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By Jun Du, Mustapha Douch, Oleksandr Shepotylo and Dongzhe Zhang

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Jun Du[1], Mustapha Douch[2,1], Oleksandr Shepotylo[1], Dongzhe Zhang[3]

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[1] Economics, Finance and Entrepreneurship Department, Aston Business School, Aston University. Jun Du: Email: j.du@aston.ac.uk; Twitter: @jundu_econ; Oleksandr Shepotylo: Email: oshepotylo@aston.ac.uk; Twitter: @shepotylo.

[2] The University of Edinburgh, Business School, Edinburgh, UK, Email: mdouch@ed.ac.uk.

[3] University of Sussex, CITP, Brighton, UK, dz91@sussex.ac.uk

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Non-Tariff Measures, Trade Margins and Firm Heterogeneity*

Jun Du[†], Mustapha Douch[‡], Oleksandr Shepotylo[§], Dongzhe Zhang[¶]

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Abstract

Non-tariff measures (NTMs) influence a firm's production and trade decisions. We study the impact of NTMs on firm-level trade and document the highly heterogeneous effect of NTMs on the export and import of UK firms in 2012-2018. We calculate ad valorem equivalents (AVE) of NTMs faced by firms of different sizes and exporting to different destinations. We also look at the range of NTMs, including technical and non-technical measures. Our results indicate that while SPS and TBT improve the quality of exports, inspection and licensing fail to address public policy concerns.

Key words: NTM, quality, import, export, food, heterogeneous firms

JEL codes: L11, F12, O14

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[†]Aston Business School, j.du@aston.ac.uk

[‡]The University of Edinburgh, Business School, Edinburgh, UK, mdouch@ed.ac.uk

[§]Aston Business School, o.shepotylo@aston.ac.uk

[¶]University of Sussex, CITP, Brighton, UK, dz91@sussex.ac.uk

1 Introduction

Non-tariff measures (NTM) are important instruments of trade policy, which address public policy concerns about the quality and safety of goods. A secular decline in import tariffs from the world average applied rate of 8.5 percent in 1994 to 2.6 percent in 2017, makes NTMs even more important.[1] In 2003, ad valorem equivalent of NTMs was estimated at 10 percent (Kee et al., 2009) and it is increasing in scope and size (WTO, 2012).[2] NTMs may serve as protectionism in disguise by allowing barriers to trade to be built, especially when tariffs are not permitted policy tools due to the WTO binding commitments. However, NTMs may be imposed to protect local industries (Grossman and Helpman, 1994), driven by economic factors (Chin et al., 2015) and political factors (Maggi et al., 2019). In particular, NTMs could be imposed to compensate for the loss of tariffs when trade liberalization prevailed.

The body of literature that examines the effects of NTMs is extensive and inconclusive. So far, the effects remain poorly understood, with most studies focusing on the direct impact of NTMs on trade; relatively few have investigated their external effects on factors such as price, quality, and competition. Theoretically, NTMs may affect both the demand for and supply of exported products through consumer preferences and producer technologies. With asymmetric information (Akerlof, 1970), stricter health and safety standards signal to consumers about better quality, which has a positive effect on demand for the product. However, more stringent health and safety regulations can require substantial modifications of production processes, investments in new technologies, and improvements in transportation infrastructure, which would increase fixed and variable production and transportation costs, preventing new entries, and pushing the industry supply curve upward. The resulting equilibrium would likely result in a higher quality product at a higher price, but the impact on the quantity would be ambiguous.

Empirically, the existing evidence has produced divergent findings, ranging from viewing NTMs as "standards as catalysts," "standards as barriers," to no discernible effects at all. The broad spectrum of evidence precludes any generalizations. The outcomes typically depend on several factors, such as the nature of the NTMs, the particular products under consideration, the countries analysed, the data sources, the measurement approaches utilized, and the estimation methodologies

[1] Source: Data on the average applied tariffs are from World Development Indicators.

[2] Kee and Nicita (2016) report that in 2011 the ad valorem equivalent of NTM was 11.5 percent.

applied in the investigation. These findings underscore the importance of conducting empirical analyses specific to particular contexts and cases.

Second, different types of NTMs have distinct effects. While sanitary and phytosanitary measures (SPS) or technical barriers to trade (TBT) serve to monitor and enforce certain quality, health, and technological standards, other types of NTMs are less benign, serving purely as a substitute for reduced tariffs to protect local markets from foreign competition. Pre-shipment inspections and non-automatic licensing do not control the safety of the product while adding red tape, increasing time at the border and cost of production. Because of their heterogeneity, NTMs are very difficult to quantify – most studies use frequency measures without capturing how costly and binding those measures are. Moreover, it is hard to compare their impact on trade across different types of NTMs and to compare it with the impact of tariffs.

Third, the effect of NTMs on export may differ for small and medium enterprises (SME) vs large multinational enterprises (MNE). Fontagné et al. (2015), looking at exports of French firms, find that the negative effect of higher SPS standards in the destination country attenuates for larger firms. Fernandes et al. (2019), looking at a large sample of developing countries' firms, find that smaller exporters are more affected in their market entry and exit decisions by the relative stringency of destination standards than larger exporters. There is also emerging research on NTM and quality. Khandelwal (2010) and Amiti and Khandelwal (2013) introduced a methodology to measure quality based on trade data. Fan et al. (2015b), Bas and Strauss-Kahn (2015), and Fan et al. (2018b) show that trade liberalization, measured as a reduction in MFN tariffs, leads to an improvement of export quality. Movchan et al. (2019) looked at the effect of NTM on exports and found that SPS regulations on inputs in upstream industries lead to exports of better-quality products. At the same time, mandatory certifications have a negative impact on quality by limiting the access of domestic companies to new technologies and equipment.

This paper examines the impact of NTMs on UK exports. We develop a model with heterogeneous firms and quality to illustrate the mechanisms through which NTMs influence a firm's level of imports and exports and formulate hypotheses on the heterogeneous impacts of NTMs at the level of a firm. We use HMRC transaction-level export and import data in 2012-2019, linked with the Inter-Departmental Business Register (IDBR)'s Business Structure Database (BSD) data to incorporate firm size, industrial affiliation and location. We disentangle the impact into upstream and downstream channels and consider quantity, quality, and price margins to identify the mechanisms, magnitude, and direction of the impact. To construct our measures of upstream and downstream levels of protection, we use the UNCTAD-WTO Integrated Trade Intelligence Portal (I-TIP) database on NTMs in 2012-2018 (Mattoo and Peters, 2018) linked with the UNCTAD Trade Analysis Information System (TRAINS) applied tariff data and bilateral imports (COMTRADE) at HS 6-digit product level to compute ad valorem equivalents (AVE) of NTMs, extending Kee et al. (2009) and Kee and Nicita (2016) methodology. This methodology allows us to estimate ad valorem equivalents of SPS, TBT and licensing in 2012-2018 for 200+ countries, which are product and trade-pair-specific.

This is the first attempt to have a comprehensive analysis of the impact of NTMs on exports from a developed country at a very granular level. The product-level exports of a firm are decomposed into quantity, price, and quality margins. The quality is estimated following Khandelwal et al. (2013) methodology. Our work is closely related to studies that examine the effect of imported inputs on firm performance (Amiti and Konings, 2007; Khandelwal and Topalova, 2011; Olper et al., 2017). It is also related to studies that look at the impact of imported inputs on trade at extensive and intensive margins (Halpern et al., 2015).

Our results show that Input NTMs have a limited impact on a firm's exports, while Output NTMs have a more prominent impact. Higher TBT imposed on imported inputs leads to inferior quality of exports, potentially due to restricted access to intermediate inputs with higher specifications. We do not find that increased SPS affects export product quality, although they are associated with lower export prices. Also, there is no evidence that Inspections or Licensing imposed on inputs affect any export quality.

While Output NTMs are impactful, the evidence suggests that all NTMs are not the same. Output SPSs reduce exports, which work through the depressed prices of exports. Output inspection and licensing increase exports. Output SPSs and TBTs improve quality of exported goods, while Output inspection and licensing achieve the opposite effect on quality. Licensing seems to push up export quality with higher prices, while Inspections raise prices but lower export quantity.

Overall, TBTs on UK exports have the least distortionary impact among all types of NTMs during the examined period, while achieving their primary objective of controlling for quality of products in the middle of the export size distribution.

Exporter size matters. First of all, micro and small firms are more impacted negatively by input NTMs on export value and quantity, while their medium and large counterparts appear to experience positive effects. Smaller firms tend to be impacted to adjust the quality of products as well, an increase in TBTs, Inspection and Licensing measures imposed on inputs affect negatively the quality of exported goods.

Further, exporters of different sizes respond to higher SPSs differently. The negative effect of Output SPSs on export value and prices increases with the size of the exporter. With better quality and lower prices, micro, small and medium-sized exporters remain selling similar quantities as before, resulting in fewer exports in value. Large exporters sharply reduce export quantity, facing large price drops.

2 NTMs background

NTMs are policy measures, other than tariffs, that can potentially have an economic effect on international trade in goods, changing traded quantities, prices, or both (UNCTAD, 2010). They comprise a diverse set of measures other than tariffs and tariff-rate quotas, given specific purpose, legal form and intended economic effect. In principle, NTMs are introduced for safety and welfare-enhancing gains and do not explicitly have a protectionist aim. Nonetheless, they could be used as protectionist measures and may in fact be perceived as such. Any policy that impacts trade can be considered an NTM even if it regulates government procurement or the labour markets (UNCTAD, 2010). As NTMs prevent entry due to compliance costs, they are usually part of preferential trade agreements (Hofmann et al., 2017) and are regulated by specific committees in the WTO.

Over time, NTMs have gained significant importance in trade policy, as the use of tariffs has steadily declined around the world. Worldwide, NTMs are estimated to be on average three times more expensive than tariffs for trade (UNCTAD). In developed countries, a recent estimate suggests that more than 80 percent of trade is affected by NTMs (Shepherd and Peters, 2020). Furthermore, evidence shows that NTMs affect small businesses disproportionally more (Fontagné et al., 2015; Fugazza et al., 2017).

Given the heterogeneity of NTMs, it is important to develop a consistent and comprehensive classification that captures different types of trade-related regulations. Developed by the UNCTAD

Table 1: Classification of non-tariff measures (NTM)

Type	Code	Description
Technical measures	A	Sanitary and phytosanitary measures
	B	Technical barriers to trade
	C	Pre-shipment inspection and other formalities
Non-technical measures	D	Contingent trade protective measures
	E	Non-automatic licensing and quantity control measures
	F	Price control measures, additional taxes and charges
	G	Finance measures
	H	Measures affecting competition
	I	Trade-related investment measures
	J	Distribution restrictions
	K	Restriction on post-sales services
	L	Subsidies
	M	Government procurement restrictions
	N	Intellectual property
	O	Rules of origin
Export Measures	P	Export related measures

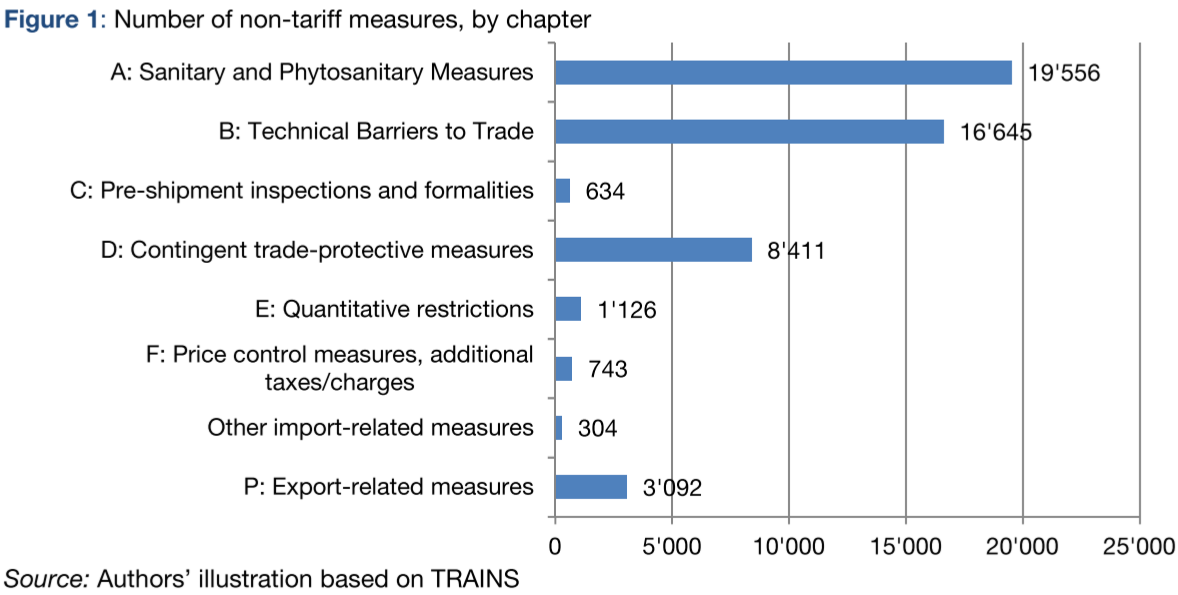
Source: UNCTAD (2013)

Multi-Agency Support Team (MAST) (UNCTAD, 2013), the measures can be broadly divided into two groups. The first type, called "technical" measures, includes regulations, standards, testing and certification, primarily sanitary and phytosanitary (SPS) and Technical Barriers to Trade (TBT) measures. The second type, called "non-technical" measures, includes quantitative restrictions (quotas, non-automatic import licensing), price measures, forced logistics or distribution channels.

