FIW – Working Paper

FIW Working Paper N°14
February 2008

Sorting It Out: Technical Barriers to Trade and Industry Productivity

Gabriel J. Felbermayr
and
Benjamin Jung

Abstract

Trade economists traditionally study the effect of lower variable trade costs. While increasingly important politically, technical barriers to trade (TBTs) have received less attention. Viewing TBTs as fixed regulatory costs related to the entry into export markets, we use a model with heterogeneous firms, trade in differentiated goods, and variable external economies of scale to sort out the rich interactions between TBT reform, input diversity, firm-level productivity, and aggregate productivity. We calibrate the model for 14 industries in order to clarify the theoretical ambiguities. Overall, our results tend to suggest beneficial effects of TBT reform but also reveal interesting sectoral variation.

JEL classifications: F12, F13, F15;
Keywords: Heterogeneous firms, international trade, single European market, technical barriers to trade, regulatory costs;

The authors

Gabriel J. Felbermayr is Assistant Professor at the Eberhard Karls University Tübingen. E-Mail: gabriel.felbermayr@uni-tuebingen.de
Benjamin Jung is staff member at the Economics Department at the University of Tübingen. E-Mail: Benjamin.jung@uni-tuebingen.de

*This paper was previously published as Tübinger Diskussionbeitrag N°315 in February 2008

1 Introduction

In the last fifty years, import duties on most relevant manufacturing goods have fallen substantially. A rising fraction of total trade is covered by free trade agreements and is therefore exempt from tariffs. Yet, even within the European Union only about 10% of total spending falls on products from other EU15 countries (Delgado, 2006). Chen (2004) explains this striking fact i.a. by the existence of *technical barriers to trade* (TBTs). TBTs impose additional export market access costs. Exporters must customize their goods to meet the import country's technical norms, its health, safety, or environmental norms, and must undergo costly product labeling and conformity assessment procedures.

Both the European Union (EU) and the World Trade Organization (WTO) acknowledge that TBTs may serve a multitude of legitimate goals; however, regulation that effectively protects incumbent domestic firms against foreign competition is deemed discriminatory and is therefore illegal. Within the context of the Single Market Programme (SMP), the EU champions *mutual recognition* of technical standards.[1] However, Ilzkovitz, Dierx, Kovacs, and Sousa (2007) argue that while about 20% of industrial production and about 26% of intra EU manufacturing trade are covered by mutual recognition, "practical implementation [...] is often hampered by legal uncertainty, administrative hassle and lack of awareness both from the side of the companies and of the Member States' authorities" (p. 61).

Progress in dismantling TBTs has been slow. The number of TBT-related complaints notified to the WTO has grown from 365 in 1995 to almost 900 in 2006 (WTO, 2007). Similarly, Conway, Janod, and Nicoletti (2005) document the persistence of discriminatory regulation in the OECD. According to the Fraser Institute, the stringency of regulatory barriers to trade has increased in many EU countries from 1995-2005 (see Gwartney, Lawson, Sobel, and Leeson, 2007). TBT related issues are increasingly important in trade negotiations. Indeed, harmonizing standards

[1]The principle of mutual recognition mandates that a product lawfully marketed in one EU country should be allowed to be sold in any other EU country even when the product does not fully comply with the technical rules in the destination country. However, countries can refuse market access for public safety, health, and environmental reasons (Articles 28 and 30 of the EC Treaty; similar regulation appears in the WTO TBT Agreement in Article 2.)

and rules rather than abolishing tariffs and quotas are "the real 21st century trade issues" (Pascal Lamy).[2]

Despite the importance of TBTs, the theoretical literature has usually focused on variable trade costs such as transportation costs or tariffs. In this paper, we model TBT liberalization as a reduction in the fixed *regulatory* costs of foreign market access. We study two scenarios. In the first, the reduction of regulatory burdens on importers is accompanied by domestic deregulation such that the implicit protection of domestic firms, T, is unchanged. We call this situation *T-neutral deregulation*. In the second scenario, regulatory requirements imposed on importers are reduced while those on domestic firms remain unchanged. We call this case *incremental mutual recognition*, since it leads towards a situation of full mutual recognition where meeting domestic regulation is enough to access foreign markets. Both scenarios are relevant empirically.

We analyze these two scenarios in a model of international trade in differentiated goods with heterogeneous firms. Out setup is essentially the one of Melitz (2003), with the difference that we focus on aggregate productivity (not welfare) and allow for *variable degrees of external scale economies* in the final good production function (as Egger and Kreickemeier, 2007). We do this, because recent literature (e.g., Corsetti, Martin, and Pesenti, 2007) has established how important the size of the scale effect is as a major determinant of the qualitative and quantitative implications of trade liberalization. Moreover, empirical work points towards substantial industry variance and generally rejects the implicit numerical choice of the scale effect parameter embodied in the traditional formulation of the Melitz (and, indeed, most Krugman (1980)-type trade models). As many other authors,[3] we work with a specific productivity distribution (Pareto) to sort out ambiguities and to parameterize the model for simulation purposes.

