Review of Development Economics, 17(3), 447–460, 2013
DOI:10.1111/rode.12042

The Impacts of Technical Barriers to Trade on Different Components of International Trade

*Xiaohua Bao and Wei-Chih Chen**

Abstract

This research studies the impacts of technical barriers to trade (TBT) on trade performance of 103 countries over the period 1995–2008. The paper analyzes how TBT influences the trade probability, trade volume and trade duration. The trade volume is further decomposed into the number of products traded (extensive margin) and the trade value of each product (intensive margin). It is found that TBT imposes inconsistent impacts on the different components of trade, and that the effects differ by country. First, TBT reduces trade probability, but increases the volume and duration of existing trade relationships. Second, the positive effect of TBT on trade volume is mainly driven by an increase in the extensive margin, and the effect on the intensive margin is not statistically significant. Finally, TBT raised by developed countries have a stronger negative impact on trade probability, while TBT implemented by developing countries have a greater positive effect on trade volume.

1. Introduction

As the World Trade Organization (WTO) has successfully cut tariff rates and reduced traditional non-tariff trade barriers, the remaining barriers, including technical barriers to trade (TBT), have become more visible and of greater relevance in the system of global trade. According to WTO statistics, 106 WTO members made 9913 TBT notifications to the WTO from 1995 to 2008. Over the period, the number of TBT notifications has greatly increased, from 365 in 1995 to 1251 in 2008. When we observe the data by country, we find that while developed countries were the main users of TBT in the early years, in recent years developing countries introduced an almost equal number of TBT. TBT are now considered a real trade problem in the 21st century (Chen and Mattoo, 2008).

Unlike other traditional trade barriers, TBT may have both trade restriction and trade promotion effects. First, having to comply with varying standards and technological regulations of importing countries will generate additional costs of production (Fischer and Serra, 2000). Thus, TBT can restrict international trade volumes, particularly if they discriminate against foreign producers. Second, the imposition of TBT can provide additional information such as the quality of products, which may lead to a trade promotion effect. Finally, TBT can influence competition among existing and potential exporters. The higher compliance cost may discourage potential exporters from entering the market, or may even drive less productive firms to leave the

* Chen: Shanghai University of Finance and Economics, Shanghai, China, 200433. Tel: +86-21-6590-7841; Fax: +86-21-6590-7458; E-mail: wei.chihchen@mail.shufe.edu.cn. Bao: Shanghai University of Finance and Economics, Shanghai, China, 200433. The authors are grateful to two anonymous referees and participants at the 2011 IEFS China Annual Meeting (Beijing) for their helpful comments. They also would like to acknowledge financial support from the Natural Science Foundation of China (70703021 and 71273161), the Ministry of Education of China (NCET-10-0537), and the Fok Ying Tung Education Foundation (121085).

market. This effect, nevertheless, can provide protection to the remaining exporters and increase their trade volume and sustainability.

As the role of TBT becomes increasingly important in the global trade system, a growing empirical literature has begun to explore the effects of TBT on international trade. However, there has been no study that thoroughly explores the impact of TBT on the various aspects of trade performance. The long-run trade performance is determined by three components (Besedeš and Prusa, 2011). The first component is the probability of establishing a trade relationship with (potential) trade partners; the second is the trade volume with (existing) trade partners; and the third is the sustainability of each established trade relationship. The main objective of the current paper is not only to simply examine whether TBT is trade promoting or restricting, but also to provide a more complete analysis of the impact of TBT on international trade. Specifically, we investigate the effect of TBT on trade performance by looking into the different components of trade: the probability of trade, the number of goods traded, the volume of each good traded, and the duration of trade.

To explore the trade reduction and promoting effects, empirical studies have attempted to quantify the TBT and analyze the direction of its trade effects by using different datasets at the country level, industry level, or even at the more detailed product level.[1] While most research has found that TBT has a negative impact on trade, some studies (Moenius, 2006; Fontagné et al., 2005; Bao and Qiu, 2012) have found evidence of the trade promotion effect of TBT. It is generally believed that the direction of TBT's impact on trade is uncertain, and the trade effects vary across different country groups and industries.

These studies, however, have largely focused on trade relationships that have already been established (with positive trade flows); zero-trade country pairs were not included in the analysis. The construction of the firm heterogeneity model by Melitz (2003) explains why some firms do not take part in trade while others engage in a tremendous amount of trade. He shows that trade volumes are influenced by both the export volume of a firm (the trade intensity), and the fraction of exporting firms in total firms (the probability of exports). Firms' export decisions depend on their productivity and the market entry cost in different markets. This study lays the foundation for new–new trade theory and also provides a new way to analyze the quantitative studies on the TBT trade effect. TBT can impose both fixed costs and variable costs (Baldwin, 2001; Baldwin and Forslid, 2010; Ganslandt and Markusen, 2001), and they affect trade in different ways: a higher variable cost decreases firms' export volumes, and an increased fixed cost makes exports less likely to be profitable for firms. Therefore, complying with standards affects both trade volumes and trade propensity (whether or not to trade).