Table 1 presents the typology of NTMs. Technical measures, A through C, are designed to regulate health and safety, technical standards, and preshipment inspections. They set requirements and regulate conformity-assessment procedures, such as certification, inspection, and quarantine. Their main goal is to address public policy concerns and market externalities, which are not related to trade. Non-technical measures, D through O, are often trade-related, such as quotas and subsidies. However, they cover a wide range of topics, from finance to competition to intellectual property and government procurement. Export control measures are much less frequent and are recorded under the single code P, which includes a wide range of topics.

UNCTAD I-TIP NTM database provides the most comprehensive data on non-tariff measures, available for more than 100 countries in 2012-2018 (Mattoo and Peters, 2018). For each 6-digit HS code product line n, it reports whether country i applies an NTM of type k towards a trading partner from country j. Record the starting and ending times for each NTM, which allows us to build a panel of bilateral NTMs in 2012-2018. In our investigation, we focus on the technical measures, including SPS (Chapter A), TBT (Chapter B), and Inspection (Chapter C), as well as the non-technical ones, such as licensing and quotas (Chapter E), which are the most common, as shown in Figure 1. [3]

Figure 1: NTM usage by chapter



Source: Mattoo and Peters (2018)

3 Related literature

Our paper is mainly related to the literature on NTM's use for trade protection and the NTM effects on trade and their externalities on economic indicators beyond trade. We provide new evidence on the differences between specific NTM measures, leading to the varied effects of their application and the role of firm heterogeneity that the growing literature is increasingly focused on. Drawing on the UK experience, the paper also relates to the fast-emerging literature on policy uncertainty on trade

[3] Chapter D Contingent trade protective measures are not available for EU, so this category has been omitted from our analysis despite its frequent application by other countries.

in the context of Brexit.

3.1 NTMs as measures for trade protection

Encompassing a broad range of measures that discriminate foreign competitors from domestic producers, NTMs are in principle designed for ensuring safety and enhancing welfare, without an explicit protectionist aim. SPS and TBT in particular, are designed to address public policy concerns. This includes whether a product subject to NTM can be potentially harmful to people, animals, or the environment; if there is a considerable asymmetric information problem; or if it may have other important externalities.

However, in practice, NTMs could be used as protectionist measures and may in fact be perceived as such. This is referred to as the trade protection substitution hypothesis, meaning the use of non-tariff measures as substitutes to import tariffs to protect domestic industries (Hoekman and Nicita, 2011). As the global average tariffs declined around the world in the trade liberalization through unilateral reforms and bilateral and regional trade agreements, NTMs have become more applied as alternative trade policy instruments.

In general, the use of non-tariff measures increased with the level of economic development of countries (Hoekman and Nicita, 2011). High-income countries use disproportionately more NTMs to regulate trade. In the United States, Ray (1981) shows that non-tariff trade restrictions have supplemented tariff protection. Baylis et al. (2011) document that the European Union food import standards significantly impacted trade of seafood products. In this case, it led to clear trade deflection away from the EU markets. The policy substitution hypothesis has also found support in southern Mediterranean countries in Tudela-Marco et al. (2015), where the EU border product path dependence matters.

NTMs may be imposed to protect local industries (Grossman and Helpman, 1994). Political economy determinants of NTMs are considered by Maggi et al. (2019), where tariff liberalization is followed by more frequent use of NTMs as the government compensates for the loss of tariffs. Orefice (2017) finds empirical support for the theoretical result, as governments often impose NTMs on a product after tariff reductions for the product. Both tariff and non-tariff trade restrictions are biased toward industries in which the United States has an apparent comparative disadvantage in world trade and away from industries where consumer welfare losses from protection would be significant.

Both economic and political factors can impact trade policy. Chin et al. (2015) argue that WTO membership, tariff and unemployment have a strong influence on the incidence of NTMs, while the exchange rate, political institution and economic size are not significant factors. Evidence suggests that unemployment and the value added of the agricultural and industrial sectors are associated with the use of NTMs in ASEAN member states (Hirang, 2019).

3.2 NTMs effects on trade

The literature on how NTMs impact trade is large and mixed. The existing literature mainly deals with the direct impact of NTMs on trade, while more recent work turns to the indirect effects and their externalities.

Theoretically, NTMs provide benefits for consumers by enhancing quality and safety, but they also induce costs for producers through imports. On the one hand, NTMs are desired by consumers as they raise trust and confidence in the imported products, which lowers transaction costs by reducing information asymmetry and potential externalities. This increases demand for products and therefore increases export sales (Xiong and Beghin, 2014). In the meantime, increased demand increases the equilibrium price, adding to consumption expenditure. This can dampen the demand. The overall effect on consumer surplus depends on the utility gain through imposing NTMs, and the strength in the consumer preferences for the product under regulation (Crivelli and Groeschl, 2016; Swinnen, 2016).

On the other hand, NTM compliance induces higher production and trade costs. It could raise the producer's fixed costs meeting the needs for upgrading practice codes and facilities, acquisition of certificates, and conformity with marketing requirements. Variable costs might need to go up too in case of prolonged delivery time due to inspection and testing procedures at customs points, rejection of certain shipments, and denial of entry of certain shipments (Xiong and Beghin, 2014; Crivelli and Groeschl, 2016). There is a higher risk of goods refusal at ports which incurs additional costs. All these result in a reduction in profits and supply. The reduced supply increases the equilibrium price and producers' revenue. Thus, the net effect on producers' profits depends on the magnitude of the positive game in revenue, compared to the size of negative implementation costs. The lower the implementation costs, the higher the gain is in revenue.

Then the optimal level of NTMs depends on the trade-off between the marginal utility gain for consumers and the marginal cost for producers. The effects on domestic welfare are determined by the trade strategies of trading partners. Unless the effect of domestic production exactly offsets the effects on domestic consumption, NTMs impact on trade (Swinnen, 2016).

Empirically, the existing evidence on how NTMs impact imports and exports also varies, ranging from NTMs being "standards as catalysts", "standards as barriers", or having no effect. Overall, it is hard to generalize the findings on the NTMs effects. Dolabella (2020) show that the effects of SPS and TBT have a large dispersion over the negative and the positive axis, which means that, these measures not only restrict trade quantities but also promote them on many occasions. The effects usually depend on the type of NTMs, products, countries examined, data, NTM measurement and estimation methodologies employed in the analysis.

3.3 Heterogeneity in NTMs effects

Santeramo and Lamonaca (2019) provides an excellent meta-analysis, reviewing the heterogeneity of NTMs effects depending on specific NTMs, products in question, and country cases. First, the types of NTMs can have different, sometimes opposite effects. Although Sanitary and Phytosanitary Standards (SPS) and Technical Barriers to Trade (TBT) are both used for agri-food products and manufactured goods, the patterns of effects seem to be that SPS effects dominate agri-food products, while TBT dominate manufactured goods. Broadly speaking, TBT tend to be catalysts for trade, while SPS show mixed evidence.

TBT tend to be catalysts for trade (de Frahan and Vancauteren, 2006). Moenius (2004) concludes that country-specific standards of importers promote imports of manufactured goods, contrary to the effect on non-manufactured goods in the agriculture sector. This is because in manufacturing, standards provide additional information about consumers' tastes and market preferences, enabling foreign firms to export more in such import standards imposing countries. Swann et al. (1996) finds that UK standards appear to increase UK exports and imports, though the effect on exports is stronger than on imports. Furthermore, idiosyncratic UK standards appear to have a stronger positive effect than internationally equivalent standards and no significant evidence was found for the notion that idiosyncratic standards negatively affect trade and competition.

Although generally NTMs are considered major barriers to trade of agri-food products (Hoekman and Nicita, 2011), SPS could have either a positive or negative impact on agri-good products (e.g. Schlueter et al., 2009; Jayasinghe et al., 2010; Crivelli and Groeschl, 2016). The divergences of the effects can vary significantly due to the peculiarity of the SPSs (Santeramo and Lamonaca, 2019). In particular, Maximum Residue Levels (MRLs) of pesticides tend to act as barriers to trade (e.g. Otsuki et al., 2001a,b; Chen et al., 2008; Ferro et al., 2015). The evidence is mainly from developing countries' exports. Hejazi et al. (2022) concludes that MRLs on insecticides are the most trade restrictive, followed by herbicides. Nevertheless, the effect of more stringent fungicide MRLs was generally not statistically or economically harmful to trade.

There is heterogeneity in NTMs effect even within agri-food products. Fontagné et al. (2005) classifies three product categories of "sensitive", "suspicious", and "remaining" products, comprising a large share of processed agri-food products. They find that NTMs, including standards, have a restrictive trade impact on agri-food trade, but not on trade in other products. While no significant trade effects exist for suspicious products, negative trade effects are observed for some of the products belonging to the "sensitive products", as well as for some agri-food products) in the group of "remaining products". In addition, Hoekman and Nicita (2011) found that NTMs have a positive effect on trade in more technologically advanced sectors and a negative effect in agriculture.

Countries and sectors of study also matter. Li and Beghin (2012) find that the demand effects of TBT and SPS on the agriculture-food sector are less likely to be positive than other sectors. The larger negative effect on agriculture and food comes mainly from developing countries. Moreover, SPS regulations on agricultural and food trade flows from developing exporters to high-income importers are more likely to be trade-impeding. Anders and Caswell (2009), who investigated the effect of the Hazard Analysis Critical Control Points (HACCP) food safety standard on seafood imports, found the negative effect for exports from developing countries and positive effect for exports from developed countries.

In Ghodsi et al. (2017) more than half of their estimates, used to determine NTMs effect on trade show a negative impact. Furthermore, even though wealthier countries apply more NTMs than poorer countries, there are smaller effects of NTMs for richer countries compared to developing countries. Fontagné et al. (2005) find that OECD agri-food exporters tend to benefit from NTMs, at the expense of exporters from developing and the least developing countries. Similarly, Henson and Loader (2001) indicates that SPS measures are a major factor influencing the ability of developing countries to exploit export opportunities for agricultural and food products in developed country markets. A plausible explanation is that they lack the needed resources to influence the multilateral trade sphere. Dolabella (2020) also find that exporters from least developed countries seem to be the most affected by NTMs.

In addition to trade value and volume, the extensive and intensive margin of trade are also subject of inquiry. Fontagné et al. (2015) show that the imposition of SPS measures reduces the participation of firms in export markets, especially for large exporters. They also show that firm size or other firm's characteristics do not seem to affect the effect of SPS imposition on the intensive margin. Similarly, Ferro et al. (2015) find that stricter MRL regulations have a negative effect on extensive margins of exports, while the effect on intensive margins was not significant.

3.4 NTMs external effects

Beyond trade, there is emerging research on NTM and product quality, price and competition. Khandelwal (2010) and Amiti and Khandelwal (2013) introduce a methodology to measure quality based on trade data. Fan et al. (2015b), Bas and Strauss-Kahn (2015), and Fan et al. (2018b) show that trade liberalization, measured as a reduction in MFN tariffs, leads to export quality upgrading. Movchan et al. (2019) looked at the effect of NTM on exports and found that SPS regulations on inputs in upstream industries lead to exports of better-quality products. Ghodsi and Stehrer (2022) show that TBTs and SPS measures do indeed imply higher quality of traded products. Stringent TBTs with more regulations imposed in each year (i.e. flows of count TBTs) have the largest impact on the quality of traded products. At the same time, mandatory certifications have a negative impact on quality by limiting access of domestic firms to new technologies and equipment.

NTMs have been found positively related to employment growth of the services sector, while negatively related to unemployment and the value added of the agricultural and industrial sectors in the ASEAN member states (Hirang, 2019).

NTMs are likely to have spillovers effect on price and competition in the product market of imported inputs (Amiti and Konings, 2007; Khandelwal and Topalova, 2011; Olper et al., 2017). It is also related to studies that look at the impact of imported inputs on trade at extensive and intensive margins (Halpern et al., 2015). However, we are not aware of many studies that looked at the impact of NTM on exporting at the firm level. This literature is rather scarce. Only recently firm-level studies on the impact of NTM on productivity have emerged. For instance, Shepotylo and Vakhitov (2015) looked at the impact of NTM on productivity of firms in the food-processing industry and found a negative effect on productivity. Given the lower the aggregation of NTMs measures employed, the more likely the results may produce specific implications of the issues of interest (Li and Beghin, 2012), a study of the NTM effect on productivity in the UK allows us to get additional evidence on the impact of NTM on productivity.