In the proposed framework, TBT reform affects the equilibrium *input diversity* (i.e., the mass of imported and domestic varieties) available in an industry, which affects the productivity of final goods producers through an external effect. TBT reform also modifies the equilibrium productivity distribution of input producers and, hence, their *average productivity*. These two

[2]EU and Asean to pave way for trade pact talks, Financial Times, 7 September 2004. At that time, Lamy was EU trade commissioner. He is now Director-General of the WTO.

[3]Egger and Kreickemeier (2007), Baldwin and Forslid (2006), Helpman, Melitz, and Yeaple (2004), etc.

forces determine the effect on industry productivity, with their relative importance given by the external scale elasticity.

Incremental mutual recognition changes the extensive margin of firm behavior; i.e., it modifies the selection of input producers into exporting and domestic sales.[4] It also affects the intensive margin, as additional competitive pressure lowers sales per firm. The two effects lead to reallocation of resources towards medium-productivity new exporters, away from the upper and lower areas of the productivity distribution. The net reallocation effect that drives average productivity of input producers depends on the relative importance of these two countervailing reallocation effects. Also the effect on input variety is theoretically unclear. It depends on industry characteristics; e.g., on the degree of productivity dispersion. It is therefore not surprising that the total effect of TBT reform on industry productivity is a complicated function of model parameters. The contribution of this paper is to analytically sort out those ambiguities.

The theoretical analysis has a couple of interesting implications. First, it may rationalize the low robustness of a positive relationship between trade openness and economic growth (see Rodríguez and Rodrik, 2000). Both variable and fixed cost trade liberalization lead to a higher volume of trade, thereby increasing openness. However, for similar parameter constellation, the former unambiguously improves productivity while the latter does not. Second, our paper suggests that the productivity effect of lower variable trade costs is importantly conditioned by the existence of fixed costs protection. Indeed, if TBTs are too high, lower transportation costs may turn out to lower industry productivity.

We offer an industry-by-industry calibration exercise in order to numerically validate whether the conditions hold under which TBT reform improves aggregate outcomes. In this *local* analysis, TBT reform turns out to reduce the productivity of the average input supplier. However, the increase in input variety more than compensates those losses, so that industry productivity improves. We also simulate the model and compare the status quo with a situation where technical requirements are harmonized across countries. This being a *global* exercise and the

[4]The selection effects rely on firm heterogeneity. Firms select themselves into exporting according to their productivity. There is overwhelming empirical evidence that this is indeed the case, see the survey by Helpman (2006).

effects of TBT reform being non-linear, it turns out that not all industries (e.g., machinery) gain from the reform. Many do gain, but only very modestly, while others experience massive productivity improvements (e.g., 35% in the case of scientific equipment).

Our paper is related to a number of studies, many of them inspired by the Single Market Programme. Using a partial equilibrium framework, Smith and Venables (1988) simulate the abolishment of trade barriers in terms of tariff equivalents between European countries. Keuschnigg and Kohler (1996) simulate the general equilibrium growth and welfare effects of lower variable trade costs in a multi-sector Krugman-type model, where scale economies play an important role. A similar simulation is done by Francois, Meijl, and van Tongeren (2005). The latter authors imulate a simultaneous cut in tariffs and TBTs, and obtain a real income gain of 0.3% to 0.5% of global GDP, depending on the country coverage.

The older literature uses models with homogeneous firms and studies the effects of lower variable trade costs. More recently, Del Gatto, Mion, and Ottaviano (2007) and Corcos, Del Gatto, Mion, and Ottaviano (2007) focus on the productivity effects of intra-EU variable trade costs reduction under quasi-linear preferences with heterogeneous firms and provide simulation results. Our paper differs, since we use the Melitz (2003) model as a point of departure and relate TBT to fixed costs of market access.

Baldwin and Forslid (2006) provide an excellent discussion of trade policy in the standard Melitz (2003) model. They also address lower market access costs and discuss the implication for the trade volume. Our paper differs from theirs in that it sorts out the intricate implications of TBT reform on industry productivity. Moreover, we allow for variable degrees of external scale economies and offer a calibration exercise.

The remainder of the paper is organized as follows. Chapter 2 introduces the analytical framework and solves for general equilibrium. Chapter 3 theoretically derives conditions under which TBT reform increases productivity, and Chapter 4 calibrates the model in order to validate these conditions for different industries. Finally, Chapter 5 concludes.

