw and fodder	1
13	Lac; gums, resins and other vegetable saps and extracts	0
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included	0
15	Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes	1
16	Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof	1
17	Sugars and sugar confectionery	1
18	Cocoa and cocoa preparations	1
19	Preparations of cereals, flour, starch or milk; pastrycooks' products	1
20	Preparations of vegetables, fruit, nuts or other parts of plants	1
21	Miscellaneous edible preparations	1
22	Beverages, spirits and vinegar	1

23	Food industries, residues and wastes thereof; prepared animal fodder	0
24	Tobacco and manufactured tobacco substitutes	1
25	Salt; sulphur; earths, stone; plastering materials, lime and cement	0
26	Ores, slag and ash	0
27	Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes	0
28	Inorganic chemicals; organic and inorganic compounds of precious metals; of rare earth metals, of radio-active elements and of isotopes	1
29	Organic chemicals	1
30	Pharmaceutical products	1
31	Fertilizers	1
32	Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints, varnishes; putty, other mastics; inks	1
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations	1
34	Soap, organic surface-active agents; washing, lubricating, polishing or scouring preparations; artificial or prepared waxes, candles and similar articles, modelling pastes, "dental waxes" and dental preparations with a basis of plaster	1
35	Albuminoidal substances; modified starches; glues; enzymes	1
36	Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations	1
37	Photographic or cinematographic goods	1
38	Chemical products n.e.s.	1
39	Plastics and articles thereof	0
40	Rubber and articles thereof	0
41	Raw hides and skins (other than furskins) and leather	0
42	Articles of leather; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut)	0

43	Furskins and artificial fur; manufactures thereof	0
44	Wood and articles of wood; wood charcoal	0
45	Cork and articles of cork	0
46	Manufactures of straw, esparto or other plaiting materials; basketware and wickerwork	0
47	Pulp of wood or other fibrous cellulosic material; waste and scrap of paper or paperboard	0
48	Paper and paperboard; articles of paper pulp, of paper or paperboard	0
49	Printed books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans	0
50	Silk	0
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric	0
52	Cotton	0
53	Vegetable textile fibres; paper yarn and woven fabrics of paper yarn	0
54	Man-made filaments	0
55	Man-made staple fibres	0
56	Wadding, felt and nonwovens, special yarns; twine, cordage, ropes and cables and articles thereof	0
57	Carpets and other textile floor coverings	0
58	Fabrics; special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery	0
59	Textile fabrics; impregnated, coated, covered or laminated; textile articles of a kind suitable for industrial use	0
60	Fabrics; knitted or crocheted	0
61	Apparel and clothing accessories; knitted or crocheted	1
62	Apparel and clothing accessories; not knitted or crocheted	1
63	Textiles, made up articles; sets; worn clothing and worn textile articles; rags	1
64	Footwear; gaiters and the like; parts of such articles	0
65	Headgear and parts thereof	0

66	Umbrellas, sun umbrellas, walking-sticks, seat sticks, whips, riding crops; and parts thereof	0
67	Feathers and down, prepared; and articles made of feather or of down; artificial flowers; articles of human hair	0
68	Stone, plaster, cement, asbestos, mica or similar materials; articles thereof	0
69	Ceramic products	0
70	Glass and glassware	0
71	Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin	1
72	Iron and steel	1
73	Iron or steel articles	0
74	Copper and articles thereof	1
75	Nickel and articles thereof	1
76	Aluminium and articles thereof	0
78	Lead and articles thereof	0
79	Zinc and articles thereof	0
80	Tin; articles thereof	0
81	Metals; n.e.s., cermets and articles thereof	0
82	Tools, implements, cutlery, spoons and forks, of base metal; parts thereof, of base metal	0
83	Metal; miscellaneous products of base metal	0
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	1
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, parts and accessories of such articles	1
86	Railway, tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds	0
87	Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof	1

88	Aircraft, spacecraft and parts thereof	0
89	Ships, boats and floating structures	0
90	Optical, photographic, cinematographic, measuring, checking, medical or surgical instruments and apparatus; parts and accessories	1
91	Clocks and watches and parts thereof	0
92	Musical instruments; parts and accessories of such articles	0
94	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, n.e.s.; illuminated signs, illuminated name-plates and the like; prefabricated buildings	1
95	Toys, games and sports requisites; parts and accessories thereof	1
96	Miscellaneous manufactured articles	1

TBT = Technical barrier to trade.
Note: TBT is a dummy which equals 1 if a product is subject to a TBT concern, and 0 otherwise.
Source: Authors' calculation.

Chinese Customs data

The second data source is the census of annual export and import transactions of Chinese firms covering 2000–12, collected by the China's General Administration of Customs. The database records a firm's ownership type, trade value, import source, export destination, and trade mode (processing versus ordinary trade) at HS 8-digit product level. These data report the free-on-board value for both exports and imports in US dollars. They also record the quantities traded in one of 12 different units of measurement, such as kilograms and square meters, which makes it possible to construct unit values. Some firms are pure trading companies and they do not engage in manufacturing. Following standard practice in the literature, we identify such intermediaries and wholesalers using keywords in firms' names and exclude them from our sample.[9] We do so to focus on the operations of firms that both produce and trade, since we are interested in how firms respond to TBTs by improving production efficiency and upgrading

[9] We drop around 25,000 wholesalers who account for a quarter of China's exports. Using the same data, Ahn et al. (2011) identified intermediaries in the same way in order to study wholesale activities.

product quality. We convert the HS codes using existing conversion tables for consistency, then aggregate them to HS 4-digit level to match with the database on standards.

We first aggregate the Customs data to firm–HS4 product–destination-year level. Because we need to square the data to construct exit dummy, to limit the sample size within manageable technical capacity, we drop small trade partners with whom trade value falls in the bottom 10 percentile of total Chinese exports. In case a firm does not export to a given product-destination, we assign a zero trade value. We further exclude occasional exporters to avoid the problem caused by export churning. Lastly, we include in our regressions firm–HS4-destination observations with positive exports for at least four times during 2000–12 period. Our final sample covers 199,095 firms with 1,198 HS 4 products exported to 73 markets, equivalent to 87,454 product-destination market combinations. Table A2 in the Appendix reports the full list of countries included in the analysis.[10] The aggregated customs data are then merged with TBT STC database from the WTO and tariff data from the World Bank's World Integrated Trade Solutions using HS 4-digit codes and year. Table 4 presents summary statistics of our variables in the model at the firm-product-destination level. At the exporter-HS 4-digit product-destination level, we have approximately 34 million observations. Mean entry rate is 10%, and mean exit rate is 8%. Over 40% of the observations belong to foreign invested firms and/or multi-destination firms.