3.5 Brexit and trade policy

This paper is also related to Brexit literature. In particular, Dhingra et al. (2017) finds that average effects on the economy are predicted to be negative under soft Brexit and more negative under hard Brexit. Moreover, the negative impacts of Brexit tend to be bigger for areas with higher average wages. While a similar negative effect is found on foreign direct investment (Dhingra et al., 2016). Ramiah et al. (2017) examines the effects of Brexit, relative to what had been anticipated, as measured by abnormal returns (ARs). The results show that the banking, travel and leisure sectors were affected negatively, with a cumulative AR of -15.37 percent for the banking sector. Sampson (2017) concludes that Brexit will make the United Kingdom poorer than it would otherwise have been because it will lead to new barriers to trade and migration between the UK and the European Union. Empirical estimates that incorporate the effects of trade barriers on foreign direct investment and productivity, find costs 2–3 times larger than estimates obtained from quantitative trade models that hold technologies fixed. Breinlich et al. (2017) show that product groups with larger direct and indirect import shares experienced higher inflation after the vote. More recently, Douch and Edwards (2021a,b) analyze the impact of the Brexit announcement shock on service and goods trade and find a significant negative effect of this macroeconomic shock on the UK.

4 Model

This section builds a model to examine the heterogeneous effects on a firm's trade margins of Non-tariff measures (NTMs) imposed on its importing intermediate inputs. Consider an economy where consumers enjoy the consumption of varieties of differentiated goods. As in the model of Melitz (2003), the varieties are produced by a mass of single-product firms, and there is only one production factor, labour. Firms can decide the price p for their varieties to maximise profits. We assume that perceived quality by consumers is a demand shifter that makes consumers willing to purchase relatively large quantities of the variety despite relatively high prices, including intangible attributes such as the brand image.

There is a pool of potential entrants. Firms draw their unit-input requirement, a, after paying a fixed cost, F_D (in labour units), to produce a variety. The unit-input requirement is drawn from a Pareto distribution with its Cumulative Distribution Function (CDF) as $G(a) = a^k$ and its Probability Density Function (PDF) as $g(a) = ka^{k-1}$. At the same time, they draw their product quality, q, which is negatively related to a. Thus, not all firms can cover the entry cost. Firms will enter until the expected profits are equal to the sunk entry cost, F_E (in labour units).

The market is assumed monopolistically competitive. Firms use a unique intermediate input to produce their final goods while the market of intermediate inputs is perfectly competitive. They choose the best input sourced abroad or at home. We assume that producing higher-quality outputs requires higher-quality inputs. The direct mapping of intermediate inputs to outputs is in line with the literature such as Verhoogen (2008), Kugler and Verhoogen (2009) and Manova and Zhang (2012), firms producing higher-quality goods pay more for their intermediate inputs. Assuming that inputs from the home country are more expensive conditional on the quality, all firms source inputs from abroad before imposing the regulations.

The government imposes regulations modelled as a fixed cost of production f (in labour units) for firms that tend to access inputs abroad. The fixed cost represents that firms might have to invest in production equipment or change procedures to comply with checks at borders or required certificates. In this way, only productive firms find importing inputs more profitable, and less productive firms choose domestic inputs. Therefore, the regulations intensified the market competition, forcing the least productive firms that produce products with the lowest quality to exit the market. Less productive firms have to charge higher prices to cover the cost, thus, they can sell fewer products and earn less revenue. In contrast, the market share is reallocated to more productive firms that charge the same prices contributing to more revenue.

4.1 Demand

Consider one country consisting of a continuum of consumers. Consumers have the standard Constant Elasticity of Substitution across varieties (CES). The consumer utility is given by

$$U = \left[\int_{i \in \Omega} (\frac{q_i}{q_D})^{\frac{1}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where c_i is the quantity consumed of a variety i,[4] q_i is the production quality and q_D is the least quality in the market. It is difficult for consumers to perceive the same product quality as producers provide mentioned in the literature, like Yue (2022). Consumers value the perceived quality or the relative quality (i.e., $\frac{q_i}{q_D}$ in our model) rather than the production quality of a product. σ is the elasticity of substitution across varieties ($\sigma > 1$), and Ω is the set of varieties available for consumption.

Consumers maximise their utility, subject to the budget constraint,

$$\int_{i \in \Omega} p_i c_i di < E \tag{2}$$

where E represents the aggregate expenditure on products. The quantity demanded of each variety can be derived as,

$$x_i = \frac{p_i^{-\sigma} (\frac{q_i}{q_D})}{P^{1-\sigma}} E \tag{3}$$

where P indicates the aggregate price index,

$$P = \left[\int_{i \in \Omega} p_i^{1-\sigma} (\frac{q_i}{q_D}) di \right]^{\frac{1}{1-\sigma}} \tag{4}$$

4.2 Intermediate-input sector

Each variety in the final good sector is produced by a unique firm in a monopolistically competitive environment. To produce, firms can choose either domestic or imported intermediate inputs. The intermediate input is assumed to be produced in a perfectly competitive environment using the labour, L. We normalise domestic income to 1 while foreign income is ω with $\omega < 1$. Higher-quality inputs require more resources in production. More precisely, the production function of intermediate

[4] i also denotes firms as each variety is produced by only one firm.

input can be expressed as follows,

$$y_{mi} = \frac{L}{q_{mi}} \tag{5}$$

where q_{mi} indexes the quality of intermediate inputs.

In a perfectly competitive environment, the price of intermediate inputs equals the average cost,

$$p^D_{mi} = q_{mi} \tag{6}$$

$$p^F_{mi} = \omega q_{mi} \tag{7}$$

The above equations show that imported inputs feature a lower price conditional on the same quality level compared to the domestic inputs. Thus, all firms import inputs in the absence of barriers to imported intermediate inputs.

4.3 Quality and price

Firms are assumed heterogeneous in production ability, a_i (the number of intermediate inputs required for one unit of final good), and the quality of final outputs is negatively related to a_i (i.e., more productive firms produce higher-quality final goods[5]).

$$q_i = a_i^{\theta} \tag{8}$$

where $\theta < -1$, indicating that differences in firm production efficiency lead to more noticeable differences in their choices for product quality.

In line with the literature, we also assume a positive relationship between the quality of inputs and the quality of a firm's final product. This means that producing higher-quality final outputs requires higher-quality inputs. For simplicity, we assume that the quality of inputs maps the quality of a firm's final product one to one, i.e. $q_{mi} = q_i$.

Given that all firms choose imported inputs, profit maximisation implies the equilibrium price

[5] This assumption is in line with the literature, for example, Verhoogen (2008) and Baldwin and Harrigan (2011).

of final outputs, which equals a constant mark-up over marginal cost,

$$p_i = \frac{\sigma}{\sigma - 1} p^F_{mi} a_i \tag{9}$$

We can further substitute the foreign-input price expression, Equation (7), and express the price function as, $p_i = \frac{\sigma}{\sigma-1}\omega a_i^{1+\theta}$. $\theta < -1$ indicates that more productive firms choose higher-quality inputs, produce higher-quality outputs and charge higher prices. Firms charge higher prices due to the high production cost of using high-quality inputs. At the same time, economies of scale result in a decrease in marginal costs and ultimately lead to lower prices. In the end, the impact of input quality is dominant and thus, productive firms charge higher prices for their final products.

Therefore, we can express the operating profits of a firm as follows:

$$\pi_i = \frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E(\omega a_i^{1+\theta})^{1-\sigma} (\frac{a_i}{a_D})^{\theta} - F_D \tag{10}$$

If $(1-\sigma)(1+\theta)+\theta < 0$, more productive firms can earn more profits. Otherwise, less productive firms earn more profits. In our model, there will be no positive solution for the unit-input threshold, a_D, under the second condition. This does not make good sense considering the perceived quality is linked to the threshold (i.e., the least quality will be negative). Thus, our model develops under the first condition assuming that $(1-\sigma)(1+\theta)+\theta < 0$. More productive firms use higher-quality inputs to produce higher-quality outputs, and thus they charge higher prices for their outputs gaining more profits.

The firm produces in the market if its revenue at least covers the fixed production costs, i.e., $\pi_i \geq 0$. This defines the zero-profit condition of the unit-input threshold, a_D, as follows:

$$\frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E(\omega a_D^{1+\theta})^{1-\sigma} = F_D \tag{11}$$

4.4 Free entry

After the entry, firms draw their unit-input requirement for one unit of the final output, a_i, from a distribution, $g(a)$. Firms then face a natural death rate each period, δ.[6]

[6] The assumption that the probability of death is independent of firm characteristics follows Melitz (2003) and Bernard et al. (2007).

Since all incumbent firms earn positive profits, the expectation of future positive profits motivates new firms to take the fixed costs, F_E (in labour units), for entry. Entrants will enter the market until the expected entry value equals the entry fixed costs. If the value is less than the costs, no firm would want to enter. The free entry condition is defined as follows:

$$EV(\frac{\pi_i}{\delta}) = F_E \tag{12}$$

where $EV(\frac{\pi_i}{\delta})$ is the expected discounted flow of profits of a prospective entrant.

We assume that the random variable, a_i, follows a Pareto distribution with density function, $g(a) = ka^{k-1}$ and cumulative distribution function, $G(a) = a^k$ where k is the shape parameter.[7] Thus, we can express the threshold as:

$$a_D^k = \frac{\delta F_E}{F_D} \frac{(1-\sigma)(1+\theta)+\theta+k}{(\sigma-1)(1+\theta)-\theta} \tag{13}$$

To ensure a positive solution for the unit-input threshold, we assume that $(1-\sigma)(1+\theta)+\theta+k > 0$.

4.5 Introducing NTMs

We model the regulations imposed by the government on imported inputs as an additional fixed cost, F (in labour units), that firms have to pay to access imported inputs. Supposing importing requires to go through certification, firms might have to invest in production equipment or change procedures, which are fixed. In this sense, not all firms can afford to import inputs now. Thus, two types of firms (Type 1: using domestic inputs and Type 2: using imported inputs) will be considered in this section. We use subscripts 1 and 2 to differentiate the variables of two types of firms. We assume that there is no tariff and focus on the effects of the NTMs. The prices charged by firms can be expressed, respectively, as follows:

$$p_1 = \frac{\sigma}{\sigma-1} p_{mi}^D a_i \tag{14}$$

$$p_2 = \frac{\sigma}{\sigma-1} p_{mi}^F a_i \tag{15}$$

[7]Following this assumption, commonly used in the literature, we can obtain closed solutions for key variables, for example, the unit-input threshold.

The profit functions are as follows:

$$\pi_1 = \frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E a_i^{(1+\theta)(1-\sigma)} (\frac{a_i}{a_1})^{\theta} - F_D \tag{16}$$

$$\pi_2 = \frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E (\omega a_i^{1+\theta})^{1-\sigma} (\frac{a_i}{a_1})^{\theta} - F_D - F \tag{17}$$

where a_1 denotes the market unit-input threshold.

After the government impose regulations, firms compare the profit difference between using domestic and imported inputs,[8]

$$\pi_2 - \pi_1 = \frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E a_i^{(1+\theta)(1-\sigma)} (\frac{a_i}{a_1})^{\theta} (\omega^{1-\sigma} - 1) - F \tag{18}$$

The zero-profit condition of the market unit-input threshold, a_1, can be defined, as follows:

$$\frac{(\frac{\sigma}{\sigma-1})^{1-\sigma}}{\sigma P^{1-\sigma}} E a_1^{(1+\theta)(1-\sigma)} = F_D \tag{19}$$

We can also define an equal-profit condition for firms with a unit-input threshold for importing inputs, a_2, finding no difference between using domestic or imported inputs, i.e., $\pi_2(a_2) - \pi_1(a_2) = 0$. With the zero-profit condition, i.e., Equation (19), the relationship between two thresholds is expressed as follows:

$$(\frac{a_2}{a_1})^{(1+\theta)(1-\sigma)+\theta} = \frac{F}{F_D} \frac{1}{\omega^{1-\sigma} - 1} \tag{20}$$

There would be two potential situations after introducing the NTMs. Under the first condition, the fixed cost, F, is insignificant. All surviving firms find it more profitable to source inputs from abroad. Under the second condition, only some productive firms can cover the fixed cost and import inputs, while others turn to domestic inputs. Our model focuses on the second one, which is more complicated and interesting to explore. Thus, we have to assume a relatively significant F that $F > (\omega^{1-\sigma} - 1)F_D$ to ensure $a_2 < a_1$.

Free entry condition, i.e. Equation (12), can be redefined. With Equation (19) and Equation

[8] We carefully checked the first-order condition of the difference between profit functions (i.e., Equation (18)). $\frac{\partial(\pi_2 - \pi_1)}{\partial a_i} < 0$ ensures that more productive firms prefer to choose imported inputs.