One direct way to apply heterogeneous firm theory to TBT research is to use firm level data. For example, Chen et al. (2008) use the World Bank's micro-level survey data of standards and compliance costs, to study the trade effect of standards in light of the market entry decision of exporting firms. The application of the firm heterogeneity model is not confined to micro-level data. Abundant bilateral trading statistics data can also capture firms' heterogeneous characteristics since exporting firms with lower productivity are inclined to export to markets with lower technical standards (Helpman et al., 2008). In terms of firm heterogeneity, fixed trading cost, and asymmetry of trade volumes, a few recent studies have appealed to the heterogeneous firms' model by Melitz (2003) and Helpman et al. (2008) to analyze the impact of TBT and liberalization on market entry. These studies adopted bilateral trade data from different countries and industries to investigate the effects of TBT, such as the impact

of regional TBT liberalization on the telecommunication and medical equipment industries (Baller, 2007), the impact of American technical regulations on trade patterns of agriculture, mining, and manufacture industries (Essaji, 2008), the impact of EU standards on African textile exports (Czubala et al., 2009) and electrical products (Portugal-Perez et al., 2010), and the harmonization and tightening of the EU maximum residues limit (MRL) on aflatoxins in 2002 and its impact on African exports of groundnut products (Xiong and Beghin, 2012). These studies generally found that TBT affect not only trade volume but trade probability as well.

Despite the recent progress in TBT empirical studies, this paper is the first to undertake a complete analysis that looks at the effects of TBT on various aspects of international trade, for example, market entry, exit, and trade volumes of existing relationships. Specifically, the current paper builds on and contributes to the existing literature in several ways. First, this paper extends the literature that focuses on the relation between TBT and market entry by using a large dataset covering manufacturing industries from all TBT notifying countries, which facilitates the comparison between developing and developed countries. The comparison is especially important because developing and developed countries differ considerably in their roles as either standard makers or standard takers.

The second contribution of the present paper is to decompose trade volumes into various components in terms of TBT's influence. The traditional empirical trade literature usually focuses on aggregate trade flows, but recent studies have begun to examine distinct components of trade separately. These studies decomposed bilateral trade flows into the number of goods traded (extensive margin) and the trade value of each good (intensive margin), then estimated how country size and other factors affect different margins (Hummels and Klenow, 2005; Crozet and Koenig, 2010; Lawless, 2010). To the best of our knowledge, Shepherd (2007) is the only one among existing TBT literature that has explicitly focused on components of trade volume. Shepherd studied the impact of EU product standards and international harmonization on the extensive margin of trade in textiles, clothing, and footwear sectors, and found that standards harmonization is associated with an increase in partner countries' export variety, particularly for developing countries. The decomposition of trade volume with existing trade partners has important welfare implications. Hummels and Klenow (2005) suggest that an increase in different margins of trade can lead to opposite welfare effects. While an increase in exports varieties will raise the exporter's welfare, an increase in the quantity of each variety may worsen the terms of trade and thus reduce welfare.

Third, we explore the connection between the duration of the trade relationship and TBT. The sustainability of each established trade relationship is one of the most important components of long-run trade performance. Besedeš and Prusa (2011) show that the survival of existing trade relationships contributes more to long-run export growth than building new trade relationships, particularly for emerging economies. Though more and more papers have begun to address the determinants of trade duration, this paper is the first to investigate its relationship with TBT.

In the present paper, we apply different models to estimate the influence of TBT on distinct components of trade. In addition, we compare the impacts of TBT across different country groups (developed and developing countries). The estimated results show that the impacts of TBT on different margins of trade are not always consistent. TBT have a negative effect on the probability of trade, but the effects on trade volumes and duration are positive. For country pairs that have not established a trade relationship, TBT work as trade barriers and reduce the probability of trade occur-

rence, but for countries that have already traded with each other, TBT can improve trade performance, likely by providing information to firms or by discouraging potential competitors from entering the markets.

The impacts of TBT on trade differ by level of development of the importers and exporters. For the probability of trade, the negative effect is stronger if TBT are imposed by developed countries than by developing countries. For the volume of trade (including the extensive and intensive margins), the trade promotion effect is more effective when TBT are imposed by developing countries than by developed countries.

2. Model Specification and the Data

The gravity model is widely used to estimate trade volumes. The international trade literature confirms that bilateral trade volumes are determined by the economic size of the trading countries and multilateral resistance, which includes bilateral geographical distance, the length of common borders, the proximity of language, and the membership of free trade zones (Anderson and van Wincoop, 2003). Accordingly, we construct the following gravity model to estimate the effect of TBT on bilateral trade.

$$\begin{aligned} Y_{ijt} = {} & \alpha_i + \alpha_j + \alpha_t + \beta \ln(1 + TBT_{jt}) + \gamma_1 \ln gdp\_ex_{it} + \gamma_2 \ln gdp\_im_{jt} \\ & + \gamma_3 \ln gdppc\_ex_{it} + \gamma_4 \ln gdppc\_im_{jt} + \gamma_5 \ln dist_{ij} + \gamma_6 contig_{ij} \\ & + \gamma_7 comlang_{ij} + \gamma_8 colony_{ij} + \gamma_9 smctry_{ij} + \mu_{ijt}. \end{aligned} \tag{1}$$

In the probit model (section 3), the dependent variable is a dummy variable representing the existence of country *i*'s export to country *j* at year *t*, while in the regression models of trade volumes (section 4), the dependent variable represents the natural logs of import share, extensive margin and intensive margin respectively. In section 5, we use the Kaplan–Meier estimator and Cox proportional hazard model to estimate the survival probability of trade relationships and the effect of TBT on trade duration.