[10] Even though the EU is considered as a single entity in the STC database, we include EU countries separately in the regression for two reasons. First, the EU accepted new members during our period of study. Second, by including individual EU country, we can control for destination-specific characteristics.

Table 4. Summary Statistics: Baseline

Variable	Obs.	Mean	Std. Dev.
TBT	34,163,285	0.07	0.25
Tariff (%)	31,760,655	5.81	8.65
AD	34,163,285	0.06	0.23
Exit	34,163,285	0.08	0.27
Entry	34,163,285	0.10	0.31
Export value (log)	12,582,995	3.44	2.45
Export price (log)	12,582,995	-5.13	2.14
Export quantity (log)	12,582,995	8.58	3.10
Quality (σ=5)	12,582,995	1.09	6.66
Size (log)	24,835,315	6.67	2.68
FIE	25,134,173	0.47	0.50
Multi-product	24,835,315	0.44	0.50
Multi-destination	24,835,315	0.47	0.50
Processing exporter	25,133,878	0.47	0.50

AD = Antidumping, FIE = foreign-invested enterprises, TBT = Technical barrier to trade.
Source: Authors' calculation.

Table 5 further details the frequency of TBT concerns in the final dataset. The frequency ranges from 5.5% to 9%. On average, 6.3% of the observations are subject to TBTs involved in the STC database.

Table 5: Number of Observations (Firm-HS-Destination) by TBT and Year

	TBT			
	(1)	(2)	(3)	(1)/(3)
Year	TBT=1	TBT=0	Total	%
2000	145,197	2,482,748	2,627,945	5.5
2001	145,197	2,482,748	2,627,945	5.5
2002	146,040	2,481,905	2,627,945	5.6
2003	176,012	2,451,933	2,627,945	6.7
2004	194,598	2,433,347	2,627,945	7.4
2005	195,674	2,432,271	2,627,945	7.4
2006	202,917	2,425,028	2,627,945	7.7
2007	239,163	2,388,782	2,627,945	9.1
2008	236,240	2,391,705	2,627,945	9.0
2009	205,958	2,421,987	2,627,945	7.8
2010	210,434	2,417,511	2,627,945	8.0
2011	218,128	2,409,817	2,627,945	8.3
2012	14,961	2,612,984	2,627,945	0.6
Total	**2,372,887**	**35,052,618**	**37,425,505**	**6.3**

HS = Harmonized System, TBT = Technical barrier to trade.
Source: Authors' calculation.

In addition to export data, we also utilise information on firms' use of imported inputs from the Customs data. Specifically, we aggregate the Customs data to obtain the total import value of intermediate inputs and the total import value of capital goods at the firm-level.

The Annual Survey of Industrial Firms

To examine the channels of firm's adjustments, we utilise production information from the Annual Survey of Industrial Firms (ASIF) collected by the National Bureau of Statistics of China for 2000–12. The survey covers all industrial firms that are state-owned enterprises, and non-state-owned enterprises with sales above RMB5 million. Industry is defined here to include mining, manufacturing, and public utilities. For this study, we focus on manufacturing firms only. This dataset contains firm-level information on the book value of fixed assets, sales,

R&D expenditure, and employee training fees, which are important to this study.[11] Following Brandt, Biesebroeck, and Zhang (2012), we drop firms that have missing, zero, or negative values for employment, fixed assets, and sales since the logarithms of these variables are not defined. We further drop firms with fewer than eight employees as they fall under a different legal regime. Following Yu (2015), we use firm name, telephone number, postal code, and address to match the ASIF data with the Customs data.

2.2. Methodology

This section seeks empirical evidence of TBTs' impact on firms' export behaviour along five dimensions: the extensive and intensive margins of trade, export value, export price and the quality of exported products. To do so, we estimate the following empirical equation

$$y_{ipdt} = \alpha + \beta TBT_{pdt} + \delta ln\,(tariff + 1)_{pdt} + \theta AD_{pdt}$$
$$+ FE_i + FE_{HS2d} + FE_{pt} + FE_{dt} + \varepsilon_{ipdt} \qquad (1)$$

where $i, p, d,$ and t denote firm, HS 4-digit product category, destination country, and year, respectively.[12] *HS2d* refers to products broadly classified at HS 2-digit chapters.

On the right hand side, our key explanatory variable is the TBT_{pdt} dummy, which carries the value of 1 if an unresolved TBT concern on product *p* exists at time *t* and 0 otherwise.[13]

We also include tariffs and anti-dumping measures as controls. *Tariff* represents effectively applied tariffs faced by Chinese firms into a given destination-sector (HS 4-digit). In this way, we can disentangle the effect of TBTs from that of tariffs. Tariff data are retrieved from the World Bank's World Integrated Trade Solutions database. *Antidumping (AD*) is a dummy variable that takes the value of 1 if the HS 4-digit product is subject to antidumping, and 0

[11] The information on R&D expenditure is only available from 2000 to 2010 and training fee is only available from 2000 to 2007.

[12] Table A3 provides full definition of variables used in our empirical analysis.

[13] Unresolved concerns at time *t* are concerns for which related parties have not reported any resolution to the WTO yet, implying the TBT is still in effect at time *t*.

otherwise. As China became the world's largest target of antidumping measures, studies on the impact of antidumping on firms have also flourished. For instance, Lu et al. (2013) found significant negative impact of antidumping on the extensive margin. Meng, Milner, and Song (2020) observed resource reallocation from low-quality producers to high-quality ones. To capture the effects of antidumping, we use information from the World Bank's Global Antidumping Database on cases against China by all trade partners. To control for unobservable product attributes, market attributes and macroeconomic shocks such as comparative advantage, product dynamics, exchange rates, amongst others, we also include HS 2-digit product-destination fixed effects, HS 4-digit product-year fixed effects, and destination-year fixed effects.