(20), two thresholds can be obtained as follows:

$$a_1^k = \frac{\delta F_E}{F_D}\frac{(1-\sigma)(1+\theta)+\theta+k}{(\sigma-1)(1+\theta)-\theta}[1+\frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma}-1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}]^{-1} \tag{21}$$

$$a_2^k = \frac{\delta F_E}{F}\frac{(1-\sigma)(1+\theta)+\theta+k}{(\sigma-1)(1+\theta)-\theta}[1+\frac{F_D}{F}[\frac{F_D}{F}(\omega^{1-\sigma}-1)]^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}]^{-1} \tag{22}$$

The introduction of NTMs has intensified market competition, given a clear relationship between two market unit-input thresholds, $a_1 < a_D$. Demands for firms, perceived quality of products and firms' revenue change accordingly.

4.6 Proposition

Specific to our model, is how the NTMs implication affects the firm's trade margins. This is described in the following propositions.

Proposition 1. The introduction of NTMs intensifies market competition (i.e., $a_1 < a_D$).

Proof: See Appendix

The introduction of NTMs intensifies market competition since some firms (less productive ones) do not find importing inputs affordable after. They have to turn to using domestic inputs which are more expensive compared to the imported ones conditional on the quality. Increasing production costs force the least productive firms (i.e., firms with a_i where $a_1 < a_i < a_D$) to exit the market. Less productive firms (i.e., firms with a_i where $a_2 < a_i < a_1$) decide to use the domestic inputs. More productive firms (i.e., firms with a_i where $a_i < a_2$) continue to import inputs.

Proposition 2. Less productive firms charge a higher price, while more productive firms charge an unchanged price after the introduction of NTMs (i.e., $p_1 < p_i$ and $p_2 = p_i$).

Proof: See Appendix

Price is only related to one firm's production marginal cost in our model, which is based on both firm's unit-input requirement and inputs. The unit-input requirement is assumed to be fixed for firms, so only inputs can impact the price. Less productive firms cannot afford the cost to access imported inputs and turn to domestic inputs. This increases the production marginal cost as domestic inputs are more expensive. In the end, they have to transfer part of the increased costs to consumers and charge a higher price. In contrast, more productive firms pay the cost and access imported inputs as before. They thus charge unchanged prices as the production marginal cost is unchanged.

Proposition 3. Less productive firms sell a smaller amount of quantity, while more productive firms sell a larger amount of quantity after the introduction of NTMs (i.e., $x_1 < x_i$ and $x_2 > x_i$).

Proof: See Appendix

Given Equation (3) where the total expenditure, E, is unchanged, one firm's demand is impacted by three factors, prices charged by firms, the perceived quality of its product and the price level of markets. A higher price discourages consumers from purchasing more products. However, a higher perceived product quality and a higher price level will attract consumers to buy the product more.

Less productive firms charge a higher price while the perceived quality of their products is becoming lower as the minimal production quality becomes higher. However, the price level increased after imposing the regulations driven from Equation (4). Taken all these together, a negative impact on quantity sold by less productive firms can be derived.

More productive firms charge the same price as before, while the perceived quality of their products becomes lower as well. However, the price level has increased. Taken all these together, a positive impact on quantity sold by more productive firms can be derived based on some assumptions about parameters. This means that the introduction of NTMs reallocates the market share in terms of quantity from the least and less productive firms to more productive firms.

Proposition 4. Less productive firms gain less revenue, while more productive firms gain more revenue after the introduction of NTMs (i.e., $r_1 < r_i$ and $r_2 > r_i$).

Proof: See Appendix

Revenue is calculated as the price multiplied by the quantity. Less productive firms gain less revenue as they sell less quantity, although they charge a higher price. In contrast, more productive firms earn more revenue by selling more quantity. This is due to the reallocation of market share.

5 Empirical strategy and identification

5.1 Ad valorem equivalents of NTMs

A binary NTM measure which takes the value of 1 if there is an NTM and 0 otherwise does not capture the stringency of the NTM, treating all of them as equally important. It is unlikely that a technical standard on the fuel efficiency of a car has a similar impact on exports as the requirement to properly label the car components. Even the same technical standard can be applied differently across countries. As a result, the same TBT may have a different impact on trade in two different countries.

To bring different NTMs to the common denominator, we introduce the idea of an equivalent tariff, that would lead to the same quantitative effect on trade as the NTM. The method, was implemented by Kee et al. (2009) and further developed in Kee and Nicita (2016). For the analytical derivation of the ad valorem equivalents of non-tariff measures, please look at the appendix. In what follows we describe the empirical implementation.

Estimation

Consider the global trade in sector s of a variety h from country p to country c. We estimate the following equation:

$$q_{hcp} = \exp(\gamma_{hcp}^{NTM} NTM_{hcp} + \gamma_{hcp}^{t} t_{hcp} + \gamma^{PTA} PTA_{cp} + Z_{cp}\gamma^{Z} D_{hc} + D_{hp}) + \epsilon_{hcp} \tag{23}$$

where

$$\beta_{hcp}^{NTM} = \beta_{h}^{NTM} + \beta_{h}^{NTM} PTA_{cp} + \beta_{1}^{NTM} share_{hc} + \beta_{2}^{NTM} share_{hp} \tag{24}$$

and

$$\beta_{hcp}^{t} = \beta_{h}^{t} + \beta_{1}^{t} share_{hc} + \beta_{2}^{t} share_{hp} \tag{25}$$

.

In this specification, Z_{cp} includes distance and contiguity. This specification does not include bilateral fixed costs, as is common in the estimation of the structural gravity. However, it is possible to control for all time-invariant bilateral fixed effects if the model is estimated on a panel.

Computing AVE NTMs

Once we estimate the model (23), we obtain the estimates β_{hcp}^{NTM} and β_{hcp}^{t} for all product lines h. To compute ad valorem equivalent of an NTM, we need to find the level of tariff t_{hcp} that would impact trade by the same amount as the NTM.

The proportionate change in trade due to an NTM is defined as

$$\frac{E(q_{hcp}|NTM_{hcp}=1)-E(q_{hcp}|NTM_{hcp}=0)}{E(q_{hcp}|NTM_{hcp}=0)}=\exp(\beta_{hcp}^{NTM})-1 \tag{26}$$

Likewise, the proportionate change in trade due to an increase in tariff by 1 percentage point equals

$$\frac{E(q_{hcp}|t_{hcp}=t+1)-E(q_{hcp}|t_{hcp}=t)}{E(q_{hcp}|t_{hcp}=t)}=\exp(\beta_{hcp}^{t})-1 \tag{27}$$

Finally, AVE NTM is defined as an equivalent tariff that has the same impact on imports as NTM

$$AVE_{hcp}=\frac{\exp(\beta_{hcp}^{NTM})-1}{\exp(\beta_{hcp}^{t})-1} \tag{28}$$

5.2 Measuring quality

Export quality

We compute a firm-product quality measure that varies with time, following the methodology developed by Khandelwal et al. (2013). To fix the notation, consider the structure of the UK exports. Each UK company operates in an industry S, defined as a five-digit SIC industry, which is mapped to 4-digit HS products denoted by h (Feenstra et al., 2002, see). The model is estimated separately for each sector S, so we suppress the index S in further notation. A firm f produces a variety of the product h, defined as fh. Each variety has horizontal and vertical attributes. The horizontal attribute defines the type of product, such as a cotton shirt or silk shirt. The vertical attribute distinguishes the quality of shirts produced by firms f and f' (i.e. Marks & Spenser shirt vs Primark shirt).

The methodology is based on a nested logit demand system (Berry, 1994), which is more flexible than a nested CES demand system. The demand derived from the nested logit is as follows

$$\ln s_{fht} - \ln s_{ot} = \lambda_{fh} + \lambda_t - \alpha p_{fht} + \sigma \ln vs_{fht} + \lambda_{fht} \tag{29}$$

where s_{fht} is firm f product h share in the sector at time t, vs_{fht} is its share in product h. p_{fht} is the price of the variety fh proxied by a unit price. Finally, s_{ot} is the share of the outside option, representing products produced by the same sector in the rest of the world. It is measured as the share of export of sector S in the rest of the world divided by the total export of sector S worldwide at time t.

Quality is defined as follows:

$$\Lambda^{EX}_{fht} = \lambda_{fh} + \lambda_t + \lambda_{fht} \tag{30}$$

It has three components. Time invariant quality attribute of company f variety h, secular trend of all varieties in sector t, and time-varying component which captures random shocks to consumer tastes, which are unobservable by the statistician.

Import quality

The methodology of estimation of import quality differs in two fundamental ways. First, we consider imports by the UK firms, so instead of modelling demand based on consumer preferences, we start with the demand for intermediate inputs derived from production technology. Second, we do not observe imports as varieties produced by specific firms. We have more aggregate information on the source country of imports, denoted as c. Therefore, the imported variety is defined as ch, such as French cheese vs Belgian cheese. In other respects, the methodology is based on the same approach. ???

We estimate the following equation

$$\ln s_{cht} - \ln s_{ot} = \lambda_{ch} + \lambda_t - \alpha p_{cht} + \sigma \ln vs_{cht} + \lambda_{cht} \tag{31}$$

where s_{cht} is country c product h share of imports in the sector at time t, vs_{cht} is its share in product h. p_{cht} is the price of the variety ch proxied by the unit price. Finally, s_{ot} is the share of the outside option, representing products produced by the same sector in the UK. It is measured as one minus import penetration of sector S in the UK at time t. It represents all domestic varieties that are available to substitute for imported varieties.

Quality is defined as follows:

$$\Lambda_{cht}^{IM} = \lambda_{ch} + \lambda_t + \lambda_{cht} \tag{32}$$

5.3 Measuring NTM at firm level

A firm purchases imports in order to produce and sells exports. Its imports are subject to the UK non-tariff measures (Input NTM) and its exports are subject to the destination country non-tariff measures (Output NTM). In this subsection, we discuss how to construct those measures using the information on the sector of the economy the firm operates in, AVE NTMs of UK and reporting country, and the type of product the firm is exporting.

Following common practice in the literature, we construct input NTMs that vary across sectors of the economy and over time. Our definition of a sector is UK Standard Industrial Classification (SIC) 2007, 5-digit sub-class categories. The underlying assumption is that all firms within a sector s use similar technologies and require similar inputs, hence they are subject to the same regulatory policy, which is exogenous from the firm's viewpoint. The fact that some firms use imported inputs, while others use local inputs reflects their endogenous decisions due to firm-level heterogeneity.

Input NTM of type k, where $k = \{A, B, C, E\}$ for sector s at time t are computed as

$$InputNTM_{st}^{k} = \sum_{p} \sum_{h} w_{shp}^{2011} \times AVE_{hUKp,t}^{k} \tag{33}$$

where $AVE_{hUKp,t}^{k}$ is the UK AVE NTM measure of type k for product line h that at time t applied against the importer from country p. w_{shp}^{2011} is a weight, which equals to the share of the value of imported inputs of product line h from country p in the total imported inputs used by sector s in production in 2011. To define those values, we use 2011 import data as reported by all firms and aggregate them to the level of sectors s. The reason that we use the data for the period before the investigated period of 2012-2018 is to avoid the endogeneity problem when the sector endogenously responds to any changes in trade policy and adjusts its technology. If we ignore those endogenous adjustments, our identification and estimation would confound the impact of NTMs on exports and the impact of endogenously changed import shares on exports.

This measure of trade policy impact on a firm fits into large and developing literature of shift-share variables, where a policy variable interacts with the measure of its intensity and the variable of interest is regressed on the shift-share variable (Adão et al., 2019; Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020). In particular, Borusyak et al. (2022) have shown that the assumption on the exogeneity of shares can be relaxed if the policy measures are assigned as good as at random. At the same time, Goldsmith-Pinkham et al. (2020) demonstrate the estimated coefficients are consistent when the exposure shares are exogenous. These results give us more confidence in our results, as our exposure measures are constructed using the period before the investigated sample and at the sector level, rather than at the firm level, which makes them exogenous from the point of view of a firm.

Our measure of the output NTM is defined as

$$OutputNTM^{k}_{hct} = AVE^{k}_{hcUKt} \tag{34}$$

where AVE^{k}_{hcUKt} is the AVE NTM measure of type k that is applied by country c against exports from the UK for product line h that at time t.

5.4 Estimated export regressions

For the dependent variable, we look at export quantity q in kilograms, export value v in USD, and export price, proxied by the unit price, defined as $p_{EX,fhct} = v_{fhct}/q_{fhct}$, and export quality $\Lambda^{EX,fhct}$. A unit of analysis is a firm f, exporting product h, to the country c, at time t. Our main variables of interest are $InputNTM^{k}_{st}$ and $OutputNTM^{k}_{ht}$, which measure the intensity of various types of NTMs applied to a product of 4-digit HS category h at time t imposed by an importing country on UK exports:

$$\ln(y_{fhct}) = \beta_{InNTM} InputNTM^k_{st} + \beta_{OutNTM} OutputNTM^k_{hct}$$
$$+X\gamma + D_{ct} + D_f + D_{ht} + \varepsilon_{fhct} \quad (35)$$

Controls include firm employment and productivity. We also control for unobserved firm heterogeneity by adding a trader-fixed effect.[9] Source market characteristics and bilateral trade costs are controlled by including source country-time fixed effects, D_{ct}, which also capture global shocks to trade. D_{ht} is the product-trend fixed effect that captures the heterogeneity of various goods and their differences in units of measurement (i.e. ingredients vs equipment). Finally, ε_{fhct} is an error term.