The independent variables in equation (1) include the typical gravity controls: gdp_ex_{it} and gdp_im_{jt} are the gross domestic product (GDP) level (in billion US dollars of the year 2005) of country *i* and country *j* in year *t*, representing the supply capability of the exporting country and the demand capacity of the importing country, respectively; $gdppc\_ex_{it}$ and $gdppc\_im_{jt}$ are per capita GDP (in 2005 US dollars) of the corresponding countries in year *t*; $dist_{ij}$ is the geographical distance (in kilometers) between the two countries, capturing the transportation cost; $contig_{ij}$, $comlang_{ij}$, $colony_{ij}$, and $smctry_{ij}$ are binary variables, representing respectively the existence of common borders, common official language, colonial history, and whether the trading partners have belonged to the same country group.[2]

In terms of the data sources, the product level bilateral trade data are obtained from United Nations Commodity Trade Statistics Database (Comtrade database). The GDP and *per capita* GDP data derive from the US Department of Agriculture (USDA) Economic Research Services International Macroeconomic Data Set. Other bilateral relationship data are obtained from the CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) database.

Our key explanatory variable is TBT_{jt}, which is the number of TBT notifications made by country *j* to the WTO in year *t*. The TBT notification data are available from the WTO's TBT Annual Reviews of the Implementation and Operation of the Agreement (1995–2008). As TBT_{jt} may take a zero value, we use $\ln(1 + TBT_{jt})$ instead

of $\ln(TBT_{jt})$. Although the mean of TBT is now increased by one unit, this modification does not impact the variance of the TBT.

Our study covers trade in manufacturing sectors in 103 countries and regions from 1995 to 2008. These 103 countries are chosen from the WTO's TBT notification database, which includes 39 developed countries and 64 developing countries.[3] Because they represent approximately 85% of the global trade volume, our study thus largely exhibits the TBT effect on global trade.

3. The Effect of TBT on the Probability of Trade

We first estimate how TBT affect the probability of trade. The model is specified in equation (1), and the dependent variable is a binary variable representing trade existence, which equals one if an exporter–importer pair has positive trade in a year. The sample covers trade data of 14 years and 103 countries, which yields 147,084 observations (103×102×14). Since this dataset has the panel data characteristics, we use year fixed effect (α_t) to control for the determinants of trade that only change over time. We also use importing country fixed effect (α_j) and exporting country fixed effect (α_i) to control for these time-invariant country characteristics. The estimation examines how TBT affect trade propensity in general. However, countries' level of development may also influence TBT effects. Accordingly, we divide all countries into two groups (developed and developing countries), and run the regression using data of countries from each group separately. As a result, there are a total of nine cases as specified at the top of Table 1.

The estimates on the key variable, TBT, are presented in the "Probit" row of Table 1.[4] It is clear that estimated coefficients on TBT are negative and statistically significant in all cases but one (column 9). In the benchmark case (column 1), a 10% increase in TBT notifications will reduce the probability of trade by 0.125%. This trade-suppressing effect of TBT is much larger on developing exporters than on developed exporters ($0.0142 > 0.0050$). Similarly, the negative impacts of TBT are stronger on developing exporters than on developed exporters, regardless whether TBT are imposed by developed countries ($0.0210 > 0.0039$) or by developing countries ($0.0034 > 0.0021$). Turning to the TBT adopted by different groups of countries, we find that the trade suppressing effects of TBT imposed by developed countries are much greater than those imposed by developing countries.[5]

These findings are in line with our expectations. First, TBT may impose additional costs on producers and exporters. The compliance cost includes both fixed costs and variable costs. For a given exporting country, the difference in standards and technical regulations across foreign countries causes diseconomies of scale for firms and affects decisions about whether to enter export markets. So TBT impede exporters' market entry and reduce the likelihood of exporting.

Second, although TBT raise costs to all exporters, they raise the costs to developing exporters more than to developed countries. Because producers from developed countries have already produced high standard products, the cost to upgrade them is not significant. In contrast, a great deal more effort will be required for producers from developing countries to bring their products up to the standard. In addition, the lack of capital and technical expertise limits developing countries' capacity to adapt to the foreign standard. When comparing the world TBT effect on the market entry of different exporters, we find that generally the negative impacts on developing countries are stronger than those on developed countries.