2 Theoretical framework

2.1 Demand for inputs

We study a single market (such as the EU) with $n+1$ identical countries. Each country is populated by a representative consumer who has symmetric Cobb-Douglas preferences for final consumption goods produced by H industries. Final output producers in each industry h are perfectly competitive. They assemble their output using a continuum of inputs $q(\omega)$ according to the same constant elasticity of substitution (CES) production function

$$y_h = M_h^{\frac{\eta_h - 1}{\sigma_h - 1}} \left(\int_{\omega \in \Omega_h} q(\omega)^{\frac{\sigma_h - 1}{\sigma_h}} d\omega \right)^{\frac{\sigma_h}{\sigma_h - 1}}, \sigma_h > 1, \eta_h \geq 0. \tag{1}$$

The set Ω_h represents the mass of available inputs in industry h, and σ_h is the elasticity of substitution between any two varieties in that industry. M_h is the measure of Ω_h and denotes the degree of *input diversity* (the number of available differentiated inputs). Expression (1) is analogous to the traditional CES production function for $\eta_h = 1$.[5] For $\eta_h = 0$, there are no external economies of scale. In the standard treatments of the Melitz (2003) or the Krugman (1980) models, the implicit choice of $\eta_h = 1$ links the effect of input diversity on output directly to the elasticity of substitution σ_h. Recent empirical work finds that $\eta_h < 1$, rejecting the standard formulation (Ardelean, 2007).

The optimal demand quantity for each input ω is

$$q(\omega) = \left(\frac{p(\omega)}{P_h} \right)^{-\sigma_h} \frac{R_h / P_h}{M_h^{1-\eta_h}}, \tag{2}$$

where R_h is aggregate industry spending on inputs, $p(\omega)$ is the price charged by an input producer to the final output producers, and

$$P_h = M_h^{-\frac{\eta_h - 1}{\sigma_h - 1}} \left(\int_{\omega \in \Omega_h} p(\omega)^{1-\sigma_h} d\omega \right)^{\frac{1}{1-\sigma_h}} \tag{3}$$

[5] The generalization is already discussed in the working paper version of the Dixit-Stiglitz (1977) paper and has been revived by Benassy (1996). Variants of it have been adopted by Blanchard and Giavazzi (2003), Egger and Kreickemeier (2007), Corsetti, Martin, and Pesenti (2007), or Felbermayr and Prat (2007).

is the price index dual to (1). Clearly, demand for variety ω is larger the smaller the price $p(\omega)$ relative to the average price of competing varieties P_h, and the larger real spending R_h/P_h. Higher input diversity M_h affects demand through two channels: indirectly, through its effect on the price level, and, if $\eta_h \neq 1$, directly, through the reduction of relevant real spending $(R_h/P_h)/M_h^{1-\eta_h}$ on each variety ω. Markups over marginal costs are constant in this framework; nevertheless we find it useful to call M_h a competition effect.

2.2 Production of inputs

Differentiated inputs are produced by a continuum of monopolistically competitive firms. Each industry draws on a single industry-specific factor L_h, which is inelastically supplied in equal quantities to all industries in all countries. Industry specificity of factors and the Cobb-Douglas utility function make sure that trade reforms generate only within rather than between-industry resource reallocation.

Input producers differ with respect to their productivity index φ; in the following we use this index instead of ω to identify firms.[6] They share the same domestic and foreign market entry costs, f_h^d and f_h^x, and the same iceberg variable trade costs $\tau_h \geq 1$. All fixed costs have to be incurred in terms of the industry-specific factor. $T_h \equiv f_h^x/f_h^d$ measures the *competitive disadvantage* of imported relative to domestically produced inputs. To ensure the existence of the selection effect (and in line with empirical evidence) we assume $\tau_h^{\sigma_h-1}T_h > 1$.

Following Melitz (2003), we assume that firms are *ex ante* identical but face uncertainty regarding their productivity φ. They learn about φ only after sinking the entry cost f_h^e. Not all of those entrants turn out to be productive enough to bear the domestic fixed costs f_h^d. Hence, they remain inactive. Firms with intermediate productivity sell on the domestic market, but cannot recover the additional fixed costs associated to foreign sales, f_h^x. The most productive firms are active on all markets. Under the assumption $\tau_h^{\sigma_h-1}T_h > 1$, there exist threshold productivity levels $0 < \varphi_h^* < (\varphi_h^x)^*$, which partition the distribution of input producers into

[6] This is possible because, in equilibrium, each input is produced by one firm only and the distribution of φ is assumed to have no mass points.

inactive firms, purely domestic ones, and exporters.

We characterize the *ex ante* productivity distribution by the Pareto.[7] The c.d.f. is $G_h(\varphi) = 1-\varphi^{-\gamma_h}$ with support on $[1,\infty)$, where the shape parameter $\gamma_h > \sigma_h - 1$ controls the dispersion of the distribution.[8]. Larger values of γ_h characterize industries in which the productivity distribution is skewed towards inefficient input producers. We can then write the probability that a given entrant (that has just paid the entry fee f_h^e) starts production by $p_h^{in} = 1-G(\varphi_h^*) = (\varphi_h^*)^{-\gamma_h}$. Analogously, $p_h^x = \frac{1-G[(\varphi_h^x)^*]}{1-G(\varphi_h^*)} = [\varphi_h^*/(\varphi_h^x)^*]^{\gamma_h}$ is the *ex-ante* (and *ex-post*) probability that one of these successful entrants will export.