6 Data

Data for this study comes from several sources. We have already discussed NTM data and the constriction of Input and Output NTMs, which are the main variables of interest. In this section, we discuss sources of export and import data and firm-level data, which we use to calculate the main dependent variables, such as value, quality, price, and quality of exports.

6.1 Trade data

Customs transaction data are available from HMRC. It is collected separately for EU and non-EU countries at monthly frequencies at the level of the national 8-10 digit products. We combine the EU and non-EU data and aggregate it to the annual frequencies at HS 4-digit products. The unit of observation is the export of firm f to country c of product h in year t.

We identify the type of exported product according to the Broad Economic Categories 5th revision (BEC) classification and categorize goods as consumer, intermediate and capital goods. We also keep track of whether the destination country is within the EU or not.

[9] In most cases a trader is matched with a firm. However, in some cases, one firm is matched with many traders. In rare cases, one trader is matched with many firms. We discuss data management in the next section.

6.2 Firm level data

The Business Structure Database (BSD), which is the snapshot of Inter-Departmental Business Register (IDBR), was used for information on the sector, size and productivity. The BSD data were merged with the customs transaction data. The matching between the trader and firm identifiers can be one-to-one, many-to-one and one-to-many. In the case of one-to-one and many-to-one, we apply the employment and productivity data of the firm to the corresponding one or many traders. However, in the case of one trader having many firm identifiers, we apportion the export data to many firms using the shares according to each firm employment.

6.3 Summary stats

Summary stats for the full sample and for each type of goods is reported in Table 2. We had 4.6 million observations in 2012-2018. 61.5% of exports go to EU countries. The average rate of SPS applied to UK exports is equivalent to a 7.5% tariff. The average TBT is 40.8%, the average inspection is 1.1%, and the average licensing is 18.2%. In terms of inputs, the UK firms are facing 3.9% SPS, 20.7% TBT, 0.1% Inspection, and 9.8% Licensing.

UK firms exported 1.982 million consumer goods, 68.1% of which went to the EU countries. Firms producing consumer goods are larger than the sample average. They faced a higher level of protection: 10.1% Output SPS, 44.9% Output TBT, and 22.3% Output Licensing, which are rates higher than for the overall sample. However, in terms of production, consumer goods exporters do not face considerably higher input NTMs.

UK firms exported 1.249 million intermediate goods and 0.350 million capital goods, 50% of which went to the EU countries. Firms producing intermediate and capital goods are smaller than average. They also face lower-than-average levels of NTMs when exporting goods. In terms of their inputs, we do not observe significant deviation from the sample average.

Table 2: Summary statistics for the full sample

	Mean	**SD**	**N**	**Mean**	**SD**	**N**
Variables		**All**			**All Consumer goods**	
EU Export	0.615	0.487	4.646e+06	0.681	0.466	1.982e+06
Output SPS	0.0754	0.242	4.646e+06	0.101	0.290	1.982e+06
Output TBT	0.408	0.669	4.646e+06	0.449	0.746	1.982e+06
Output Inspection	0.0107	0.0544	4.646e+06	0.0105	0.0559	1.982e+06
Output Licsencing	0.182	0.370	4.646e+06	0.223	0.408	1.982e+06
Input SPS	0.0388	0.0765	4.646e+06	0.0499	0.0969	1.982e+06
Input TBT	0.207	0.139	4.646e+06	0.194	0.149	1.982e+06
Input Inspection	0.00132	0.00295	4.646e+06	0.00104	0.00235	1.982e+06
Input Licensing	0.0979	0.0908	4.646e+06	0.101	0.102	1.982e+06
Quality	-1.092	3.527	4.569e+06	-0.109	3.444	1.962e+06
Log employment	3.093	1.841	4.646e+06	3.194	1.971	1.982e+06
Log labour productivity	5.215	1.056	4.646e+06	5.230	1.083	1.982e+06
Log export value	8.116	2.776	4.646e+06	7.827	2.829	1.982e+06
Log export quantity	4.385	2.971	4.577e+06	4.384	2.926	1.964e+06
Log export price	3.731	2.108	4.577e+06	3.438	1.979	1.964e+06
Sample		**All Intermedaite Goods**			**All Capital Goods**	
EU Export	0.497	0.500	1.249e+06	0.503	0.500	349,726
Output SPS	0.0315	0.157	1.249e+06	0.00956	0.0711	349,726
Output TBT	0.395	0.596	1.249e+06	0.350	0.574	349,726
Output Inspection	0.0117	0.0547	1.249e+06	0.0218	0.0709	349,726
Output Licsencing	0.159	0.318	1.249e+06	0.135	0.245	349,726
Input SPS	0.0275	0.0545	1.249e+06	0.0212	0.0349	349,726
Input TBT	0.222	0.134	1.249e+06	0.207	0.140	349,726
Input Inspection	0.00152	0.00323	1.249e+06	0.00215	0.00472	349,726
Input Licensing	0.0910	0.0755	1.249e+06	0.0935	0.0715	349,726
Quality	-1.840	3.098	1.230e+06	-1.992	2.070	345,527
Log employment	2.923	1.701	1.249e+06	2.893	1.739	349,726
Log labour productivity	5.183	1.038	1.249e+06	5.243	1.138	349,726
Log export value	8.581	2.542	1.249e+06	8.922	2.535	349,726
Log export quantity	4.119	2.825	1.232e+06	4.535	2.931	346,112
Log export price	4.468	2.104	1.232e+06	4.396	2.249	346,112

7 Results

7.1 Baseline Results

Our analysis begins with estimating the impact of NTMs of different types imposed on inputs (imports) and outputs (exports) on firms' export margins as described in equation (35). The baseline results are presented in Table 3. On average for overall firms, Input NTMs do not seem to have a statistically significant impact on a firm's export value and quantity margins. We find evidence that SPSs imposed on imported inputs have a negative and significant effect on export prices. Further, TBT measures imposed on inputs have a negative and significant impact on the quality of exports. This suggests that technical restrictions on imported goods are likely to restrict technology adoption and upgrading for production, which ultimately reduces productivity premium for exporting. A good example is import restrictions imposed on machinery and equipment. This is largely consistent with some existing evidence on mandatory certification Ghodsi and Stehrer (2022).

Compared to Input SPSs, Output SPSs measures play a more prominent role in affecting export margins. As expected, the four types of SPSs have different effects. For overall firms, Output SPS has a negative and significant effect on export value, price and quantity. Consistent with the findings in the literature, this suggests that SPSs imposed on exported goods resemble additional trade costs (Xiong and Beghin, 2014; Crivelli and Gröschl, 2016), and therefore higher trade costs lead to lower export value and quantity. Interestingly though, increased SPSs do not raise prices, implying that additional costs are likely absorbed by producers or exporters.

Output SPS and Output TBT both have a positive and significant effect on the quality of UK exports, implying these measures are likely to encourage producers to improve the quality of products for exporting in the face of raised trade barriers of SPS and TBT. This is consistent with some existing evidence Fan et al. (2015a, 2018a).

By contrast, Inspection and Licensing almost work in a reversed way. Inspections of UK exported goods make the products significantly more expensive and reduce quantity exported. Licensing, on the other hand, significantly increases price and quantity. Both measures are associated with higher export values. Since licensing NTMs also include quantitative restrictions, it indicates that conditional on the fact that a firm exports, it exports more at intensive margins to the markets that are more heavily protected against foreign competition. Importantly, both inspections and licensing have a negative impact on quality of the UK exports.

In summary, increased Output SPSs reduce exports, while Output inspection and licensing increase exports. Output SPSs and TBTs improve the quality of exported goods, while Output inspection and licensing achieve the opposite effect on quality. Licensing seems to push up export quality with higher prices, while Inspections raise prices but lower export quantity, presumably due to weakened demand.

Table 3: Non-tariff measures and export margins

	(1)	(2)	(3)	(4)
Dependent variable:	Value	Price	Quantity	Quality
Input NTM				
SPS	0.148	-0.231**	0.353	0.0508
	(0.237)	(0.111)	(0.238)	(0.172)
TBT	0.0136	0.0887	-0.0796	-0.104*
	(0.0835)	(0.0638)	(0.0709)	(0.0572)
Inspections	-0.324	0.654	-1.225	-0.756
	(1.349)	(0.968)	(1.393)	(1.109)
Licensing	-0.0395	0.0441	-0.0639	0.0210
	(0.115)	(0.0849)	(0.114)	(0.0917)
Output NTM				
SPS	-0.221***	-0.159***	-0.0599**	0.388***
	(0.0397)	(0.0240)	(0.0277)	(0.0378)
TBT	-0.00860	0.00217	-0.00924	0.0378***
	(0.00934)	(0.00428)	(0.00866)	(0.0109)
Inspections	0.163***	0.330***	-0.168***	-0.872***
	(0.0445)	(0.0300)	(0.0493)	(0.112)
Licensing	0.141***	0.0403***	0.103***	-0.0399**
	(0.0143)	(0.00839)	(0.0145)	(0.0168)
Log of employment	0.0266***	-0.0172**	0.0457***	0.00303
	(0.00830)	(0.00872)	(0.0106)	(0.00552)
Log of productivity	0.0129*	-0.000249	0.0136*	-0.00235
	(0.00761)	(0.00459)	(0.00787)	(0.00448)
Observations	4,645,515	4,576,519	4,576,519	4,568,351
R-squared	0.436	0.664	0.465	0.261
Trader FE	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.2 Firm Heterogeneity

Input NTM

Next, we move to firm heterogeneity in the impact of trade policy following the Melitz model and abundant empirical studies (Goldberg and Pavcnik, 2016; Costinot et al., 2020; Haaland and Venables, 2016). We explore the heterogeneous impact of input NTMs across exporters of different sizes. We calculate size quartiles for each exporter based on total exports in a given year and interact them with input NTMs. The interaction terms are added to the model (35). The results are presented in Table 4, which only reports the coefficients of the interaction terms.

What becomes immediately clear is that size matters. We first look at the heterogeneous effects of Input SPS on value, price, quantity and quality of exports for micro (1st Quartile) through large (4th Quartile) exporters. We notice that the overall negative effect of SPS observed in the results reported earlier is driven by micro and small exporters. Large exporters experience the opposite, a positive effect on the export value and quantity as a result of higher Input SPS. There is no significant effect of Input SPS on export quality. In other words, more protection against imports leads to a significant reduction in export values for micro and small firms. Furthermore, this reduction of export values for micro-sized firms is due to selling goods at lower prices and lower quantities due to the increase in Input SPS. Whereas large firms raise the quantity of the goods they export, and therefore export more in value. Raised Input SPS do not affect the quality of products for firms of any size.

Similarly, for the impact of Input TBT we see similar patterns with that of Input SPS measure. Negative and larger effects are felt by micro and small exporters, while positive and increasing are for larger firms. Further, higher Input TBT has a negative and statistically significant impact on the quality of exports of micro and small firms. This is not the case for larger firms as raised Input TBT have no impact on the quality of exports.

The overall picture of Input NTMs appears that micro and small firms export less in quantity when experiencing higher Input TBT, while maintaining the same price as before. As a result, smaller firms export less in value. It is likely that smaller firms are unable to adapt to higher technical requirements of the higher TBT measure which usually needs investment for technology upgrading. In comparison, capable of allocating resources to adapt to higher Input TBT specifications, larger exporters are in a better position to sustain their exports. Medium-sized exporters may not be able to raise prices, but by selling more, they end up exporting more in value. Large firms are in an even better position, by not only exporting more in quantity but also raising price. This leads to an emphatic advantage in higher export extensive margin. It is possible that large firms can achieve this outcome by transferring additional costs of meeting TBT requirements to customers, possibly due to market power.

What is really interesting is how exporters of different sizes respond to increased Input TBT with quality change. Medium and large exporters do not improve product quality as a result of higher Input TBT. In contrast, micro and small firms respond to increased Input TBT with lowering quality, reflecting the adjustment in the market positioning strategy of small firms.

Moreover, the effect of Inspections and Licensing measures show somewhat similar results. The overall patterns of negative impact on trade margins discussed above for all firms tend to be more pronounced among micro and small firms. More specifically, there is a statistically significant and highly negative effect on export value and export quantity among micro and small-size firms and a positive effect on medium and large companies. They also have a negative and significant impact on the quality of exports for micro firms. Looking at export values, quantity and quality the coefficients are much larger when compared to the previous two measures and significant at 0.01 percent level. Micro-size firms' exports drop significantly in response to the higher inspection. The large negative effect on export values in response to higher inspection on inputs is accompanied by a large decrease in the quantity of products supplied, i.e. lower quantity, and of lower quality when inspection measures become more strict. Medium and large firms see large positive coefficients on their export values, and this is accompanied by an increase in export quantities.

Taken together, the results suggest significant negative effects of input NTMs on micro and small firms on export value and quantity, while the positive effects on medium and large companies. Nevertheless, little effect is estimated on the price of goods exported. While an increase in TBTs, Inspection and Licensing affect negatively the quality of exported goods of small exporters mainly.