Table 1. Summary of Effects of TBT on Trade

Importers	*All*			*Developed*			*Developing*		
Exporters	*All* (1)	*Developed* (2)	*Developing* (3)	*All* (4)	*Developed* (5)	*Developing* (6)	*All* (7)	*Developed* (8)	*Developing* (9)
(I)									
Probit	−0.0125***	−0.00504***	−0.0142***	−0.0146***	−0.00389***	−0.0210***	−0.00389*	−0.00210*	−0.00340
	(0.00136)	(0.000730)	(0.00241)	(0.00149)	(0.000582)	(0.00313)	(0.00210)	(0.00124)	(0.00339)
Import share	0.0246***	0.0164**	0.0280***	0.0232**	0.0181	0.0223	0.0272***	0.0168	0.0352***
	(0.00695)	(0.00839)	(0.0103)	(0.0112)	(0.0134)	(0.0162)	(0.00887)	(0.0106)	(0.0135)
Extensive	0.0197***	0.0108	0.0266***	0.0158	0.00818	0.0213	0.0187**	0.00397	0.0294**
	(0.00629)	(0.00687)	(0.00961)	(0.0101)	(0.0105)	(0.0153)	(0.00801)	(0.00871)	(0.0126)
Intensive	0.00491	0.00560	0.00132	0.00736	0.00992	0.00104	0.00847	0.0129	0.00575
	(0.00540)	(0.00637)	(0.00816)	(0.00849)	(0.00959)	(0.0129)	(0.00705)	(0.00833)	(0.0107)
Hazard rate	0.976***	0.952***	0.980*	0.964**	0.992	0.959**	0.995	0.955**	1.003
	(0.00887)	(0.0168)	(0.0102)	(0.0156)	(0.0295)	(0.0175)	(0.0112)	(0.0209)	(0.0129)
(II)									
Probit	—	—	—	—	—	—	—	—	ns
Import share	+	+	+	+	ns	ns	+	ns	+
Extensive	+	ns	+	ns	ns	ns	+	ns	+
Intensive	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hazard rate	—	—	—	—	ns	—	ns	—	ns
(III)									
Extensive	80%	66%	95%	68%	45%	96%	69%	24%	84%
Intensive	20%	34%	5%	32%	55%	4%	31%	76%	16%

Panel (I) reports the estimated coefficients or effects: numbers are partial effects in the Probit model, and are hazard ratios in the Cox model. Panel (II) shows signs of the effects. "ns" means the effect is insignificant. Panel (III) reports the relative contribution of the extensive margin and the intensive margin regarding the effects of TBT on import share. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Third, normally developing countries' technical standards are relatively lower than those of the developed countries', so when comparing the TBT effects from different importers, we find that for any given exporter group (i.e. all exporters, developed exporters or developing exporters,) the negative impacts of TBT from developed countries are more severe than those from developing countries.

4. The Effects of TBT on the Extensive and Intensive Margins of Trade

In this section, we estimate the effect of TBT on trade volumes. Moreover, we investigate how TBT influence trade volumes: Do TBT influence trade volume by changing the number of products being traded (extensive margin), or by affecting the value of trade of each product on average (intensive margin)?

Decomposition of Import Share

To investigate how TBT affect the extensive/intensive margin of trade, the first step is to decompose total trade volume. The decomposition method is similar to Hummels and Klenow's (2005) and Chen (2013) except that we now calculate the importers' share of each exporter's total exports. Consider the total export value from a specific exporter, country i, to all other countries. Importer j's import share of country i's total exports in year t is

$$import\_share_{ijt} = \frac{\sum_{k \in S_{ijt}} (v_{ijkt})}{\sum_{k \in S_{iwt}} (v_{iwkt})} \tag{2}$$

where k is a product category defined by HS6, and w indicates "rest of the world," which represents all countries other than i and j in the sample. v_{ijkt} is the trade value of product k that importer j imports from i, and $v_{iwkt} = \Sigma_j v_{ijkt}$ is the total export value of product k from i. S_{iwt} is the complete set of products that country i exports to the rest of the world in year t. S_{ijt} is a subset of S_{iwt} containing only those products from which importer j has received positive imports from i (i.e. those k with $v_{ijkt} > 0$). The sum of all countries' import shares of exporter i's market equals one (Σ_j import_share$_{ijt}$ = 1 for all i and t).

The import share can be decomposed into the extensive and intensive margins:

$$\frac{\sum_{k \in S_{ijt}} (v_{ijkt})}{\sum_{k \in S_{iwt}} (v_{iwkt})} = \frac{\sum_{k \in S_{ijt}} (v_{iwkt})}{\sum_{k \in S_{iwt}} (v_{iwkt})} \times \frac{\sum_{k \in S_{ijt}} (v_{ijkt})}{\sum_{k \in S_{ijt}} (v_{iwkt})}. \tag{3}$$

The first component is the extensive margin, which is an index that measures the number of products importer j imports from i ($k \in S_{ijt}$) relative to the number of products that i exports to all countries ($k \in S_{iwt}$). Each product is weighted by its total export value from i, v_{wkt}. The extensive margin increases with the number of products that country j imports ($k \in S_{ijt}$) relative to that of the world imports ($k \in S_{iwt}$).

The second component, the intensive margin, is defined as the ratio of importer j's import value from i, relative to all countries' import values from i of those same products from which j has positive import from i ($k \in S_{ijt}$).

Based on equation (3), the overall import share can be decomposed linearly into the extensive and intensive margins after taking natural logs. When we regress the

logs of import share, extensive margin, and intensive margin on the same set of regressors, the effect of each regressor can be decomposed additively. That is, $\hat{\beta}^{IS} = \hat{\beta}^{EM} + \hat{\beta}^{IM}$, where $\hat{\beta}^{IS}, \hat{\beta}^{EM}$, and $\hat{\beta}^{IM}$ are the estimated coefficients in the import share, extensive margin, and intensive margin regression, respectively.