We consider various outcomes of firms' export behaviour. In particular, our dependent variables y_{ipdt} include (i) exit and (ii) entry as measurement of the extensive margin, (iii) export value (intensive margin), (iv) export price, and (v) product quality. *Exit* is a dummy which receives the value of 1 if there is no export by the firm in year t but exports in year t-1, and 0 otherwise. On the contrary, the dummy variable *Entry* equals 1 if there is no export in year t-1 but export in year t. Higher fixed cost raises the cut-off productivity for firms to export, driving less productive firms out of the destination market, triggering trade diversion to market with more relaxing requirements (Melitz, 2003; Chaney, 2008). Therefore, we expect a negative impact of TBTs on entry and exit.

Export value is computed as the log of export value of incumbent exporters. The impact of TBTs on intensive margin is ambiguous. Surviving exporters may enjoy larger market share due to the reduced competition following the exit of less efficient exporters. On the contrary, increased variable costs could result in smaller export value.

Export price is the log of unit value computed as export value over quantity. We expect a positive relationship between TBTs and export price due to the added trade costs, and the increased market power resulting from reduced competition.

Product quality is estimated at firm-product level following Khandelwal (2010) and Amiti and Khandewal (2013). Product quality is not observed directly. Unit values, defined as the ratio of trade value over quantity for each product, are

observable and often used in earlier studies as a proxy (Schott, 2004; Hummels and Klenow, 2005). Notwithstanding its simplicity, unit value may be driven by factors other than quality. For example, higher prices do not necessarily reflect better quality but result from higher production costs. To overcome this issue, Khandewal (2010) proposed a novel approach to estimate quality using both unit value and export quantity. Quality is defined as the unobserved attributes of a variety that make consumers willing to purchase relatively large quantities of it despite relatively high prices.

We estimate the effective quality—as it enters consumer's utility—of product p exported to destination d by firm i in year t, using the following demand equation:

$$\ln\left(Quantity_{ipdt}\right) + \sigma \ln\left(Price_{ipdt}\right) = FE_p + FE_{dt} + \epsilon_{ipdt} \qquad (2)$$

Then the estimated quality is $\ln\left(\widehat{Quality}_{ipdt}\right) = \hat{\epsilon}_{ipdt}$. Conditional on price, a variety with a larger quantity (demand) is assigned higher quality. Keith and Ries (2001) showed that the value of the elasticity of substitution σ is between 5 and 10. We set it at the commonly used value $\sigma = 5$ (e.g. Manova and Yu, 2017), but our results are robust to alternative choices over σ.

We expect a positive relationship between the imposition of restrictive TBTs and quality upgrading. Due to asymmetric information problem, domestic consumers only observe the average quality. As a result, in the absence of standards, low-quality products could force high-quality ones out of the market (Disdier, Gaigné, and Herghelegiu, 2018). The introduction of technical standards addresses this market failure by raising the quality threshold for the products to enter the market.

To further examine the net welfare impact of standards, we decompose export prices into quality- and quality-adjusted export price, whereas the latter is measured as the difference between estimated coefficients on export prices and quality (Hayakawa et al., 2019). A negative coefficient on quality-adjusted export price suggests benefits to the consumers.

Previous studies suggested differential impact of trade policy on individual firms. To examine the potential firm heterogeneity, we divide our sample into subsamples by firms' characteristics. We fix all values of firm characteristics at the initial year to avoid endogeneity and switching. We consider the following aspects of firm heterogeneity. First, we control for firm size. Models on trade and firm heterogeneity suggest that the impact of a trade barrier on export behaviour depends on the productivity of the firm (Melitz, 2003). High-productive firms are more likely to overcome the added trade costs. Following Fontagné et al. (2015), we use total export values as a proxy for a firm's capacity to bear additional costs. Alternatively, we also control for a firm's ownership type. We assign a dummy variable, which equals 1 for foreign-invested firms, assuming that they are more productive and possess a strong business network that helps them overcome hurdles more easily.[14]

Second, we consider firms' initial product quality. Meng, Milner, and Song (2020) found that the extent of firms' quality upgrading depends on ex-ante product quality. Disdier, Gaigné, and Herghelegiu (2018) proposed a similar argument. Facing more stringent quality standards, firms with initial higher quality could survive. Firms whose initial product quality falls below the standard either have to upgrade the quality or withdraw from the market. As such, ex-ante product quality could be an important source of firm heterogeneity in response to NTMs.

Third, we consider the destination-product portfolio of the firm, i.e. multi-destination firms versus single-destination firms. Firms serving multiple markets may find it easier to divert their export sales toward trade partners with less stringent regulations due to low costs of diversion (Fontagné and Orefice, 2018). Our multi-destination variable is a dummy that takes the value of 1 if a firm exports a HS 4-digit product to more than one market, and 0 otherwise.

Fourth, we compare processing firms versus ordinary firms. One special feature of the Chinese manufacturing sector is the prevalence of processing firms, who obtain tariff-exempted raw materials and intermediate inputs from abroad,

[14] Productivity premiums of FDI over domestic firms are well documented in the literature. See, for example, Kimura and Kiyota (2006), Tomiura (2007), Antràs and Yeaple (2014), and Cozza, Rabellotti, and Sanfilippo (2015).

process them locally, and export the final value-added products. Existing evidence highlights the importance of distinguishing between processing exporters and non-processing exporters in explaining a firm's export behaviour (Yu, 2015). Relatively lower fixed costs and special tariff treatments allow the former to participate in the global market despite their inferiority in various aspects such as productivity, R&D, and skill intensity (Dai, Maitra, and Yu, 2016). These factors, in turn, have implications for trade margins and product quality upgrading. As some firms engage in both ordinary trade and processing trade, we categorise firms whose share of processing trade accounts for at least 90% of total exports as processing firms, with the rest classified as ordinary firms.[15]

Endogeneity issues

The inclusion of fixed effects in equation (1) has addressed endogeneity concerns related to selection and omitted variable bias. However, they are insufficient to tackle reverse causality. TBTs could aim at relatively more import-intensive products as a tool to limit trade flow. This is not likely the case in our analysis: these concerns are raised by China, but the TBTs affect exporters from other countries as well.[16] Indeed, 82% of the TBT concerns are raised jointly by more than one WTO member.