Output NTMs

We further explore the heterogeneity of the impact of Output NTMs across exporters of different sizes. Again, exporter size plays an important role in the heterogeneity of the effect of Output

Table 4: Export size and Input NTM

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:		Value				Price		
Type of Input NTM:	SPS	TBT	Inspection	Licensing	SPS	TBT	Inspection	Licensing
Micro (1st Quartile)	-1.926***	-1.184***	-16.82***	-1.975***	-0.259**	0.0214	0.173	-0.0711
x Input NTM	(0.179)	(0.0864)	(2.259)	(0.123)	(0.124)	(0.0529)	(1.087)	(0.0810)
Small (2nd Quartile)	-0.362**	-0.204**	2.235	-0.344***	-0.127	0.0459	0.913	0.0288
x Input NTM	(0.158)	(0.0805)	(1.869)	(0.117)	(0.116)	(0.0565)	(1.487)	(0.0841)
Medium (3rd Quartile)	0.317	0.375***	9.329***	0.495***	-0.0629	0.0857	1.134	0.102
x Input NTM	(0.203)	(0.103)	(2.139)	(0.132)	(0.113)	(0.0650)	(1.637)	(0.0822)
Large (4th Quartile)	1.603***	1.005***	12.99***	1.397***	-0.0207	0.112**	2.980	0.0977
x Input NTM	(0.310)	(0.103)	(4.791)	(0.177)	(0.130)	(0.0558)	(2.941)	(0.0872)
Observations	4,645,515	4,645,515	4,645,515	4,645,515	4,576,519	4,576,519	4,576,519	4,576,519
R-squared	0.437	0.437	0.437	0.437	0.664	0.664	0.664	0.664
Trader FE	Y	Y	Y	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y	Y	Y	Y	Y

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent variable:		Quantity				Quality		
Type of input NTM:	SPS	TBT	Inspection	Licensing	SPS	TBT	Inspection	Licensing
Micro (1st Quartile)	-1.692***	-1.204***	-17.54***	-1.891***	-0.268	-0.237***	-4.723***	-0.312***
x Input NTM	(0.217)	(0.0894)	(2.352)	(0.133)	(0.172)	(0.0556)	(1.598)	(0.103)
Small (2nd Quartile)	-0.256	-0.249***	1.199	-0.365***	-0.125	-0.126**	-0.580	-0.0888
x Input NTM	(0.177)	(0.0794)	(2.159)	(0.136)	(0.148)	(0.0526)	(1.748)	(0.0942)
Medium (3rd Quartile)	0.352*	0.276***	7.726***	0.380***	-0.144	-0.0335	1.188	-0.0116
x Input NTM	(0.203)	(0.0831)	(2.287)	(0.138)	(0.195)	(0.0600)	(1.845)	(0.110)
Large (4th Quartile)	1.618***	0.889***	9.957**	1.303***	0.222	0.0145	1.361	0.109
x Input NTM	(0.291)	(0.0998)	(4.009)	(0.176)	(0.327)	(0.0741)	(2.509)	(0.162)
Observations	4,576,519	4,576,519	4,576,519	4,576,519	4,568,351	4,568,351	4,568,351	4,568,351
R-squared	0.466	0.466	0.466	0.466	0.261	0.261	0.261	0.261
Trader FE	Y	Y	Y	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NTMs. Results are presented in Table 5, which shows only the coefficients of the interaction terms.

The first observation from the SPS effect is that it is pervasive across exporter-size bands. Output SPS has a negative and significant impact on export value, which works through the depressed price of exports. It perhaps indicates the high degree of competition in the markets that are more regulated with SPS, such as agri-good products. They are characterised by a large number of producers who are small relative to the market size. Therefore, an increase in trade costs is not passed through on consumers but is absorbed by producers who are also competing in price and quality. This can be seen from improved quality for all sizes. The negative effect on value and prices increases with the size of the exporter. With better quality and lower prices, micro, small- and medium-sized exporters keep selling similar quantities as before. This inevitably leads to a lower value of export, which might suggest lower profit margins in the end. By contrast, large exporters sharply reduce export quantity, facing a large price decline. This could have resulted in the diversion of exported goods towards the domestic market or reconfiguring the export portfolio with products of higher quality. An example could be to move away from exporting fresh seafood to canned seafood.

We do not see any heterogeneity with respect to Output TBT. The positive impact of Output TBTs reported in Table 3 works through improved quality of small- and medium-sized exporters. It may be concluded that TBTs on UK exports have the least distortionary impact among all types of NTMs during the examined period while achieving their primary objective of controlling for quality of products in the middle of the export size distribution.

Inspections and Licensing, on the other hand, have a large, distribution-distortionary impact on UK exports, by suppressing exports of micro exporters and boosting exports of large exporters. The mechanism through which it is achieved differs. Inspections have a large, positive and significant impact on prices that the UK firms pass on to consumers in foreign countries at the expense of quality (with the exception of large exporters). Inspections also significantly reduce export quantity by micro exporters. Licensing has a positive and significant impact on both prices and quantities of exports. It can be explained by the mechanism of lower competition, which allows firms that have licenses to pass higher prices and sell more. At the same time, the effect on quality is negative and significant for small, medium and large firms. We can conclude that Output Inspections and Licensing introduce high distortions and reduce competition without achieving better quality products.

Table 5: Export size and Output NTM

Dependent variable	(1) Value	(2) Price	(3) Quantity	(4) Quality
Micro x Output SPS	-0.116***	-0.0781***	-0.0313	0.235***
	(0.0233)	(0.0142)	(0.0235)	(0.0361)
Small x Output SPS	-0.167***	-0.131***	-0.0332	0.397***
	(0.0369)	(0.0187)	(0.0358)	(0.0486)
Medium x Output SPS	-0.158***	-0.121***	-0.0343	0.378***
	(0.0569)	(0.0249)	(0.0538)	(0.0422)
Large x Output SPS	-0.477***	-0.323***	-0.158**	0.550***
	(0.123)	(0.0769)	(0.0715)	(0.109)
Micro x Output TBT	0.00320	-0.00399	0.00842	-0.0113
	(0.01000)	(0.00545)	(0.00926)	(0.0143)
Small x Output TBT	0.00483	0.000562	0.00536	0.0631***
	(0.0118)	(0.00644)	(0.0124)	(0.0158)
Medium x Output TBT	-0.0156	0.00912	-0.0239	0.0602***
	(0.0180)	(0.00818)	(0.0176)	(0.0187)
Large x Output TBT	-0.0291	0.00106	-0.0266	0.0271
	(0.0225)	(0.00970)	(0.0199)	(0.0261)
Micro x Output Inspection	-0.0320	0.257***	-0.292***	-0.986***
	(0.0437)	(0.0296)	(0.0511)	(0.158)
Small x Output Inspection	0.187**	0.248***	-0.0639	-0.975***
	(0.0844)	(0.0488)	(0.0959)	(0.166)
Medium x Output Inspection	0.192**	0.314***	-0.115	-0.770***
	(0.0837)	(0.0564)	(0.0911)	(0.166)
Large x Output Inspection	0.452***	0.561***	-0.116	-0.731***
	(0.130)	(0.0973)	(0.149)	(0.222)
Micro x Output Licensing	0.0583***	0.0112	0.0498***	0.166***
	(0.0156)	(0.00903)	(0.0154)	(0.0208)
Small x Output Licensing	0.0927***	0.0319**	0.0624***	-0.0920***
	(0.0211)	(0.0133)	(0.0208)	(0.0283)
Medium x Output Licensing	0.183***	0.0351**	0.150***	-0.125***
	(0.0285)	(0.0160)	(0.0313)	(0.0275)
Large x Output Licensing	0.245***	0.0922***	0.154***	-0.0907**
	(0.0320)	(0.0202)	(0.0315)	(0.0408)
Observations	4,645,515	4,576,519	4,576,519	4,568,351
R-squared	0.437	0.664	0.466	0.261
Trader FE	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.3 Product Heterogeneity

This section considers whether NTMs on inputs and outputs have different implications depending on the products that these firms are exporting. Table 6 reports the effect of NTMs with the model specification (35), estimated on the three sub-samples - consumer, intermediate, and capital goods. The selection into product categories is performed using the BEC to HS mapping available at the World Integrated Trade Solution website.[10] Columns (1)-(4) report the results for the consumer goods sub-sample, columns (5)-(8) for intermediate goods, and columns (9)-(12) for capital goods.

For Input NTMs, there is a negative and significant impact of TBT on the quality of consumer and intermediate goods. Consumer goods are also very sensitive to input Inspections, which have a positive and significant effect on prices. SPS has opposing and significant effects on prices (negative) and quantities (positive) of intermediate and capital goods exports. Finally, Licensing has a positive and significant effect on the quality of capital goods exports.

For Output NTMs, higher SPS improves the quality of Consumer and Intermediate goods, while having a negative impact on the quality of Capital goods. It is not surprising, since the presence of SPS for capital goods indicates that they are unlikely imposed for health and safety reasons and more likely for protectionist reasons as capital goods are not produced for private consumption and as such have no threats to public health and safety. Higher Output TBT improves the quality of Intermediate and Capital goods. They target intermediate and capital goods and have a small, but significant impact on prices and quantities of consumer goods exports. Inspections have a strong negative effect on the quality of consumer and intermediate goods, while a positive and significant effect on the quality of capital goods. Finally, Output Licensing has a strong negative effect on the quality of intermediate and capital goods.

[10]We use HS combined to BEC concordances available at https://wits.worldbank.org/product_concordance.html

Table 6: NTMs and different types of exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Type of export:	Consumer goods				Intermediate goods				Capital goods			
Dependent variable:	Value	Price	Quantity	Quality	Value	Price	Quantity	Quality	Value	Price	Quantity	Quality
Input NTMs												
SPS	0.0680	-0.0432	0.112	0.130	0.166	-0.417**	0.564**	-0.190	0.912	-0.772**	1.731***	0.421
	(0.322)	(0.150)	(0.283)	(0.216)	(0.207)	(0.177)	(0.261)	(0.305)	(0.652)	(0.335)	(0.642)	(0.367)
TBT	0.00825	0.119	-0.121	-0.168*	0.0251	0.0778	-0.0590	-0.127*	0.108	0.247**	-0.141	-0.0729
	(0.104)	(0.0770)	(0.107)	(0.0881)	(0.0694)	(0.0570)	(0.0809)	(0.0691)	(0.175)	(0.108)	(0.164)	(0.101)
Inspections	1.815	3.654*	-1.776	-2.524	-0.194	-0.569	0.0619	-1.689	-2.703	-4.033*	1.229	-0.523
	(2.773)	(1.924)	(2.722)	(2.308)	(1.439)	(1.129)	(1.735)	(1.428)	(2.714)	(2.262)	(2.293)	(1.345)
Licensing	0.00858	0.00736	0.00449	0.165	-0.0477	0.123	-0.157	0.0733	-0.159	-0.0613	-0.0954	0.234*
	(0.157)	(0.115)	(0.155)	(0.150)	(0.118)	(0.110)	(0.159)	(0.115)	(0.223)	(0.168)	(0.232)	(0.133)
Output NTMs												
SPS	-0.0756	-0.125***	0.0484	0.141***	0.171*	0.0362	0.140**	0.0508	-0.695**	-0.167**	-0.543**	-1.159***
	(0.0604)	(0.0378)	(0.0371)	(0.0472)	(0.0997)	(0.0587)	(0.0620)	(0.0955)	(0.307)	(0.0825)	(0.272)	(0.127)
TBT	0.00255	-0.0210***	0.0244*	-0.00859	-0.0398*	-0.0100	-0.0290*	0.183***	-0.237***	-0.0653***	-0.170***	0.0458*
	(0.0141)	(0.00573)	(0.0131)	(0.0129)	(0.0204)	(0.0109)	(0.0175)	(0.0187)	(0.0415)	(0.0245)	(0.0357)	(0.0240)
Inspections	-0.102	0.392***	-0.498***	-3.216***	-0.179***	-0.0988**	-0.0842	-1.445***	-0.118	0.497***	-0.611***	0.937***
	(0.0739)	(0.0474)	(0.0754)	(0.162)	(0.0642)	(0.0432)	(0.0779)	(0.272)	(0.148)	(0.133)	(0.178)	(0.225)
Licensing	0.136***	0.109***	0.0272	-0.0120	0.0176	-0.0275*	0.0467	-0.153***	0.317***	-0.315***	0.631***	-0.819***
	(0.0214)	(0.0101)	(0.0219)	(0.0267)	(0.0371)	(0.0146)	(0.0361)	(0.0329)	(0.0595)	(0.0477)	(0.0762)	(0.0689)
Observations	1,970,779	1,953,133	1,953,133	1,950,531	1,238,180	1,221,378	1,221,378	1,218,896	339,253	335,701	335,701	335,130
R-squared	0.460	0.685	0.495	0.295	0.452	0.673	0.474	0.354	0.530	0.702	0.588	0.537
Trader FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.4 Exports to EU vs Extra-EU

We also analyse heterogeneity in the average effect of different types of Output NTMs with respect to the UK export destinations. In Table 7 we add the interaction term of an indicator of exporting to EU with Output NTM variables to the baseline model (35), and analyse how the increase of different NTMs impacts firms' trade margins.[11] The EU SPS and TBT regulations have a more negative effect on the value and quantity of UK exports relative to the rest of the World's regulations. At the same time, they have a significantly stronger positive impact on UK export quality. Higher EU Output Inspections and Licensing help to increase the value of UK exports due to significantly higher prices (Inspections) and quantity (Licensing). At the same time, they both have a strong negative impact on quality of the UK exports. These again indicate that while Output SPS and TBT are mostly fit for purpose, Output Inspections and Licensing create rents for companies that are able to penetrate the EU market and do not really stimulate quality improvements.