Input producers have linear production functions $q(\varphi) = \varphi l_h(\varphi)$, where $l_h(\varphi)$ denotes the employment of the industry-h specific factor in firm φ. Profit maximization of input producers results in the standard rule for determining the ex-factory (f.o.b.) price, i.e. $p_h(\varphi) = w_h/(\rho_h\varphi)$, where $\rho_h = 1-1/\sigma_h$. Since the description of technology (1) is identical over all countries, we may pick the factor price specific to some industry, w_h, as the numeraire. In the following, we focus on that industry.

Optimal demand (2) and the pricing rule of input producers imply that revenues earned on the domestic market are given by

$$r_h^d(\varphi) = R_h (P_h\rho_h\varphi)^{\sigma_h-1}/M_h^{1-\eta_h}. \tag{4}$$

By symmetry, producers who find it optimal to sell to a foreign market generate revenues of $r_h(\varphi) = r_h^d(\varphi)\left(1+n\tau_h^{1-\sigma}\right)$. In turn, profits from selling domestically and exporting to one foreign market are respectively given by

$$\pi_h^d(\varphi) = r_h^d(\varphi)/\sigma_h - f_h^d, \tag{5}$$

$$\pi_h^x(\varphi) = \tau_h^{1-\sigma} r_h^d(\varphi)/\sigma_h - f_h^d T_h. \tag{6}$$

[7]This assumption is not necessary for many properties of the model; see Melitz (2003). However, it allows to understand the importance of industry dispersion to sort out the potentially ambiguous effects of various forms of trade liberalization on industry productivity. The Pareto has been used, i.a., by Melitz, Helpman, and Yeaple (2004), Baldwin and Forslid (2006) or Egger and Kreickemeier (2007). It fits well empirically, see Axtell (2001) or Corcos, Del Gatto, Mion, and Ottaviano (2007).

[8]The assumption $\gamma_h > \sigma_h - 1$ makes sure that the equilibrium sales distribution converges.

2.3 Industry aggregation

The productivity of final output producers (*industry productivity)* depends on *input diversity* (the number of available inputs), and on the *average productivity* level of input producers. Input diversity has a domestic and an imported component: $M_h = M_h^d + nM_h^x$, where n is the number of identical import (and, by symmetry: export) markets. Since $M_h^x = p_h^x M_h^d$, one can express M_h as $M_h = M_h^d \left(1 + np_h^x\right)$.

The average productivity level of domestic input producers, $\tilde{\varphi}_h^d$, is defined as the mean over sales-weighted productivities of all active producers.[9] Using the Pareto assumption,

$$\left(\tilde{\varphi}_h^d\right)^{\sigma_h - 1} = \frac{\int_{\varphi_h^*}^{\infty} \varphi^{\sigma_h - 1} dG_h\left(\varphi\right)}{1 - G\left(\varphi_h^*\right)} = \frac{\gamma_h}{\gamma_h - \left(\sigma_h - 1\right)} \left(\varphi_h^*\right)^{\sigma_h - 1}. \tag{7}$$

Equation (7) shows that the endogenously determined entry cutoff productivity level φ_h^* shapes the average productivity of domestically produced inputs. The average over exporters, $\tilde{\varphi}_h^x$, is constructed analogously, and crucially depends on the export cutoff productivity level $\left(\varphi_h^x\right)^*$.

Given perfect *symmetry* across countries, the average productivity of inputs used in production of the final good, $\tilde{\varphi}_h$, is

$$\left(\tilde{\varphi}_h\right)^{\sigma_h - 1} = \frac{1}{1 + np_h^x} \left(\tilde{\varphi}_h^d\right)^{\sigma_h - 1} + \frac{np_h^x}{1 + np_h^x} \left(\frac{\tilde{\varphi}_h^x}{\tau_h}\right)^{\sigma_h - 1}, \tag{8}$$

where productivities of foreign firms are adjusted for iceberg transportation costs τ_h and average productivities of domestic and imported varieties are weighted by their respective shares in total input diversity.

The weighting in (8) implies that $q\left(\tilde{\varphi}_h\right) = R_h M_h^{-\frac{\eta_h + \sigma_h - 1}{\sigma_h - 1}} / P_h$. In $\eta_h = 0$ (i.e., in the absence of industry externalities), the output of the average firm is equal to average output $R_h / \left(P_h M_h\right)$. Similarly, applying (8) to the industry price index (3), one has $P_h = M_h^{-\frac{\eta_h}{\sigma_h - 1}} p\left(\tilde{\varphi}_h\right)$. Hence, if $\eta_h = 0$, the price index is equal to the price chosen by the average firm.