Nevertheless, to control for this unlikely but non-trivial issue, following Fontagné and Orefice (2018), we use an instrument variable (IV) and run a 2SLS specification. Specifically, our instrument $IV\ TBT_{pdt}$ is a dummy variable which equals 1 if two conditions hold: (i) if country *d* has an active TBT concern on at least one product other than *p*; and (ii) if at least a third country other than *d* has an active TBT concern over product *p* at time *t*. Otherwise, it equals 0. The idea is that the probability of an active TBT concern from country *d* over product *p* is positively

[15] Under this definition, the share of processing trade exporters is 32% (19,789 out of 61,150 firms) in 2000 and it goes down to 10% (20,662 out of 231,791 firms) in 2010, implying a large increase in the relative share of ordinary trade. Alternatively, we assign a processing dummy, which equals 1 if a firm is engaged in processing trade. The key result holds.

[16] In principle, NTMs are imposed in a non-discriminatory manner. Indeed, over 90% of NTMs are unilateral. They do not specify any individual affected country. Exceptions often fall in SPSs, not TBTs, under special circumstances: for example, when a disease occurs in a specific country and measures are put in place to limit the risk of spreading the disease. These measures, if any, are often temporary.

correlated with the probability of country *d* imposing a TBT on products other than *p*, and with the probability of product *p* being protected by a third country. The imposition of TBTs by third countries other than *d* and the imposition of TBTs on a product other than *p* are exogenous to Chinese exports of product *p* to destination *d*. Alternatively, we lag TBT by 1 year and re-estimate equation (1). It is less likely that exports in year *t* drive a regulation in year *t*-1. In both IV and lagged estimations, we control for applied tariffs and antidumping measures at the country-product level in order to isolate the effect of TBT concerns from tariff and antidumping protections.[17]

3. Empirical Results

3.1. Impact of TBTs on firms' export behaviour—baseline results

On the extensive and intensive margins

Table 6 reports the baseline results on the impact of TBTs on firm export behaviour. After controlling for tariffs and anti-dumping, the coefficient on TBTs is positive and statistically significant for all outcome variables. On exit probability, the results suggest standards act as a trade cost, pushing exporters out of the market. By definition, concerns raised to the WTO and recorded in the STC database are perceived to be trade-restrictive. This result mimics similar findings from previous studies (Fontagné and Orefice, 2018; Curzi et al., 2020). However, the economic impact is small. The imposition of a standard on a certain product raises the probability of stopping exporting that product by only 0.3%. The impact on entry is insignificant.

[17] Fontagné and Orefice (2018) also controlled for tariffs in their estimations using IV and lagged TBT dummy. They examine the effects of TBT on the extensive margin, intensive margin, and export price (but not product quality) of French firms.

Table 6: Baseline Result: TBT and Firms' Export Behaviour

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00335***	0.000585	0.0492***	0.0447***	0.228***	-0.183***
	(0.000595)	(0.000606)	(0.0142)	(0.00811)	(0.0355)	(0.0282)
Tariff	0.00746***	-0.00189	-0.357***	-0.0661*	-0.622***	0.556***
	(0.00168)	(0.00201)	(0.0895)	(0.0400)	(0.181)	(0.148)
AD	0.000685**	-0.00183***	0.0248*	0.00847	0.0587**	-0.0502**
	(0.000305)	(0.000403)	(0.0150)	(0.00607)	(0.0285)	(0.0235)
Fixed effects	Firm, HS2-destination, HS4-year, destination-year					
N	31760357	31760357	11859500	11859500	11859500	11859500
R-sq	0.057	0.042	0.323	0.749	0.456	0.489

HS = Harmonized System, AD- Antidumping, TBT = Technical barriers to trade.
Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Source: Authors' calculation.

On the welfare impact of TBTs—prices versus quality

Moreover, surviving exporters enjoy increased export sales and charge higher export prices. TBTs are associated with as much as 4.9% increase in export sales and 4.5% increase in export prices for firms who can surmount the extra requirement. One possible source of higher prices is higher production cost, which is then passed through to customers. However, a price increase accompanied by larger export sales implies the role of quality. Indeed, we find statistically significant evidence of quality upgrading. Our results show a substantially larger effect on the estimated product quality than that on unit value, suggesting firms adjust both quality and production efficiency. The net welfare effect on consumers is shown through the negative coefficient on quality-adjusted prices. In other words, in the presence of standards, consumers can obtain a better-quality product with the same amount of money.

Worth noting here is that, in absolute terms, all estimated coefficients on NTMs are smaller than those of tariffs, especially those of export values and quality (4.9% versus 35.7%, and 22.8% versus 62.2%, respectively). Except for exit probability, tariff coefficients also bear the opposite signs. This result again confirms the relatively neutral nature of standards compared to tariffs: they serve as both a public policy tool and a barrier to trade.

3.2. Robustness check

In this section we modify our baseline specification to check the robustness of our results. We first report the estimation using average HS 6-digit product quality. One may be concerned that analysis at HS 4-digit level masks substantial product heterogeneity at more disaggregated level. As such, changes within the HS 4-digit category could affect the result. Ideally, one should be able to estimate equation (1) using a more detailed classification such as HS 6-digit or even at the national tariff line. However, such an exercise is impossible because STC data only provide information of affected products at HS 4-digit level. As a robustness check, we proceed as follows. We first estimate product quality at HS 6-digit level. Then we compute, at HS 4-digit level, average HS 6-digit product quality, and average of demeaned HS 6-digit product quality across firms. We re-estimate equation (1) using this new measure of product quality at HS 4-digit level on the left-hand side. Table 7 shows the results. Both specifications provide qualitatively similar results with the baseline regression.