In Table 8 we further analyse the heterogeneity of the Output NTMs effect by exporter size, similar to the results in Table 5, but distinguishing EU vs non-EU destinations. In particular, we start by looking at the heterogeneous effects of SPS on exports. Firms exporting into the EU member countries experience negative and significant effects on export value, price and quantity from stringent SPS on inputs (with the exception of the coefficient of SPS on quantity for medium exporters, which is negative, but not significant). However an increase in the quality of exported goods suggests a selection effect on the type of products sold in the EU market. This impact is more pronounced for large exporters. In particular, large firms exporting to EU-member countries are facing a significant negative impact on the value of exports, with a higher negative coefficient than we have seen for micro- and medium-sized firms. At the same time, the additional positive effect of SPS in the EU on quality is increasing with the exporter size.

In addition, focusing on the effect of an increase in strictness of TBT measures on firms exporting to the EU shows a negative and significant effect on the value and quantity of micro exporters. The additional effect of the EU Output TBT on the quality is universally positive for all exporters and significant for micro- to medium-sized ones. Sensitivity of quality to Output TBT monotonically declines with the export size, pointing to different strategies taken by exporters of different size,

[11] Here EU is referred to the other 27 members.

Table 7: Impact of Output NTM for EU and non-EU destinations of the UK exports

Dependent variable	(1) Value	(2) Price	(3) Quantity	(4) Quality
Output SPS	0.0991***	-0.0484***	0.149***	0.282***
	(0.0275)	(0.0125)	(0.0278)	(0.0405)
Output TBT	0.0102	-0.0208***	0.0320***	-0.155***
	(0.00717)	(0.00396)	(0.00794)	(0.0164)
Output Inspections	0.0950***	0.250***	-0.151***	-0.600***
	(0.0352)	(0.0239)	(0.0396)	(0.122)
Output Licensing	0.0206**	0.0459***	-0.0266**	0.204***
	(0.00853)	(0.00670)	(0.0111)	(0.0247)
EU x Output SPS	-0.424***	-0.143***	-0.278***	0.140***
	(0.0406)	(0.0250)	(0.0341)	(0.0525)
EU x Output TBT	-0.0274***	0.0281***	-0.0548***	0.242***
	(0.00990)	(0.00547)	(0.00994)	(0.0197)
EU x Output Inspections	0.223	0.393***	-0.194	-2.434***
	(0.263)	(0.138)	(0.280)	(0.280)
EU x Output Licensing	0.176***	-0.00580	0.185***	-0.349***
	(0.0192)	(0.0113)	(0.0197)	(0.0301)
Observations	4,645,515	4,576,519	4,576,519	4,568,351
R-squared	0.437	0.664	0.466	0.261
Trader FE	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

while penetrating the EU markets. The smaller exporters are likely to aim at niche markets with higher quality products, while larger firms do not tailor their products specifically for EU regulations and do not adjust to higher quality for the EU markets.

For what concerns inspection as an NTM what emerges is that those impact significantly the quality of products exported in all markets, and have a strong positive and significant effect on prices of small to large exporters. Finally, in terms of Licensing, firms that are able to overcome this barrier are able to export to the EU significantly more goods and at lower quality. The large exporters also are able to charge a significantly higher price. The quality of exports universally deteriorates for firms of all sizes who export to the EU.

Interestingly, SPS appears to be a key non-tariff barrier for firms trading with the EU. In particular, what emerges is that SPS tend to improve the quality of goods among firms exporting to the EU. While higher TBT leads to a positive effect on quality only for micro- to medium-sized exporters. Whereas, inspections dampen the quality of goods irrespective of the market. The impact of these non-tariff barriers has a heterogeneous effect on firms' size, which depends on the market of export. In particular, micro-size firms tend to be negatively affected by all NTMs in terms of their export value irrespective of the market they export to.

8 Imports

We briefly analyse the effects of NTMs on UK's imports. While this topic deserves a separate discussion, the purpose of this exercise for our study is to highlight the mechanisms of the impact of imported goods on UK exports. This is particularly relevant given the fact that the UK is a net importer of goods according to Office of National Statistics in 2019 it showed a deficit of £130.9 billion.[12] To this extent we analyse the heterogenous effects of NTMs applied on imported inputs by estimating the following equations. For the dependent variable, we look at import quantity q in kilograms, import value v in USD, and import price, proxied by the unit price, defined as $p_{IM,fhct} = v^{IM}_{fhct}/q^{IM}_{fhct}$, and import quality $\Lambda^{IM,hct}$. A unit of analysis is a firm f, importing product h, from country c, at time t. Our main variables of interest is NTM^{k}_{hUKpt}, which measures the intensity of various types of NTMs applied to a product of 4-digit HS category h from country p at

[12] https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/bulletins/internationaltradeinuknationsregionsandcities/2019.

Table 8: Impact of Output NTM for EU and non-EU destinations for exporters of different sizes

Dependent variable	(1) Value	(2) Price	(3) Quantity	(4) Quality
Micro (1st Quart.)#EU#Output SPS	-0.276***	-0.128***	-0.137***	0.293***
	(0.0385)	(0.0226)	(0.0382)	(0.0492)
Small (2nd Quart.)#EU#Output SPS	-0.221***	-0.140***	-0.0757*	0.422***
	(0.0416)	(0.0216)	(0.0401)	(0.0504)
Medium (3rd Quart.)#EU#Output SPS	-0.224***	-0.130***	-0.0899	0.354***
	(0.0621)	(0.0288)	(0.0577)	(0.0450)
Large (4th Quart.)#EU#Output SPS	-0.638***	-0.387***	-0.252***	0.606***
	(0.131)	(0.0837)	(0.0790)	(0.121)
Micro (1st Quart.)#EU#Output TBT	-0.0367**	0.00196	-0.0377***	0.130***
	(0.0146)	(0.00799)	(0.0133)	(0.0162)
Small (2nd Quart.)#EU#Output TBT	0.00548	0.00438	0.00245	0.0995***
	(0.0130)	(0.00732)	(0.0132)	(0.0173)
Medium (3rd Quart.)#EU#Output TBT	-0.0190	0.0156*	-0.0341*	0.0848***
	(0.0190)	(0.00882)	(0.0184)	(0.0195)
Large (4th Quart.)#EU#Output TBT	-0.0283	0.00521	-0.0298	0.0446
	(0.0249)	(0.0108)	(0.0218)	(0.0306)
Micro (1st Quart.)#EU#Output Inspections	0.542	0.126	0.377	-2.740***
	(0.390)	(0.143)	(0.399)	(0.437)
Small (2nd Quart.)#EU#Output Inspections	1.041**	0.627***	0.396	-2.695***
	(0.405)	(0.216)	(0.452)	(0.357)
Medium (3rd Quart.)#EU#Output Inspections	0.0240	0.598**	-0.599	-3.147***
	(0.483)	(0.298)	(0.502)	(0.437)
Large (4th Quart.)#EU#Output Inspections	-0.737	1.211***	-1.949***	-3.734***
	(0.580)	(0.284)	(0.548)	(0.556)
Micro (1st Quart.)#EU#Output Licensing	0.0766**	0.00484	0.0758***	-0.130***
	(0.0299)	(0.0168)	(0.0288)	(0.0266)
Small (2nd Quart.)#EU#Output Licensing	0.121***	0.0242	0.0985***	-0.162***
	(0.0263)	(0.0162)	(0.0255)	(0.0323)
Medium (3rd Quart.)#EU#Output Licensing	0.240***	0.0304	0.211***	-0.151***
	(0.0333)	(0.0188)	(0.0362)	(0.0308)
Large (4th Quart.)#EU#Output Licensing	0.327***	0.101***	0.227***	-0.133***
	(0.0393)	(0.0220)	(0.0363)	(0.0471)
Observations	4,645,515	4,576,519	4,576,519	4,568,351
R-squared	0.437	0.664	0.466	0.261
Trader FE	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y
Product Trend FE	Y	Y	Y	Y

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

time t imposed by UK:

$$\ln(y_{fhct}) = \beta_{NTM} NTM^{k}_{hUKpt}$$
$$+X\gamma + D_{pt} + D_f + D_{ht} + \varepsilon_{fhct} \tag{36}$$

Controls include firm employment and productivity. We also control for unobserved firm heterogeneity by adding a trader-fixed effect. We also control for product-specific trends and for country-year fixed effects.

Thus, in Table 9 we analyse how different NTMs impact the import margins of UK importers. Consistent with our previous results, more stringent SPS and TBT induce firms to import significantly better quality products. But, it comes at a cost of reducing the price and quantity of inputs.

UK pre-shipment inspections make firms reduce the quantity and quality of imports, which also come at a higher price. These effects indicate that Inspections introduce high barriers to trade without achieving good outcomes in terms of public policy objectives. Licensing marginally improves the quality of imported goods, but has similar undesirable impacts on the other margins of imports.

The impact on EU imports is different from the impact on goods from the rest of the World. SPS has a stronger negative impact on the value and quantity of imports, while significantly improving their quality. TBT on EU imports has a qualitatively similar impact as EU SPS. Inspection and Licensing of EU imports to the UK has an additional negative and significant impact on value and quantity, while a positive and significant impact on price. Inspections are associated with lower quality, while licensing generates a small but significantly positive effect on quality.

Overall, the results are broadly consistent with the indication that SPS and TBT on a firm's imported inputs improve the quality of their exports, while Licensing and Inspection have negative effects.

9 Discussion

Overall, we see heterogeneous effects across firms in response to NTMs increase. That is bigger firms are affected positively or at least less negatively, than smaller ones, when looking at exports. The

Table 9: NTM and margins of UK imports

Dependent variable:	(1) Value	(2) Price	(3) Quantity	(4) Quality	(5) Value	(6) Price	(7) Quantity	(8) Quality
SPS	-0.179***	-0.0414***	-0.136***	0.0701***	-0.0686*	-0.0622***	-0.00694	-0.0194**
	(0.0285)	(0.0140)	(0.0306)	(0.00585)	(0.0412)	(0.0204)	(0.0438)	(0.00894)
TBT	-0.131***	0.0103**	-0.142***	0.0531***	-0.120***	0.0157***	-0.137***	0.0724***
	(0.00899)	(0.00420)	(0.0101)	(0.00224)	(0.00879)	(0.00526)	(0.0103)	(0.00301)
Inspection	-0.907***	0.455***	-1.363***	-0.523***	-1.844***	0.449***	-2.291***	1.210***
	(0.226)	(0.118)	(0.254)	(0.124)	(0.256)	(0.151)	(0.294)	(0.316)
Licensing	-0.203***	0.0503***	-0.254***	0.0167***	-0.255***	0.0718***	-0.327***	0.00956**
	(0.0156)	(0.00770)	(0.0174)	(0.00339)	(0.0168)	(0.00987)	(0.0199)	(0.00457)
EU x SPS					-0.252***	-0.0294*	-0.219***	0.131***
					(0.0476)	(0.0167)	(0.0483)	(0.00654)
EU x TBT					-0.143***	0.00681	-0.149***	0.0365***
					(0.0139)	(0.00572)	(0.0150)	(0.00284)
EU x Inspection					-0.302	0.453***	-0.758**	-1.636***
					(0.344)	(0.169)	(0.377)	(0.109)
EU x Licensing					-0.164***	0.0325***	-0.198***	0.0247***
					(0.0213)	(0.0100)	(0.0228)	(0.00417)
Observations	3,210,338	3,187,539	3,187,539	3,187,539	3,210,338	3,187,539	3,187,539	3,187,539
R-squared	0.366	0.696	0.548	0.911	0.366	0.696	0.549	0.911
Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Trader FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered at trader id in parentheses. Controls include firm size and productivity.
*** p<0.01, ** p<0.05, * p<0.1

effect is mostly driven by changes in quantity. We can find literature that supports these results. Fontagné et al. (2015) finds that the negative effects of SPS on trade are lessened for big firms. The interpretation presented in the paper is that big firms exporting in several sector-markets, having resources to move from unaffected to SPS affected markets, are able to cope with the SPS imposition and might even benefit from the reduced competition in the SPS imposing market. Whereas, looking at the literature on TBTs, Kamal and Zaki (2018) finds that smaller firms are more adversely affected by TBTs in their export participation. Moreover, firms generally tend to increase their market diversification in response to TBTs, especially true for large firms.