Using optimal pricing of inputs in P_h and recognizing that aggregate productivity $A_h = 1/P_h$, we are now ready to write the level of aggregate *industry productivity* as a function of average

[9] See Melitz (2003), p. 1700.

productivity and input diversity

$$A_h = \rho \tilde{\varphi}_h M_h^{\frac{\eta_h}{\sigma_h - 1}}. \tag{9}$$

Industry productivity[10] increases as ρ goes up so that markups and the amount of resources used for fixed costs are lower. Industry productivity is directly proportional to average productivity of input producers $\tilde{\varphi}_h$. It depends positively on input diversity M_h as long as η_h is strictly positive. The term $\frac{\eta_h}{\sigma_h - 1}$ is the elasticity of industry productivity with respect to input diversity.[11] The aim of the subsequent analysis is to understand how A_h changes with different types of TBT reform. To do this, we need to endogenize $\tilde{\varphi}$ and M_h. Typically, TBT liberalization moves these two components of industry productivity in opposite directions. Hence, the elasticity $\frac{\eta_h}{\sigma_h - 1}$ will play a crucial role.

2.4 General equilibrium

In this section, we solve for the equilibrium values of M_h and $\tilde{\varphi}_h$. The discussion is deliberately brief, since it is close to Melitz (2003) and to Baldwin and Forslid (2006); the only difference comes through $\eta_h \neq 1$. Equilibrium is determined by four conditions.

Zero cutoff profit (ZCP) conditions. The domestic ZCP condition identifies the firm φ_h^* that is indifferent between selling domestically and remaining inactive; the foreign ZCP condition locates the firm $(\varphi_h^x)^*$ that is indifferent between selling domestically and also selling on the n symmetric foreign markets. Formally, the ZCPs are

$$\pi_h^d(\varphi_h^*) = 0, \qquad \pi_h^x[(\varphi_h^x)^*] = 0. \tag{10}$$

Using the profit functions derived in (5) and (6), the zero cutoff profit conditions imply that $r_h^d(\varphi_h^*) = \sigma_h f_h^d$ and $r_h^d[(\varphi_h^x)^*] = \sigma_h f_h^d \tau_h^{\sigma_h - 1} T_h$. Then (4) links the export cutoff $(\varphi_h^x)^*$ and the

[10]This is the *ideal* measure of industry productivity. Measuring productivity empirically is not trivial (see Levinsohn and Petrin, 2003). Gibson (2006) points out that productivity effects induced by Melitz (2003)-type reallocation of market shares within industries are not reflected by data-based measures of productivities, (e.g., value added per worker).

[11]If $\eta_h = 1$, (9) is formally equivalent to the expression describing total welfare in Melitz (2003).

domestic entry entry cutoff φ_h^*[12]

$$(\varphi_h^x)^* = \varphi_h^* \tau_h T_h^{\frac{1}{\sigma_h - 1}}. \tag{11}$$

Moreover, using the definition of $\tilde{\varphi}_h^d$ (7) and the condition linking the two cutoff productivities (11), one can link the average productivity of domestic firms with those of exporters

$$\tilde{\varphi}_h^x = \tau_h T_h^{\frac{1}{\sigma_h - 1}} \tilde{\varphi}_h^d. \tag{12}$$

It follows from (11) that the probability of exporting conditional on successful entry is given by

$$p_h^x = \tau_h^{-\gamma_h} T_h^{-\frac{\gamma_h}{\sigma_h - 1}}. \tag{13}$$

Our results so far allow to express average productivity $\tilde{\varphi}_h$, as defined in (8), by using (12)

$$\tilde{\varphi}_h = \tilde{\varphi}_h^d \left(\frac{1 + n p_h^x T_h}{1 + n p_h^x} \right)^{\frac{1}{\sigma_h - 1}}. \tag{14}$$

Both the domestic and the foreign market ZCPs can be combined and graphed in $(\varphi_h^*, \bar{\pi}_h)$ −space by using the definition of average profits (defined over active firms, *ex post* perspective) $\bar{\pi}_h = \pi_h^d \left(\tilde{\varphi}_h^d \right) + n p_x^x \pi_h^x \left(\tilde{\varphi}_h^x \right)$ and noting that $\tilde{\varphi}_h^d$ and $\tilde{\varphi}_h^x$ are both functions of φ_h^*. It is well known that, given the Pareto assumption, average profits $\bar{\pi}_h$ do not depend on φ_h^*.[13]

Free entry. The free entry condition ensures that *expected* profits (from the ex ante perspective) cover entry costs f_h^e :

$$\frac{p_h^{in} \bar{\pi}_h}{\delta_h} = f_h^e, \tag{15}$$

where δ_h is the exogenous Poisson exit rate of producers and $p_h^{in} = (\varphi_h^*)^{-\gamma_h}$ is the likelihood that a random productivity draw allows a producer to at least break even on the domestic market. Clearly, this free entry condition defines an upward-sloping relationship between $\bar{\pi}_h$ and φ_h^*. Equating that condition with the combined ZCP condition discussed above, one can determine the entry cutoff productivity level φ_h^* as a function of exogenous variables only[14]

$$\varphi_h^* = \left[\frac{\sigma_h - 1}{\gamma_h - (\sigma_h - 1)} \frac{f_h^d}{\delta_h f_h^e} \left(1 + n p_h^x T_h \right) \right]^{\frac{1}{\gamma_h}}. \tag{16}$$

[12]Derivations of analytical results are detailed in the Appendix.