Table 7: Quality Upgrading at HS 6-digit Level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Average quality of HS6 product				**Demeaned quality of HS6 product**			
	Full sample	**TBT countries only**	**Related HS2 only**	**Lagged**	**Full sample**	**TBT countries only**	Related HS2 only	Lagged
TBT	0.209***	0.163***	0.211***		0.186***	0.140***	0.187***	
	(0.0312)	(0.0347)	(0.0336)		(0.0299)	(0.0343)	(0.0325)	
Tariff	-0.292**	-0.881***	-0.283		-0.270**	-0.867***	-0.243	
	(0.134)	(0.248)	(0.173)		(0.133)	(0.247)	(0.171)	
AD	0.0462**	0.0553*	0.0667**		0.0384*	0.0494	0.0601**	
	(0.0209)	(0.0311)	(0.0305)		(0.0206)	(0.0301)	(0.0301)	
L.TBT				0.205***				0.191***
				(0.0413)				(0.0424)
L.Tariff				-0.281**				-0.277*
				(0.135)				(0.143)
L.AD				0.0434**				0.0405*
				(0.0217)				(0.0220)
Fixed effects	Firm, HS2-destination, HS4-year, destination-year							
N	11,859,500	6,076,874	7,240,745	11,617,037	11,803,300	6,050,392	7240745	8264453
R-sq	0.425	0.415	0.452	0.425	0.408	0.400	0.441	0.426

Note: Std. err. are clustered at the firm level. * 0.10 ** 0.05 *** 0.01
HS = Harmonized System, AD = Antidumping, TBT = Technical barrier to trade.
Source: Authors' calculation.

Next, we re-estimate equation (1) after further data cleaning. Table 8 presents the results. First, we limit our destination *d* to members imposing the TBT of interest. We observe that TBTs concentrate on a few markets such as the EU, Japan, and the US. To control for the possibility that firms may divert their trade to a TBT-free market, we limit our sample to TBT countries only. Second, we focus on related HS 2-digit sectors to mitigate the problems that may arise from pooling TBTs on unrelated products together. Also, we can compare the treatment group (i.e. HS 4-digit under the same HS 2-digit sector, which are subject to TBTs) versus the control group (i.e. HS 4-digit under the same HS 2-digit sector, which are not subject to TBTs). Third, we drop the year 2012 as this is the last year in our data and only a few TBTs were observed in the STC database. Again, the estimated coefficients confirm the robustness of our baseline result.

Table 8. Other Robustness Checks

(a) TBT countries only

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00384***	-0.000474	0.0528***	0.0358***	0.196***	-0.160***
	(0.000734)	(0.000753)	(0.0180)	(0.00947)	(0.0401)	(0.0319)
N	15975745	15975745	6076874	6076874	6076874	6076874
R-sq	0.054	0.043	0.333	0.731	0.455	0.527

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

(b) TBT related HS 2-digit

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00415***	0.000776	0.0548***	0.0448***	0.234***	-0.189***
	(0.000678)	(0.000648)	(0.0154)	(0.00876)	(0.0384)	(0.0306)
N	19274470	19274470	7240745	7240745	7240745	7240745
R-sq	0.060	0.043	0.299	0.759	0.495	0.527

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

(c) Drop 2012 sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00129**	-0.000766	0.0600***	0.0502***	0.261***	-0.211***
	(0.000625)	(0.000723)	(0.0194)	(0.0108)	(0.0473)	(0.0378)
N	29356449	29356449	10766742	10766742	10766742	10766742
R-sq	0.062	0.040	0.322	0.754	0.464	0.496

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

(d) Market share

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00368***	0.000150	0.0435***	0.0445***	0.221***	-0.177***
	(0.000592)	(0.000609)	(0.0152)	(0.00811)	(0.0361)	(0.0289)
Market share	-0.232***	0.314***	4.928***	0.194***	5.705***	-5.511***
	(0.000557)	(0.00116)	(0.0240)	(0.00612)	(0.0366)	(0.0322)
N	31760357	31760357	11859500	11859500	11859500	11859500
R-sq	0.061	0.048	0.363	0.749	0.464	0.499

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

HS = Harmonized System, AD = Antidumping, TBT = Technical barrier to trade.

Source: Authors' calculation.

We also ask whether exporters respond to TBTs differently according to their market share, defined as a firm's share in total exports of product *p* to destination *d* in year *t*. To that, we add a control on firms' market share. Our estimated result implies that firms with larger market share are less likely to exit, more likely to increase their sales, prices and, ultimately, upgrade product quality. Estimated coefficients on TBTs remain qualitatively similar to those obtained from the baseline estimation in Table 6.

3.3. Endogeneity issue

Table 9 presents the estimation results with IV. First-stage estimation shows robust results, as all coefficients are statistically significant. A large joint F-stat implies TBT concerns raised by third countries serve as a strong instrument. The impact of TBTs on incumbent exporters is significantly larger than the estimates obtained from the baseline regression. Impact on entry and exit, however, is different from the baseline result. The coefficient on exit is insignificant, whereas the impact on entry is positive and significant. One possible explanation is that the TBT signals product quality, enhancing consumers' confidence in the product, thus generating larger demand (Movchan, Shepotylo, and Vakhitov, 2019). Moreover, for China, the TBT-imposing countries are large trade partners in terms of GDP and market potential, which induces more entries than non-TBT countries (as shown in Figure 1).

Table 9: IV Estimation—TBT Concerns Raised by Third Countries

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A, second-stage: dependent variable	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
TBT	0.00151	0.00258**	0.127***	0.0937***	0.502***	-0.408***
	(0.00110)	(0.00121)	(0.0262)	(0.0148)	(0.0654)	(0.0522)
Tariff	0.00750***	-0.00193	-0.358***	-0.0663*	-0.623***	0.557***
	(0.00168)	(0.00201)	(0.0893)	(0.0400)	(0.181)	(0.147)
AD	0.000706**	-0.00185***	0.0239	0.00787	0.0554*	-0.0475**
	(0.000305)	(0.000401)	(0.0149)	(0.00612)	(0.0286)	(0.0236)
Panel B, first-stage: dependent variable	TBT					
IV TBT	0.424***	0.424***	0.473***	0.473***	0.473***	0.473***
	(0.0136)	(0.0136)	(0.0153)	(0.0153)	(0.0153)	(0.0153)
Fixed effects	Firm, HS2-destination, HS4-year, destination-year					
N	31,760,357	31,760,357	11,859,500	11,859,500	11,859,500	11,859,500
Joint *F-stat*	972.15	972.15	959.53	959.53	959.53	959.53

HS = Harmonized System, AD = Antidumping, TBT = Technical barrier to trade.
Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Source: Authors' calculation.