Estimated Results and Analysis

We estimate three separate regressions based on equation (1) with different dependent variables: the natural logs of import share, extensive margin, and intensive margin, as defined in equation (3). The sample used in this section contains only exporter–importer years that have positive trade. The sample size is smaller than that of the probit model in section 3, which is a balanced panel including observations of both zero trade and positive trade. Estimated coefficients represent the elasticity of trade under the condition that the country pairs actually trade with other. As in section 3, we control for importing country, exporting country, and year fixed effects in the regressions.

The estimated results of TBT effects on trade are reported in Table 1. TBT have a positive impact on import shares, and the trade promoting effects are statistically significant in the benchmark estimation (column 1): a 10% increase in TBT notifications is associated with a 0.246% increase in import share. The effects of TBT notifications imposed by developing countries (column 7) are slightly greater and statistically more significant than that are imposed by developed countries (column 4). In terms of exporter country groups, we also find that the positive effect is greater on developing exporters (columns 3) than on developed exporters (columns 2).

In the benchmark estimation (column 1), we observe that the effect on the extensive margin is significantly positive. However, TBT do not have a significant effect on the intensive margin. The decomposition method introduced in the previous subsection ensures that the estimated coefficients in the import share regression will be decomposed additively into the extensive and intensive margins. In the benchmark (column 1), a 10% increase in TBT notifications will raise the import share by 0.246%. This effect can be decomposed into a 0.197% (significant) increase in the extensive margin, and a 0.049% (insignificant) increase in the intensive margin. The extensive margin accounts for 80% (0.197/0.246) and the intensive margin accounts for 20% (0.049/0.246). From columns 1–3, the extensive margin contributes a greater share (66%~95%) of effects of TBT on import share, while intensive margin accounts for only 5%~34% of the contribution (and is insignificant). To facilitate the comparison, we summarize the relative importance of TBT effects on the extensive and intensive margins in the last panel of Table 1.

For developed importers (columns 4–6), we can see that TBT have no significant impacts on either the extensive or intensive margin. When we turn to developing importers (columns 7–9), we find that TBT have significantly positive effects on developing exporters, but not on developed exporters. The relative importance of the extensive and intensive margins is similar across importers, but it differs by exporter country group. The extensive margin accounts for a greater proportion of TBT's effect for developing exporters than for developed exporters. For instance, when TBT are imposed by developed countries, the extensive margin accounts for 96% on developing exporters, but it only accounts for 45% on developed exporters. When TBT are raised by developing countries, the difference is even larger (84% vs 24%).

The results of this section can be summarized as follows. (1) An increase in TBT will raise trade volumes of existing trade relationships. This trade-promoting effect

differs from the trade suppressing effect that is found in estimations of trade probability. The finding is similar to that of Bao and Qiu (2012), which uses bilateral trade values as the dependent variable. (2) The positive effects of TBT on trade volume are stronger and are more significant when TBT are imposed by developing countries than when they are imposed by developed countries. This is at variance from the probit regression, in which TBT imposed by developed importers have greater effects on trade probability than TBT imposed by developing countries. (3) The positive effects of TBT on trade volumes are greater on developing exporters than on developed exporters. This finding is consistent with that of the probit regression. (4) By decomposing TBT effects on import share into extensive and intensive margins, we find that the extensive margin accounts for a greater proportion of the effects than the intensive margin in most cases, including the benchmark. TBT increase trade volumes primarily by expanding the range of goods traded, and not by increasing the trade value of those goods that are already being traded.

The decomposition strategy introduced in the previous subsection is applied only to trade relationships that have positive trade flows. Zero trade observations are not included in the sample of this section. While the probit estimation in section 3 shows that TBT decreases the probability of trade participation, the estimated results of the current section show that TBT increases the volume of trade, once the exporters decide to enter the market (positive trade flows).[6] The fact that TBT impede the export probability but promote the import share is interesting but not surprising. First, TBT can have a dual impact on production and trade costs. On the one hand, meeting a standard in each export market requires an individual fixed cost to establish the capacity and subsequently variable production costs (Ganslandt and Markusen, 2001; Chen et al., 2008). On the other hand, TBT can reduce exporters' information costs if they convey information on industrial requirements or consumer tastes that would be costly to collect in the absence of standards (Portugal-Perez et al., 2010). If the costs of adapting products to foreign markets are small relative to information costs, a positive effect might occur. Bao and Qiu (2010) found that TBT is more likely to have a trade promotion effect for products that are more sophisticated and for which consumers lack information about the quality of the imports, such as manufacturing products. Since we use data of all HS6 manufacturing products, the effect is expected to be positive. Second, for firms that have already entered a foreign market, TBT adopted by the importer may discourage the entry of potential competitors, which can increase the trade volumes of existing exporters. A similar explanation might be that when some marginalized countries are impeded from the export market, the resources reallocation effect allows the incumbent exporters receive larger import shares.