[13]See, e.g., Baldwin and Forslid (2006).

[14]Noting that (13) relates p_h^x to exogenous variables.

Substituting φ_h^* into the definition of the *domestic* average productivity (7) one can determine $\tilde{\varphi}_h^d$. Finally, using (13) and (14) allows to compute the average productivity defined over all input producers, $\tilde{\varphi}_h$. Note that the above analysis has not used any factor market clearing condition; $\tilde{\varphi}_h$ is therefore independent from L_h. Moreover, when solving for $\tilde{\varphi}_h$, input diversity is irrelevant. Input diversity M_h can be found recursively, i.e., *given* $\tilde{\varphi}_h$.

Stationarity condition. The fourth equilibrium condition allows to pin down input diversity. In a stationary equilibrium, in any country, the mass of successful entrants $p_h^{in} M_h^e$ must equal the mass of producers hit by the exit shock $\delta_h M_h^d$. Hence,

$$p_h^{in} M_h^e = \delta_h M_h^d. \tag{17}$$

As shown in Melitz (2003, p. 1704), under stationarity, aggregate revenue R_h is fixed by the size of L_h (and the normalization of the $h-$factor price). This determines downs equilibrium input diversity by $M_h = R_h / r^d (\tilde{\varphi}_h)$. Using the zero cutoff profit conditions (10), we obtain equilibrium industry diversity

$$M_h = \frac{L_h}{\sigma_h f_h^d} \left(\frac{\varphi_h^*}{\tilde{\varphi}_h} \right)^{\sigma_h - 1}. \tag{18}$$

3 Industry productivity effects of TBT reform

Totally differentiating industry productivity (9) yields

$$\hat{A}_h = \frac{\eta_h}{\sigma_h - 1} \hat{M}_h + \widehat{\tilde{\varphi}}_h. \tag{19}$$

We use the conventional 'hat' notation to denote an infinitesimally small deviation of a variable from its initial level ($\hat{x} = dx/x$). Any type of trade liberalization has potential implications for the cutoff productivity levels φ_h^* and $(\varphi_h^x)^*$, and hence for productivity averages of domestic and international firms, $\tilde{\varphi}_h^d$ and $\tilde{\varphi}_h^x$, respectively. The productivity level of the average firm $\tilde{\varphi}_h$ is a weighted average over domestic and international firms, with the relative weights potentially being affected by TBT reform, too. Different trade liberalization scenarios may have similar effects on cutoff productivities (the *extensive* margin); yet, they may lead to drastically different patterns of inter-industry resource reallocation along the *intensive* margin, and, hence, different results for industry productivity. The literature has not fully recognized this point yet.

Input diversity adjusts to changes in the entry cutoff $\tilde{\varphi}_h$ and average productivity φ_h^* such that factor markets clear (see equation (18)). For the assessment of industry productivity, both effects need to be combined, with the elasticity $\eta_h / (\sigma_h - 1)$ playing a crucial role. Hence, the overall effect of TBT reform on industry productivity works through a number of different mechanisms and is likely to be ambiguous theoretically. In the extreme case where $\eta_h = 0$ (Blanchard and Giavazzi, 2003), (19) simplifies substantially as variation in input diversity has no bearing on industry productivity. Also the case where $\eta_h = 1$, typically studied in the literature, turns out offer more clear-cut results. In this special case ((19)) is formally isomorphic to the description of welfare in the Melitz (2003) model. The contribution of the present paper is to discuss the empirically relevant situation where $\eta_h \in (0, 1)$ and to focus on TBT reform rather than on the more widely studied case of variable trade cost liberalization.

We assume that fixed market costs f_h^d and f_h^x have two components: fixed *distribution costs*, $\bar{f}_h^d$ and $\bar{f}_h^x$, and fixed regulatory costs, $\tilde{f}_h^d$ and $\tilde{f}_h^x$, that relate to approval and conformity assessment costs. The latter is set by national authorities, but differs from a tax since it does not generate revenue. We define as a TBT reform any policy measure that reduces regulatory costs for foreign firms $\tilde{f}_h^x$. Hence, harmonization of standards, i.e., $\tilde{f}_h^d = \tilde{f}_h^x$, need not be a TBT reform. Full-fledged *mutual recognition* of standards, in contrast, would make licensing procedures for imported varieties redundant, hence $\tilde{f}_h^x = 0$. Only in this case do TBTs disappear entirely.