Our alternative specification using lagged TBTs as the independent variable also yields similar results to the baseline estimation (Table 10). One possible explanation is the STC database records the year when a concern was first raised, not the year when the regulation came into effect. The affecting country is more likely to submit a concern after the negative impact of the TBT has been visible. In other words, it is likely that a certain lag exists between the time a TBT is enforced and the year recorded in the database. Therefore, we may not observe different results with the baseline regression by adding one more lag.

Table 10: Lagged TBT as Explanatory Variable

	(1)	(2)	(3)	(4)	(5)	(6)
	Exit	Entry	Export value	Export price	Quality	Quality-adjusted price
L.TBT	0.00184***	0.00169*	0.0555***	0.0419***	0.223***	-0.181***
	(0.000708)	(0.000950)	(0.0185)	(0.0104)	(0.0464)	(0.0371)
L.Tariff	0.00431**	-0.00389*	-0.361***	-0.0627	-0.612***	0.549***
	(0.00181)	(0.00217)	(0.0881)	(0.0400)	(0.181)	(0.147)
L.AD	0.000345	-0.00200***	0.0201	0.0106*	0.0625**	-0.0519**
	(0.000337)	(0.000448)	(0.0148)	(0.00620)	(0.0292)	(0.0241)
Fixed effects	Firm, HS2-destination, HS4-year, destination-year					
N	29356449	29356449	11617037	11617037	11617037	11617037
R-sq	0.052	0.032	0.324	0.748	0.456	0.489

HS = Harmonized System, AD = Antidumping, TBT = Technical barrier to trade.
Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Source: Authors' calculation.

3.4. Addressing firm heterogeneity

In this section we examine the potential heterogeneous effect of TBTs on price and quality conditioning on firm size, firm ownership, initial product quality, firms' trade status and multi-destination firms. Results are presented in Table 11.

Table 11: TBT and Firms' Quality Upgrading: Firm Heterogeneity

(a) Firm Size

	(1)	(2)	(3)	(4)	(5)	(6)
	Large firms			Small firms		
	Export price	Quality	Quality-adjusted price	Export price	Quality	Quality-adjusted price
TBT	0.0367***	0.250***	-0.213***	0.0538***	0.243***	-0.189***
	(0.0117)	(0.0510)	(0.0407)	(0.00996)	(0.0427)	(0.0336)
N	3577472	3577472	3577472	3518207	3518207	3518207
R-sq	0.684	0.363	0.406	0.789	0.536	0.562

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

(b) Firm Ownership

	(1)	(2)	(3)	(4)	(5)	(6)
	FIEs			non-FIEs		
	Export price	Quality	Quality-adjusted price	Export price	Quality	Quality-adjusted price
TBT	0.0180**	0.145***	-0.127***	0.0621***	0.277***	-0.215***
	(0.00894)	(0.0394)	(0.0317)	(0.00952)	(0.0417)	(0.0331)
N	5537507	5537507	5537507	6321196	6321196	6321196
R-sq	0.740	0.462	0.482	0.763	0.459	0.489

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01. Firm, HS2-destination, HS4-year, destination-year fixed effects are included. AD and tariffs are included.

(c) Initial Product Quality

	(1)	(2)	(3)	(4)	(5)	(6)
	Initial high-quality firms			Initial low-quality firms		
	Export price	Quality	Quality-adjusted price	Export price	Quality	Quality-adjusted price
TBT	0.0403***	0.226***	-0.185***	0.0563***	0.285***	-0.229***
	(0.0107)	(0.0479)	(0.0384)	(0.0106)	(0.0457)	(0.0364)
N	3695198	3695198	3695198	3471307	3471307	3471307
R-sq	0.791	0.465	0.475	0.739	0.432	0.514

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Firm, HS2-destination, HS4-year, destination-year fixed effects are included.
AD and tariffs are included.

(d) Number of Destinations

	(1)	(2)	(3)	(4)	(5)	(6)
	Multi-destination firms			Single-destination firms		
	Export price	Quality	Quality-adjusted price	Export price	Quality	Quality-adjusted price
TBT	0.0290***	0.166***	-0.137***	0.0466***	0.221***	-0.174***
	(0.00684)	(0.0319)	(0.0263)	(0.0103)	(0.0446)	(0.0349)
N	6193601	6193601	6193601	5665227	5665227	5665227
R-sq	0.809	0.551	0.574	0.728	0.453	0.488

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Firm, HS2-destination, HS4-year, destination-year fixed effects are included.
AD and tariffs are included.

(e) Trade Status (Processing versus Ordinary Trade)

	(1)	(2)	(3)	(4)	(5)	(6)
	Processing trade			Ordinary trade		
	Export price	Quality	Quality-adjusted price	Export price	Quality	Quality-adjusted price
TBT	0.0557***	0.433***	-0.378***	0.0374***	0.178***	-0.140***
	(0.0197)	(0.0864)	(0.0689)	(0.00790)	(0.0353)	(0.0284)
N	1068561	1068561	1068561	10775367	10775367	10775367
R-sq	0.736	0.526	0.542	0.752	0.455	0.490

Note: Std. err. are clustered at the HS4-destination level. * 0.10 ** 0.05 *** 0.01.
Firm, HS2-destination, HS4-year, destination-year fixed effects are included.
AD and tariffs are included.
HS = Harmonized System, AD = Antidumping, TBT = Technical barrier to trade.
Source: Authors' calculation.

Overall, we find similar results with the baseline estimation across outcome variables. Both large and small surviving exporters respond to TBTs by raising the export prices and product quality, although the magnitude is comparable between two groups (Panel A). When we proxy firm size by ownership type, i.e. foreign-invested enterprises (FIEs) versus Chinese domestic firms, the magnitude of impact is noticeably larger for Chinese domestic firms (Panel B). This result fits the common discussion in the literature that FIEs are more productive and produce high-quality products. Facing a new standard, the compliance cost for FIEs could be smaller, which then translates into smaller increases in export price. Furthermore, firms whose product quality is close to or has already exceeded the new requirement may have less motivation to upgrade quality, resulting in a smaller estimated parameter (Panel C). Indeed, estimated results from initial product quality in Panel C support this argument. Although both firms produce high-quality product, defined as those in the top three deciles of initial product quality, and those in the bottom three deciles raise unit values and upgrade quality, the impact is stronger for the second group.