The cost effects and information effects of TBT may both differ by country group. On the one hand, the trade suppressing effect induced by higher compliance cost is expected to be stronger when TBT are imposed by developed countries than by developing countries. On the other hand, the trade promoting effects induced by more information could be stronger for developing importers' TBT than developed importers', since information is less transparent in developing countries. For developing countries, the positive information effect is more likely to outweigh the negative cost effect, leading to a greater positive effect on total import shares. Another explanation is that if the trade promotion effect of TBT is caused by reducing the entry of potential trade partners, this effect is likely to be stronger for countries that have more potential trade partners. Apparently, developing countries have fewer existing trade partners (or more potential trade partners) than developed countries, and thus

TBT imposed by developing countries can improve import performance more than that by developed countries.

5. The Effect of TBT on the Duration of Trade

The Duration of Trade and Survival Analysis

Estimations in sections 3 and 4 show that TBT influences the probability, extensive margin, and intensive margin of trade in different ways. In this section, we investigate the connection between TBT and the dynamic pattern of trade. Specifically, we use survival analysis to explore how TBT affect the duration of trade.

Trade duration indicates the length of time that a trade relationship has existed without a break. While the extensive and intensive margins measure a country's cross-sectional trade performance, the duration of trade represents how long a trade relationship has persisted before it is terminated. Besedeš and Prusa (2011) show that the survival of existing trade relationships plays a more important role in determining long-run export growth than building new trade relationships. The empirical trade literature finds that the duration of trade at the industry and product-level is surprisingly short, a medium of 2–3 years. The duration of trade relationship differs by industry, geographical region, and product type; and it is jointly determined by variables in the search model and gravity model (Besedeš and Prusa, 2006a,b; Nitsch, 2009; Chen, 2012).

Estimations in section 3 show that an increase of TBT between trading partners reduces the probability of international trade. Based on the evidence, TBT can also change the trade status between countries dynamically. Exporters that lack the capability of meeting the requirements of TBT will stop exporting. TBT increase the cost of trade, which may consequently terminate existing trade relationships. In addition, TBT may also provide additional information and act as protection by reducing competition for existing exporters that continue exporting after the imposition of TBT.

The TBT data are available for the period of 1995–2008. The UN Comtrade data used in this section record bilateral trade beginning sometime during 1995–2008 and ending before 2010, to be matched with the TBT data. Trade data are reported annually, and thus the duration of trade relationship is measured in years. For instance, Honduras had positive imports from the USA in 1995–2007 but not in 2008–2010; thus, the observed length of this trade relationship is 13 years. Nigeria has two spells of imports from the USA, each having a duration of 8 years (1996–2003) and 5 years (2006–2010), respectively. Multiple spells of the same country pair are treated as independent, and all spells are included in the survival analysis.

The observed duration of a trade relationship does not always equal the real duration owing to data censoring. For instance, the last year of the USA–Nigeria second spell is 2010, which is also the last year that trade data are available. It is quite possible that Nigeria will continue to import from the USA in 2011, but the information is not yet recorded in the current dataset. The length of this trade relationship should be interpreted as at least 5 years instead of exactly 5 years. Using observed duration as the dependent variable in regular regression models can lead to bias owing to data censoring, however. To account for data censoring, we use the Kaplan–Meier non-parametric estimator to study the duration of bilateral trade.[7] The average duration is 9.5 years. The survival probability of the first year is 77%, and that of the 16th year is 50%. About a quarter of trade relationships are termi-

nated within the first year after being established, but about half of them last 16 years or more. Even measured at the country level, variation in the duration of trade is large.

Trade duration also differs by country group. Trade between two developed countries has the largest average duration (12 years), while trade between developing countries has the least (8 years). The probability of survival in the 16th year for trade between two developed countries is 70%, while that between two developing countries is only 36%. Trade duration is greater if the exporter (importer) is a developed country than if it is a developing country.

Model Specification and Estimated Results

To explore the effect of TBT on trade duration, we estimate a Cox proportional hazard model that accounts for censoring:

$$h_s(t, x, \beta) = h_{s0}(t)e^{x'\beta} \tag{4}$$

where t denotes the survival time of a trade relationship, x represents a vector of covariates, and β is a set of coefficients to be estimated. The vector of covariates, x, includes the explanatory variables in equation (1) which are summarized in section 2. Each observation in the sample represents a spell of service. Covariates are merged with each spell by the starting year of the trade relationship, and dummies of starting year are included in the model. The baseline hazard ($h_{s0}(t)$) captures how hazard changes as a function of survival time t. A failure event represents the termination of an active trade relationship. The estimation accounts for censoring of trade relationships that begin in the first year (1995) or end in the last year (2010) of the sample.

The estimated hazard ratios of TBT, $e^{\hat{\beta}}$ is summarized in Table 1. When a covariate increases by one unit, the hazard rate (the conditional probability of failure) becomes $e^{\hat{\beta}}$ times as large as the original. A positive $\hat{\beta}$ is equivalent to a hazard ratio greater than one, which indicates that an increase in the covariate will raise the hazard rate and lead to a shorter duration of trade.