We consider two scenarios of TBT reform. In the first, policy makers lower the burden on foreign firms $\tilde{f}_h^x$, but also adjust regulatory costs for domestic firms $\tilde{f}_h^d$ such that the competitive disadvantage of foreign firms, T_h, remains unchanged. We term this case *T-neutral deregulation.* In the second scenario, $\tilde{f}_h^x$ is reduced, while $\tilde{f}_h^d$ remains fixed. Any marginal reduction in $\tilde{f}_h^x$ brings the economy closer to the ideal situation of full mutual recognition. Hence, we call our second scenario *incremental mutual recognition.* Throughout, we assume that distribution-related fixed costs are such that the partitioning of firms into exporters and purely domestic firms is maintained (i.e. $\bar{f}_h^x / f_h^d > \tau_h^{1-\sigma_h}$).[15]

[15]Deregulation of entry costs (f_h^e) is beyond the scope of this paper. Lower entry costs induce additional

3.1 T-neutral deregulation

In this scenario, f_h^x and f_h^d both fall, but T_h remains constant. Therefore, the export probability p_h^x (13), which depends on fixed market access costs only through T_h, is fixed. It is also clear, that the domestic φ_h^* and the export cutoff productivity levels $(\varphi_h^x)^*$ move proportionally (see (11)). To understand the effect of T-neutral deregulation, note that φ_h^* is determined in $(\varphi_h^*, \bar{\pi}_h)$ −space by the intersection of the ZCP condition and the free entry condition. In the present context, the first is a horizontal line, while the latter is upward-sloping. Domestic deregulation does not affect the free entry locus. However, the ZPC condition shifts downwards, so that φ_h^* falls. The reasoning is as follows. The ZCP locus summarizes combinations of $\bar{\pi}_h$ and φ_h^* for which the marginal firm φ_h^* just breaks even. When fixed costs f_h^d fall, the firm starts to make profits. To restore zero profits, the firm's revenue has to fall. This is achieved by tighter competition: either relative prices have to increase or residual demand has to drop. This is however not limited to firm φ_h^*; profits fall for all firms; hence $\bar{\pi}_h$ goes down.

The effect on the cutoff productivities at hand, one can now use Figure 1 to gain some intuition on the reallocation of market shares that domestic deregulation entails. The figure shows sales $r_h(\varphi)$ per firm as a function of productivity. This locus is upward-sloping as more efficient firms have higher sales (given $\sigma > 1$). Since total sales R_h are pinned down by L_h, r_h can be read as a measure of market share. The sales function changes with T-neutral deregulation.[16] Due to the increase in the number of traded varieties, competition goes up, which means that incumbent exporters and domestic-only firms lose market share (intensive margin).

Since domestic and foreign market entry costs fall in proportion, the probability of exporting, given successful entry, does not change (see equation (13)). Moreover, the entry cutoff levels shift proportionally. Hence, the reallocation of market shares towards less productive firms directly translates into a decrease in average productivity. We shall discuss the effect on average

entry, which increases competition and reduces realized profits, resulting in a (proportional) shift of the cutoff productivity levels to the right and an increase in average productivity (see Bernard, Redding, and Schott, 2005, and Felbermayr and Prat, 2007, in slightly different settings).

[16] Figure 2 in Melitz (2003) which studies the reallocation of market shares as an economy moves from autarky to trade. Our Figure 1 is similar, but studies incremental trade liberalization.

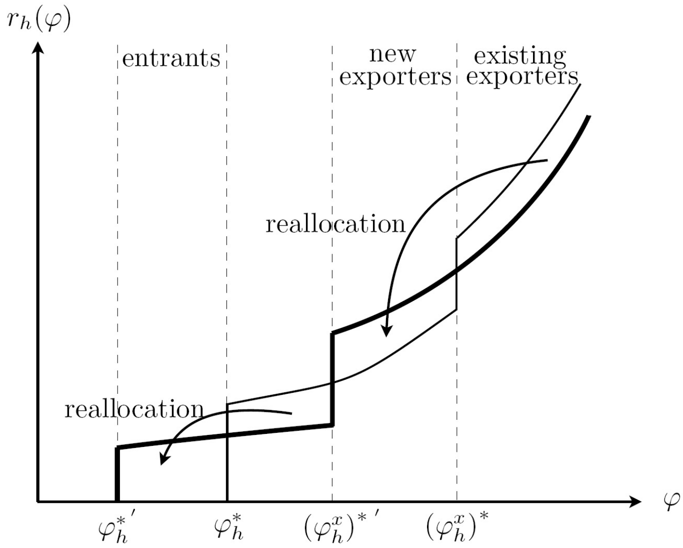

Figure 1: Within-industry reallocation of market shares as response to T-neutral deregulation.

productivity, input diversity, and industry productivity in more detail below.

Average productivity of input producers. The change in average productivity is completely driven by the change in the entry cutoff productivity level, i.e.$\widehat{\tilde{\varphi}}_h/\hat{f}_h^d = \hat{\varphi}_h^*/\hat{f}_h^d$ (see (14) and (7)). Totally differentiating (16) yields[17]

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{f}_h^d} = \frac{1}{\gamma_h} > 0. \tag{20}$$

Thus, average productivity declines in response to T-neutral deregulation. The parameter γ_h is inversely related to the degree of productivity dispersion (heterogeneity) in the industry. In the extreme case where $\gamma_h \to \infty$, all firms are identical and there cannot be any selection or reallocation effect (as long as all firms remain exporters or purely domestic). The room of reallocation is bigger as γ_h is smaller and industry heterogeneity is larger. It is therefore natural that the effect of T-neutral deregulation on average productivity is larger the smaller γ_h.