Turning to multi-destination versus single-destination firms, we observe a similar picture: single-destination firms respond more strongly to TBTs (Panel D). The presence of TBTs is correlated with a 4.6% increase in the price compared to 2.9% for multi-destination firms. The estimates on quality upgrading are also larger for single-destination firms. This could reflect the relatively limited capacity of single-destination firms to divert their trade to other markets, pushing them to improve quality in order to maintain their presence in the current market.

Panel E contrasts results for processing firms and non-processing firms. The former are more responsive to TBT imposition. Surviving processing firms increase the price by 7.7% compared to 4.1% amongst the ordinary firms. Quality upgrading is also more vigorous amongst the former. One possible explanation is the capacity of processing firms to access raw materials and imported intermediate inputs, making them more capable of upgrading the products.

3.5. From TBT confrontation to quality upgrading—the mechanism

As our results show positive and significant impact of TBTs on quality upgrading, we continue to explore the underlying mechanism through which firms upgrade their products.

Following the conceptual discussion in Ing et al. (2016), and due to data availability, we consider the adjustments on (i) imported intermediate inputs; (ii) imported capital goods; (iii) investment; (iv) R&D; and (v) training fees. Imported intermediate input is defined as the logarithm of total imported intermediate goods in USD. Imported capital goods are measured as the logarithm of total imported capital goods in USD. The classification of intermediate inputs and capital goods follows Broad Economic Categories by UN Comtrade.

Investment includes both machinery and buildings. As the production data do not contain information on investment, following the literature (e.g. Brandt, Biesebroeck, and Zhang, 2012), we use the book value of fixed capital stock and perpetual inventory method to estimate real capital stock. Accordingly, the investment is the difference of capital stock between *t* and *t*-1. Investment enters our regression in investment ratio, i.e. investment over lagged capital stock.

Lastly, we include R&D in log form (as R&D plus one) as well as R&D intensity over total sales, while training fee is measured as the log of training fee plus one.

We use the matched ASIF-Customs firm-level data and 2SLS to estimate the mechanism. Table 12 demonstrates the results, with panel A for the second stage results and panel B for the first stage results. The first stage estimation results show a positive and statistically significant effect of the TBT on imported intermediate inputs, imported capital goods, and R&D expenditure. Consistent with our expectation, firms respond strongly to TBTs by raising their imported intermediate inputs, capital goods, and R&D. However, the coefficients on training and investment are insignificant.[1] In panel A, the outcome variable is the demeaned product quality across firms. Given differentiation across products, we cannot compare the quality of different goods in a firm's production portfolio in absolute

[1] At the first stage regression, the low joint F-stat of these two variables suggest the problem of weak instruments.

terms. Therefore, we first estimate product quality at HS 4-digit level by equation (2) and then demean every export product quality by the average observed across all firms exporting that HS 4-digit product category. For a multi-product firm, it is the simple average of demeaned quality of its all products. By demeaning product quality, we obtain the distance between a firm's product quality from the market average in percentage terms rather than in absolute levels. Our estimation result implies that the demeaned product quality increases by approximately 2.9%, 5.2%, and 8.3% because of a 10% increase in imported intermediate inputs, imported capital goods, and R&D expenditure, respectively.

Table 12: Mechanism

	(1)	(2)	(3)	(4)	(5)
Panel A, second-stage: dependent variable	Demeaned quality				
L.Imported intermediate inputs	0.292**				
	(0.117)				
L.Imported capital goods		0.524**			
		(0.237)			
L.Investment/lagged capital stock			0.171		
			(0.156)		
L.R&D				0.837**	
				(0.360)	
L.Training					3.044
					(2.061)
Panel B, first-stage: dependent variable	L.Imported intermediate inputs	L.Imported capital goods	L.Investment/ lagged capital stock	L.R&D	L.Training
L.TBT	0.256***	0.143***	0.401	0.0916***	0.0407*
	(0.0454)	(0.0391)	(0.332)	(0.0224)	(0.0246)
Controls	L.Tariff, L.AD				
Fixed effects	Firm, Industry-year				
N	336197	336197	272958	295421	190650
Joint *F-stat*	31.87	13.31	3.32	19.54	4.46
Note: Std. err. are clustered at the firm level. * 0.10 ** 0.05 *** 0.01					

HS = Harmonized System, TBT = Technical barrier to trade.
Source: Authors' calculation.

4. Conclusion and Policy Implications

We analyse the impact of TBTs on Chinese firms' trade margins and product quality, controlling for various aspects of firm heterogeneity. We focus our analysis on measures which are perceived as trade barriers. To do so, we utilise a comprehensive Customs database covering all transactions at firm-product-year level, matched with the Annual Survey of Industrial Firms and the WTO's database on Specific Trade Concerns. We find that TBTs are associated with higher probability to exit. Surviving exporters enjoy larger sales and charge higher export prices. We also find robust evidence for the quality upgrading effects of TBTs. Firms upgrade their product quality by expanding their R&D and investment and importing more intermediate inputs and capital goods. The impact of TBTs on quality upgrading offsets that on price increases, resulting in lower quality-adjusted export prices. This suggests the welfare-enhancing effect of TBTs. The results hold after controlling for potential endogeneity. We observe the differences in magnitude across different sub-groups of firms. The direction of impact, however, remains consistent. Our findings have important policy implications. As tariffs have declined to a low level, increasing attention has been paid to the trade impact of standards. The conventional trade-negotiation approach which advocate the removal of non-tariff barriers proves to be difficult and ineffective given the complex nature of NTMs (Doan and Rosenow, 2019; UNCTAD, 2020). Since NTMs serve legitimate purposes, in most cases elimination is not an option. The key policy question in addressing NTMs, then, is how to minimise their trade costs, thus improving export competitiveness, while ensuring their effectiveness in addressing market failures.

Our findings highlight the neutrality and complexity of NTMs: they serve legitimate public policy goals, yet they are trade-restrictive. For effective policy intervention, it is crucial to understand the differential impact of standards at firm level. Conditioning on individual firm characteristics, there are losers and winners. Higher trade costs drive less-competitive firms out of the export markets and result in redistribution of market shares amongst the surviving players. More efficient firms gain from the reduced competition and improved consumers' confidence in the quality of the product through the introduction of standards. As such, from

exporting countries' perspective, supporting firms to improve compliance capacity would contribute to enhancing firms' survival and growth in the international market. For imposing countries, standards act as a signal for product quality, ensuring consumer's welfare. Therefore, instead of removal, a more pragmatic approach to minimise trade costs lies in the proper design and effective implementation of standards.