As in sections 3 and 4, we separate countries into different groups based on the level of development. The significant hazard ratios of TBT are all less than one: more TBT will decrease the hazard rate of trade failure, which will extend the duration of trade. In the benchmark case in column 1, if the number of TBT notifications is doubled, the hazard rate of an established trade relationship will become 0.976 times as large as the original, as long as other covariates remain unchanged. The hazard ratio is significantly less than one in six out of nine cases, and it is stronger for trade between developed and developing countries (columns 6 and 8). This trade-promoting effect of TBT is very different from that of the probit model. While the probit model shows how TBT affect the probability of positive trade between two countries, the Cox proportional hazard model shows how TBT affect the probability of failure conditional on a trade relationship that has already existed. For a trade relationship that has yet to be established, an increase in TBT will reduce the likelihood of trade establishment; but for country pairs that have already traded with each other, an increase in TBT will reduce the chance of failure and will extend trade duration. As in section 4, a possible explanation is that TBT provides protection to existing trade relationships by discouraging potential competitors from entering the market.

6. Conclusions

This paper explores how technical barriers to trade (TBT) affect different components of countries' trade performance. The estimations on trade probability, volume, and duration expand the scope of recent empirical work on TBT, and provide a deeper and more complete analysis of TBT's impacts on trade.

TBT can have both trade restricting and promoting effects. On the one hand, the imposition of TBT will increase the fixed and variable costs of trade, which is expected to restrict the probability and volume of trade, respectively. On the other hand, TBT can provide information to consumers, which will enhance consumers' confidence and increase trade flows. In addition, TBT can promote the trade performance of existing exporters by discouraging potential competitors from entering the market or by driving the marginal exporters out of the market.

The estimated results show that TBT decrease the probability of trade but increase the volume and duration of existing trade relationships. This finding indicates that for countries that have not traded with each other, the cost effect dominates, and thus the probability of trade decreases with TBT. For country pairs that have already traded with each other, the reallocation or information effects are more prominent, thus increasing the volume of trade and extending trade duration.

The empirical results presented here have important implications for the regulatory reform process of governments. In general, we find that the imposition of TBT can improve or worsen a country's trade performance along with its welfare. Since the imposition of TBT has the potential to improve a country's welfare, simply reducing the number of TBT is not always optimal policy in the trade liberalization process. Evidence of the TBT's negative impact on market entry suggests that trade preferences in virtue of international harmonization might be one way to promote market entry or market diversification, that is, expansion in the export market. The advantage of international harmonization is that it can limit the scope for regulatory protectionism, and thus attenuate any possible negative impacts of TBT, especially on developing exporters. We also find that the extensive margin (number of products traded) accounts for a major share of TBT's positive effects on trade volume, and expansion in the extensive margin is most likely to lead to welfare improvement for the exporters. The trade promotion effects of TBT on trade volume are greater and more significant when TBT are adopted by developing countries. These two pieces of evidence imply that TBT imposed by developing countries are likely to increase both the trade flows and the welfare of exporters that trade with these importing countries.

Several possible extensions of this paper may help better understand the trade effects of the TBT. Because we use aggregate TBT notifications at country level owing to data limitation, one potentially feasible project would be to use the available 30% TBT notifications at the product level to quantify the impact of TBT on trade. Another extension of this paper is related to the trade diversion effect. The current paper is limited to only the TBT imposing country and its export trade partners. TBT may have trade diversion effect as well, however, because firms are self-selected into those markets with looser standards. An interesting topic for future research is to examine the trade effect of TBT for third parties.

References

Anderson, James E. and Eric van Wincoop, "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review* 93 (2003):170–92.