10 Conclusion

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10.1 Alternative results

Results of the heterogeneous impact of output NTMs to different world regions are presented in Table 10.

11 Model proof

11.1 Proof for Proposition 1

From Equation (20), we know that $a_1 > a_2$. This means less productive firms will use domestic inputs while more productive firms will use imported inputs after introducing the NTMs.

Table 10: NTM and UK exports by region

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:				**Value**				
Region:	OECD	Euro	Europe and Central Asia	Middle East	South Asia	North America	South America	Common-wealth
Output SPS	0.377***	-0.109**	0.232	0.109	0.180***	0.593***	0.165**	0.0635
	(0.0607)	(0.0440)	(0.289)	(0.105)	(0.0657)	(0.121)	(0.0786)	(0.0805)
Output TBT	-0.00408	-0.0158	0.0275	0.0713*	-0.0581**	-0.0434*	-0.0189	0.00722
	(0.0190)	(0.0139)	(0.0538)	(0.0382)	(0.0251)	(0.0232)	(0.0320)	(0.0199)
Output Inspection	0.386*	1.382***	-0.0144	-0.0390	0.296	0.471	-0.140	-0.347**
	(0.205)	(0.501)	(0.485)	(0.138)	(0.185)	(0.329)	(0.195)	(0.137)
Output Licensing	-0.0176	0.0517*	0.0192	-0.104**	-0.196***	-0.0344	-0.0154	-0.0601*
	(0.0344)	(0.0265)	(0.121)	(0.0461)	(0.0381)	(0.0380)	(0.0491)	(0.0331)
Observations	1,183,870	1,183,870	1,183,870	1,183,870	1,183,870	1,183,870	1,183,870	1,183,870
R-squared	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370
Dependent variable				**Price**				
Region	OECD	Euro	Europe and Central Asia	Middle East	South Asia	North America	South America	Common-wealth
Output SPS	-0.0177	-0.00695	-0.120	0.0399	-0.00285	-0.0810	0.0512	-0.148***
	(0.0331)	(0.0188)	(0.133)	(0.0444)	(0.0386)	(0.0549)	(0.0421)	(0.0360)
Output TBT	-0.0635***	0.0317***	-0.128***	-0.0650***	-0.0449***	-0.0475***	-0.0403**	-0.0223*
	(0.0114)	(0.00716)	(0.0317)	(0.0179)	(0.0149)	(0.0127)	(0.0201)	(0.0116)
Output Inspection	-0.433***	0.366	-1.050***	-0.0150	-0.157	-0.433**	0.310***	0.0225
	(0.123)	(0.317)	(0.231)	(0.0852)	(0.124)	(0.174)	(0.114)	(0.0871)
Output Licensing	0.0831***	-0.0645***	0.143*	0.119***	0.0746***	0.0709***	0.0209	0.0496**
	(0.0208)	(0.0134)	(0.0749)	(0.0291)	(0.0245)	(0.0210)	(0.0288)	(0.0217)
Observations	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787
R-squared	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688
Dependent variable				**Quantity**				
Region	OECD	Euro	Europe and Central Asia	Middle East	South Asia	North America	South America	Common-wealth
Output SPS	0.386***	-0.0982**	0.337	0.0680	0.181**	0.654***	0.124	0.199**
	(0.0710)	(0.0470)	(0.340)	(0.105)	(0.0715)	(0.136)	(0.0862)	(0.0928)
Output TBT	0.0618***	-0.0486***	0.153**	0.141***	-0.0155	0.00784	0.0272	0.0329
	(0.0215)	(0.0149)	(0.0663)	(0.0448)	(0.0274)	(0.0259)	(0.0401)	(0.0228)
Output Inspection	0.818***	0.960*	1.061*	-0.0379	0.456**	0.893**	-0.436*	-0.349**
	(0.222)	(0.533)	(0.576)	(0.163)	(0.203)	(0.364)	(0.240)	(0.156)
Output Licensing	-0.101**	0.113***	-0.128	-0.219***	-0.264***	-0.101**	-0.0374	-0.109***
	(0.0411)	(0.0291)	(0.135)	(0.0569)	(0.0472)	(0.0453)	(0.0576)	(0.0413)
Observations	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787	1,167,787
R-squared	0.470	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Dependent variable				**Quality**				
Region	OECD	Euro	Europe and Central Asia	Middle East	South Asia	North America	South America	Common-wealth
Output SPS	0.744***	-0.115**	0.122	0.845***	-1.539***	2.111***	-0.514***	0.376
	(0.0904)	(0.0532)	(0.369)	(0.145)	(0.176)	(0.260)	(0.115)	(0.409)
Output TBT	-0.376***	0.155***	0.173***	0.137***	-0.0602	-0.731***	-0.0151	0.00176
	(0.0276)	(0.0167)	(0.0669)	(0.0393)	(0.0764)	(0.0421)	(0.0420)	(0.0341)
Output Inspection	2.110***	-0.154	1.259*	0.665**	-2.342***	2.965***	0.454	-2.008***
	(0.361)	(0.458)	(0.746)	(0.282)	(0.667)	(0.683)	(0.286)	(0.606)
Output Licensing	0.340***	-0.0447	-0.544***	0.0476	-0.272**	0.467***	0.324***	-0.202***
	(0.0490)	(0.0307)	(0.170)	(0.0555)	(0.112)	(0.0481)	(0.0718)	(0.0597)
Observations	1,165,644	1,165,644	1,165,644	1,165,644	1,165,644	1,165,644	1,165,644	1,165,644
R-squared	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0.242

Standard errors clustered at trader level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To prove $a_D > a_1$, we take the ratio of a_1 and a_D by using Equation (13) and (21).

$$\frac{a_1}{a_D} = [1 + \frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma} - 1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}]^{-1} < 1 \tag{A.1}$$

Equation (21) shows that $a_D > a_1$, which means that the least productive firms exit the market after introducing the NTMs. The market competition is intensified.

11.2 Proof for Proposition 2

To obtain price changes for Type 1 and Type 2 firms, we take the ratio of p_i and p_1 or p_2 by using Equation (9), Equation (14) and Equation (15).

$$\frac{p_i}{p_1} = \frac{p_{mi}^F}{p_{mi}^D} \tag{A.2}$$

$$\frac{p_i}{p_2} = \frac{p_{mi}^F}{p_{mi}^F} \tag{A.3}$$

Simplify Equation (A.2) by substituting Equation (6), (7) and (8), we can obtain that $\frac{p_i}{p_1} = \omega < 1$. Thus, less productive firms will charge a higher price after introducing the NTMs. In contrast, Equation (A.3) shows that more productive firms will charge the same price as before.

11.3 Proof for Proposition 3

To obtain quantity changes for Type 1 and Type 2 firms, we have to clarify Equation (3) for firms before the introduction of the NTMs, Type 1 firms and Type 2 firms after the introduction of the NTMs, respectively.

For firms before the introduction of the NTMs, quantity can be simplified as $x_i = \frac{(\frac{\sigma}{\sigma-1})^{-\sigma}\omega^{-\sigma}a_i^{-\sigma(1+\theta)}}{P^{1-\sigma}}(\frac{a_i}{a_D})^{\theta}E$ by substituting the price function, i.e. Equation (9), and the quality function, i.e. Equation (8). The zero-profit condition, Equation (11), then allows us to express it as follows:

$$x_i = \frac{\sigma - 1}{\omega}F_D a_i^{\theta-\sigma(1+\theta)} a_D^{(1+\theta)(\sigma-1)-\theta} \tag{A.4}$$

For Type 1 firms after the introduction of the NTMs, quantity can be simplified as $x_1 = \frac{(\frac{\sigma}{\sigma-1})^{-\sigma}a_i^{-\sigma(1+\theta)}}{P^{1-\sigma}}(\frac{a_i}{a_1})^{\theta}E$ by substituting the price function, i.e. Equation (14), and the quality function, i.e. Equation (8). The zero-profit condition, Equation (19), then allows us to express it as follows:

$$x_1 = (\sigma - 1)F_D a_i^{\theta-\sigma(1+\theta)} a_1^{(1+\theta)(\sigma-1)-\theta} \tag{A.5}$$

For firms before the introduction of the NTMs, quantity can be simplified as $x_2 = \frac{(\frac{\sigma}{\sigma-1})^{-\sigma}\omega^{-\sigma}a_i^{-\sigma(1+\theta)}}{P^{1-\sigma}}(\frac{a_i}{a_1})^{\theta}E$ by substituting the price function, i.e. Equation (15), and the quality function, i.e. Equation (8). The zero-profit condition, Equation (19), then allows us to express it as follows:

$$x_2 = \frac{\sigma - 1}{\omega} F_D a_i^{\theta-\sigma(1+\theta)} a_1^{(1+\theta)(\sigma-1)-\theta} \tag{A.6}$$

We take the ratio of x_1, i.e. Equation (A.5) and x_i, i.e. (A.4).

$$\frac{x_1}{x_i} = \omega(\frac{a_1}{a_D})^{(1+\theta)(\sigma-1)-\theta} \tag{A.7}$$

Given $\omega < 1$, $a_1 < a_D$ and $(1+\theta)(\sigma-1)-\theta > 0$, we know this ratio is smaller than 1. This means that less productive firms can sell less quantity after introducing the NTMs.

We then take the ratio of x_2, i.e. Equation (A.6) and x_i, i.e. (A.4).

$$\frac{x_2}{x_i} = \omega^{1-\sigma}(\frac{a_1}{a_D})^{(1+\theta)(\sigma-1)-\theta} \tag{A.8}$$

Equation (A.8) can be expressed as $\frac{x_2}{x_i} = (\frac{a_1^{1+\theta}}{\omega a_D^{1+\theta}})^{\sigma-1}(\frac{a_1\omega}{a_D})^{-\theta}(\frac{1}{\omega})^{-\theta}$. We expect this ratio to be bigger than 1. We know the last term, i.e. $(\frac{1}{\omega})^{-\theta} > 1$. Now we are going to prove the following equation is bigger than one as well,

$$(\frac{a_1^{1+\theta}}{\omega a_D^{1+\theta}})^{\sigma-1}(\frac{a_1\omega}{a_D})^{-\theta} \tag{A.9}$$

Given that $(1+\theta)(\sigma-1+\theta) > 0$, we can find the following equation, which is smaller than Equation (A.9),

$$(\frac{a_1^{1+\theta}}{\omega a_D^{1+\theta}})^{\sigma-1}(\frac{a_1\omega}{a_D})^{(1+\theta)(\sigma-1)} \tag{A.10}$$

Substituting a_D and a_1 by using Equation (13) and Equation (21) into Equation (A.10) leads to the following equation,

$$\{[1+\frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma}-1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}]^{-\frac{2}{k}}\frac{1}{\omega}\}^{(1+\theta)(\sigma-1)} \tag{A.11}$$

Equation (A.11) can be further expressed as,

$$[\omega^{\frac{2}{k}}+\omega^{\frac{2}{k}}\frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma}-1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}]^{-\frac{2}{k}(1+\theta)(\sigma-1)} \tag{A.12}$$

Given that $-\frac{2}{k}(1+\theta)(\sigma-1)<0$, $\omega^{\frac{2}{k}}+\omega^{\frac{2}{k}}\frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma}-1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}$ has to be smaller than one to obtain Equation (A.12) bigger than one. Thus, given that $(1+\theta)(1-\sigma)+\theta<0$ and $\frac{1}{\omega^{1-\sigma}-1}>1$, we can find the following equation, which is smaller than Equation (A.12),

$$[\omega^{\frac{2}{k}}+\omega^{\frac{2}{k}}\frac{F}{F_D}]^{-\frac{2}{k}(1+\theta)(\sigma-1)} \tag{A.13}$$

Finally, we find that under the assumption $\omega^{\frac{2}{k}}(1+\frac{F}{F_D}]) < 1$, Equation (A.13) is bigger than one. At the same time, we can conclude that Equation (A.8) is bigger than one. More productive firms sell more quantity after introducing the NTMs. Under this condition, we can also find that $\omega^{\frac{2}{k}}+\omega^{\frac{2}{k}}\frac{F}{F_D}(\frac{F}{F_D}\frac{1}{\omega^{1-\sigma}-1})^{\frac{k}{(1+\theta)(1-\sigma)+\theta}}<1$.

11.4 Proof for Proposition 4

One firm's revenue is calculated as the price multiplied by the quantity. We can take the ratios of one firm's revenue before introducing the NTMs and revenue of a Type 1 firm or a Type 2 firm.

$$\frac{r_1}{r_i}=\frac{p_1}{p_i}\frac{x_1}{x_i}=(\frac{a_1}{a_D})^{(1+\theta)(\sigma-1)-\theta} \tag{A.14}$$

Given that $a_1<a_D$ and $(1+\theta)(\sigma-1)-\theta>0$, Equation (A.14) is smaller than one. This means that although less productive firms can sell their products at high prices, the decrease in sales ultimately leads to a decrease in the firms' revenue after introducing the NTMs.

More productive firms charge the same price as before and can sell more products. Thus, they can earn more revenue after introducing the NTMs.