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Appendix

Table A1: TBT product-destination: Example

Chapter 32: Tanning extracts, dyes, pigments, paints

HSCodeRev2	HSDescription	firstyear_raised	lastyear_raised	Membersmaintaining
3201	Tanning extracts of vegetable origin;	2003	2011	European Union
3202	Synthetic organic tanning substances	2003	2011	European Union
3203	Colouring matter of vegetable or anir	2003	2011	European Union
3204	Synthetic organic colouring matter, w	2003	2011	European Union
3205	Colour lakes; preparations as specifi	2003	2011	European Union
3206	Other colouring matter; preparations	2003	2011	European Union
3207	Prepared pigments, prepared opacifi	2003	2011	European Union
3208	Paints and varnishes (including enam	2003	2011	European Union
3209	Paints and varnishes (including enam	2003	2011	European Union
3210	Other paints and varnishes (including	2003	2011	European Union
3211	Prepared driers.	2003	2011	European Union
3212	Pigments (including metallic powders	2003	2011	European Union
3213	Artists', students' or signboard painte	2003	2011	European Union
3214	Glaziers' putty, grafting putty, resin c	2003	2011	European Union
3215	Printing ink, writing or drawing ink an	2003	2011	European Union

Table A2. List of Countries and Regions Included in the Analysis

AGO (Angola), ARE (United Arab Emirates), ARG (Argentina), AUS (Australia), AUT (Austria), BEL (Belgium), BEN (Benin), BGD (Bangladesh), BRA (Brazil), CAN (Canada), CHE (Switzerland), CHL (Chile), COL (Colombia), CZE (Czech Republic), DEU (Germany), DNK (Denmark), DZA (Algeria), EGY (Egypt), ESP (Spain), FIN (Finland), FRA (France), GBR (United Kingdom), GHA (Ghana), GRC (Greece), HKG (Hong Kong), HUN (Hungary), IDN (Indonesia), IND (India), IRL (Ireland), IRN (Iran), ISR (Israel), ITA (Italy), JOR (Jordan), JPN (Japan), KAZ (Kazakhstan), KEN (Kenya), KGZ (Kyrgyz Republic), KHM (Cambodia), KOR (Korea, Republic), KWT (Kuwait), LBR (Liberia), LKA (Sri Lanka), MAC (Macao), MAR (Morocco), MEX (Mexico), MYS (Malaysia), NGA (Nigeria), NLD (Netherlands), NOR (Norway), NZL (New Zealand), PAK (Pakistan), PAN (Panama), PER (Peru), PHL (Philippines), POL (Poland), PRT (Portugal), ROM (Romania), RUS (Russia), SAU (Saudi Arabia), SGP (Singapore), SDN (Sudan), SVK (Slovak Republic), SWE (Sweden), SYR (Syrian Arab Republic), TGO (Togo), THA (Thailand), TUR (Turkey), TWN (Taiwan), UKR (Ukraine), USA (United States), VEN (Venezuela), VNM (Viet Nam), ZAF (South Africa)

Table A3. Definitions of Variables

Variables	Definitions	Sources
TBT	A dummy variable which equals one if an unresolved TBT concern on product *p* exported to country *d* exists at time *t*, and otherwise zero	WTO's Specific Trade Concerns (STC) database
Tariff (%)	Effectively applied tariffs faced by Chinese firms into a given destination-sector (HS 4-digit)	World Bank's World Integrated Trade Solutions database
AD	A dummy variable which takes the value of 1 if the HS-4 digit product is subject to antidumping, and 0 otherwise	World Bank's Global Antidumping Database
Exit	A dummy which receives the value of 1 if there is no export by the firm in year t but exports in year t-1, and 0 otherwise.	China's General Administration of Customs
Entry	A dummy which receives the value of 1 if there is no export by the firm in year t-1 but exports in year t, and 0 otherwise.	Same as above
Export value (log)	Logarithm of export value in USD	Same as above
Export quantity (log)	Logarithm of export quantity in USD	Same as above
Export price (log)	Logarithm of unit value in USD computed as export value over quantity	Same as above
Quality (σ=5)	Estimated product quality following Amiti and Khandewal (2013). The value of the elasticity of substitution equals five.	Same as above
Size (log)	Logarithm of total export value	Same as above
FIE	Foreign invested enterprises dummy	Same as above

Multi-destination	Multi-destination firm dummy	Same as above
Processing	Processing exporter dummy	Same as above
Imported intermediate inputs (log+1)	Logarithm of total imported intermediate goods in USD. Intermediate goods follows the classification of Broad Economic Categories (BEC) by UN Comtrade.	Same as above
Imported capital goods (log+1)	Logarithm of total imported capital goods in USD. Capital goods follows the classification of Broad Economic Categories (BEC) by UN Comtrade.	Same as above
Investment/lagged capital stock	Investment ratio. Capital stock is estimated following Brandt, Biesebroeck, and Zhang (2012)	Annual Survey of Industrial Firms, National Bureau of Statistics of China
R&D (log+1)	Logarithm of R&D expenditure plus one	Same as above
Training fee (log+1)	Logarithm of training expenditure plus one	Same as above

FIE = foreign-invested enterprise, AD = Antidumping, R&D = research and development, TBT = technical barrier to trade.
Source: Authors' calculation.

Table A4. Summary Statistics- Mechanism

Variable	Obs.	Mean	Std. Dev.
Demeaned quality	462,877	0.39	4.54
Imported intermediate inputs (log+1)	815,608	4.60	6.23
Imported capital goods (log+1)	815,608	1.76	4.22
Investment/lagged capital stock	522,821	3.69	16.08
R&D (log+1)	633,097	1.42	2.76
Training fee (log+1)	381,854	1.50	1.96
TBT	815,608	0.17	0.37
Tariff (log+1)	815,608	0.04	0.05
AD	815,608	0.22	0.42

AD = Antidumping, TBT = technical barrier to trade.
Source: Authors' calculation.

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