Baldwin, Richard, "Regulatory Protectionism, Developing Nations and a Two-Tier World Trade System," CEPR discussion paper 2574 (2001).
Baldwin, Richard and Rikard Forslid, "Trade Liberalization with Heterogeneous Firms," *Review of Development Economics* 14 (2010):161–76.
Baller, Silja, "Trade Effects of Regional TBT Liberalization: A Heterogeneous Firms Approach," World Bank Policy Research working paper 4124 (2007).
Bao, Xiaohua and Larry D. Qiu, "Do Technical Barriers to Trade Promote or Restrict Trade? Evidence from China," *Asia-Pacific Journal of Accounting & Economics* 17 (2010):253–78.
———, "How Do Technical Barriers to Trade Influence Trade Flows?" *Review of International Economics* 20 (2012):691–706.
Beghin, John C. and Jean-Christophe Bureau, "Measurement of Sanitary, Phytosanitary and Technical Barriers to Trade," in *The Impact of Regulations on Agri-food Trade*, Paris, OECD (2001).
Besedeš, Tibor and Thomas J. Prusa, "Product Differentiation and Duration of US Import Trade," *Journal of International Economics* 70 (2006a):339–58.
———, "Ins, Outs, and the Duration of Trade," *Canadian Journal of Economics* 39 (2006b):266–95.
———, "The Role of Extensive and Intensive Margins and Export Growth," *Journal of Development Economics* 96 (2011):371–79.
Chen, Maggie Xiaoyang and Aaditya Mattoo, "Regionalism in Standards: Good or Bad for Trade?" *Canadian Journal of Economics* 41 (2008):838–63.
Chen, Maggie Xiaoyang, Tsunehiro Otsuki, and John S. Wilson, "Standards and Export Decisions: Firm-level Evidence from Developing Countries," *Journal of International Trade and Economic Development* 17 (2008):501–23.
Chen, Wei-Chih, "Innovation and Duration of Exports," *Economics Letters* 115 (2012):305–08.
———, "The Extensive and Intensive Margins of Export: The Role of Innovation," *The World Economy* 36 (2013):607–35.
Crozet, Matthieu and Pamina Koenig, "Structural Gravity Equations with Intensive and Extensive Margins," *Canadian Journal of Economics* 43 (2010):41–62.
Czubala, Witold, Ben Shepherd, and John S. Wilson, "Help or Hindrance? The Impact of Harmonized Standards on African Exports," *Journal of African Economies* 18 (2009):711–44.
Essaji, Azim, "Technical Regulations and Specialization in International Trade," *Journal of International Economics* 76 (2008):166–76.
Ferrantino, Michael, "Quantifying the Trade and Economic Effects of Non-tariff Measures," OECD Trade Policy working papers 28 (2006).
Fischer, Ronald and Pablo Serra, "Standards and Protection," *Journal of International Economics* 52 (2000):377–400.
Fontagné, Lionel, Mondher Mimouni, and Jean-Michel Pasteels, "Estimating the Impact of Environmental SPS and TBT on International Trade," *Integration and Trade Journal* 28 (2005):7–37.
Ganslandt, Mattias and James R. Markusen, "Standards and Related Regulations in International Trade: A Modeling Approach," NBER working paper 8346 (2001).
Helpman, Elhanan, Marc Melitz, and Yona Rubinstein, "Estimating Trade Flows: Trading Partners and Trading Volumes," *Quarterly Journal of Economics* 123 (2008):441–87.
Hummels, David and Peter J. Klenow, "The Variety and Quality of a Nation's Exports," *American Economic Review* 95 (2005):704–23.
Korinek, Jane, Mark Melatos, and Marie-Luise Rau, "A Review of Methods for Quantifying the Trade Effects of Standards in the Agri-food Sector," OECD working paper 79 (2008).
Lawless, Martina, "Deconstructing Gravity: Trade Costs and Extensive and Intensive Margins," *Canadian Journal of Economics* 43 (2010):1147–72.
Maskus, Keith E., Tsunehiro Otsuki, and John S. Wilson, "Empirical Framework for Analyzing Technical Regulations and Trade," in Keith E. Maskus and John S. Wilson (eds), *Quantify*

ing the Impact of Barriers to Trade: Can it be Done? Ann Arbor, The University of Michigan Press (2001).
Melitz, Marc J., "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica* 71 (2003):1695–725.
Moenius, Johannes, "The Good, the Bad and the Ambiguous: Standards and Trade in Agricultural Products," IATRC Summer Symposium, 28–30 May, Bonn, Germany (2006).
Nitsch, Volker, "Die Another Day: Duration in German Import Trade," *Review of World Economics* 145 (2009):133–54.
Portugal-Perez, Alberto, Jose-Daniel Reyes, and John S. Wilson, "Beyond the Information Technology Agreement: Harmonization of Standards and Trade in Electronics," *The World Economy* 33 (2010):1870–97.
Santos Silva, João and Silvana Tenreyro, "The Log of Gravity," *The Review of Economics and Statistics* 88 (2006):641–58.
Shepherd, Ben, "Product Standards, Harmonization, and Trade: Evidence from the Extensive Margin," World Bank Policy Research working paper 4390 (2007).
Xiong, Bo and Beghin, John, "Does European Aflatoxin Regulation Hurt Groundnut Exporters from Africa?" *European Review of Agricultural Economics* 39 (2012):589–609.

Notes

1. Maskus et al. (2001), Beghin and Bureau (2001), Ferrantino (2006), Korinek et al. (2008) among others for a review of TBT quantifying methods and its economic effects (including trade effects).
2. This variable equals one if countries were or are belonging to the same state or the same administrative entity for a long period. For example, countries belong to the same empire or belong to the same administrative colonial area.
3. There are 106 countries and economies in the WTO TBT report database, but trade data are available for only 103 countries of them. Some of the data for Qatar, Taiwan, and EU are unavailable and have therefore been dropped. According to the World Bank's standards in 2008, countries can be classified into three groups depending on per capita income. We treat the high income group as the developed countries, and the middle income and low income groups as the developing countries. By this definition, among 103 countries in the dataset, 39 are developed countries and 64 are developing countries.
4. The complete regression results of TBT effects on trade probability are omitted to save space. We do so for TBT effects on all the components of trade, including the extensive/intensive margins in section 4 and duration in section 5.
5. TBT can have a lag effect on trade performance. To check the possible lagged effect, we replace the current TBT with lagged TBT (from one to three years, respectively) in the estimation. The main result does not change. However, the effect of lagged TBT is weaker than that of the current TBT. The estimates indicate that the impact of TBT on trade performance is stronger in the year of submission than in later years.
6. We also estimate the model in equation (1) with the Poisson pseudo-maximum-likelihood (PPML) estimator proposed by Santos Silva and Tenreyro (2006), in which zero trade observations are included. The coefficients on TBT are negative but less significant, which is in line with our expectation: the negative effect on trade participation and the positive effect on the volume of existing trade relationships offset each other. When these two effects are considered concurrently, the influence of TBT on trade performance becomes less significant. We appreciate a referee's suggestion on estimating the model accounting for zero trade.
7. The complete estimated results using the Kaplan–Meier estimator are omitted to save space.