[17]Recall that changes in the regulatory component directly translate into changes in total market access costs, i.e. $\hat{f}_h^d = \widehat{\tilde{f}}_h^d$

Input diversity. As argued above, lowering fixed market entry costs attracts new input producers to start production and makes it profitable for additional firms to export. The change in input diversity is given by $\hat{M}_h = -\hat{f}_h^d + (\sigma_h - 1)\left(\hat{\varphi}_h^* - \widehat{\widetilde{\varphi}}_h\right) < 0$. In the present scenario, the entry cutoff productivity level $\hat{\varphi}_h^*$ and average productivity $\widehat{\widetilde{\varphi}}_h$ move proportionally. Hence, the elasticity of input diversity with respect to f_h^d is

$$\frac{\hat{M}_h}{\hat{f}_h^d} = -1. \tag{21}$$

Industry productivity. The industry productivity effect combines the input diversity effect and the effect on input producers' productivity. This leads to the following proposition.

Proposition 1 ***(T-neutral deregulation)*** *Industry productivity only increases in response to T-neutral deregulation, if the degree of external economies of scale is larger than the inverse dispersion measure of the Pareto*

$$\frac{\eta_h}{\sigma_h - 1} > \frac{1}{\gamma_h}. \tag{22}$$

Proof. Follows from using (20) and (21) in (19). ■

Hence, the elasticity of aggregate productivity with respect to input diversity has to be sufficiently large in order to overcompensate the loss in average productivity. Note that, in the case of $\eta_h \geq 1$, the above inequality always holds (by the regularity condition $\gamma_h > \sigma_h - 1$). Hence, domestic deregulation always makes the final goods producer more productive. However, this result is not general: in the empirically relevant case, where $\eta_h < 1$, the industry productivity effect is ambiguous.

3.2 Incremental mutual recognition

This scenario implies a reduction of T_h with f_h^d held constant. Consider again the determination of the domestic cutoff productivity φ_h^* in $(\varphi_h^*, \bar{\pi}_h)$ −space. The free entry condition does not change as T_h falls. However, the ZPC condition now shifts up, so that φ_h^* goes up. The marginal domestic producer is not an exporter; hence there is no direct effect of the reduction in f_h^x. However, the entry of foreign importers makes competition tougher, revenue per firm goes

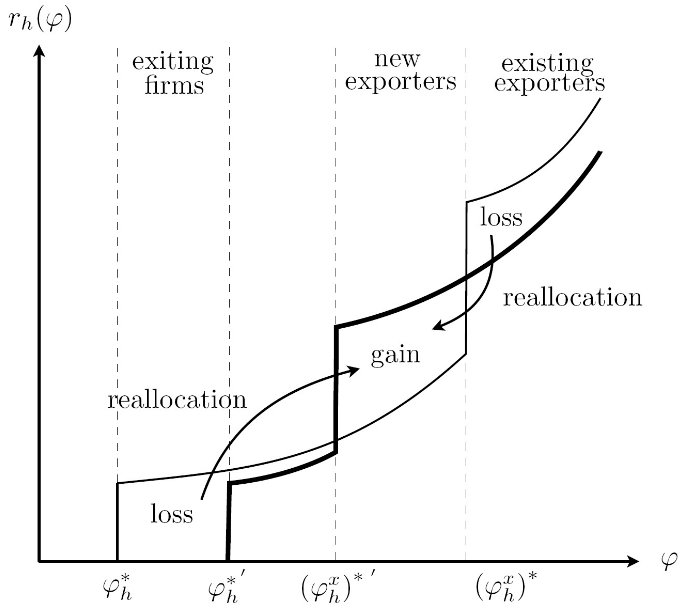

Figure 2: Within-industry reallocation of market shares as response to incremental mutual recognition.

down, and the φ_h^* firm starts to make losses. To restore zero profits, there must be an upwards adjustment of $\bar{\pi}_h$. The number of competitors or their average productivity (or both) have to go down.

Hence, φ_h^* increases while $(\varphi_h^x)^*$ goes down. Figure 1 provides some intuition on the reallocation of market shares: the emergence of new exporters causes a loss of market share to incumbent exporters and domestic firms. Since new exporters are firms with medium levels of productivity, the net effect on average productivity is ambiguous.

Average productivity of input producers. $\tilde{\varphi}_h$ only increases in response to a cut in T_h if the shape parameter γ_h is large enough. The intuition is straightforward: The larger the shape parameter γ_h, the more mass is given to low productive firms, thus giving a high potential for reallocation from fairly unproductive, exiting firms to new exporters.

If the initial level of competitive disadvantage of importers is already smaller than 1, there is almost no export selection effect, and $\tilde{\varphi}_h$ never increases in response to a TBT reform regardless of the shape parameter γ_h. We may summarize the result in Lemma 1.

Lemma 1 ***(Average productivity)*** *Fix f_h^d and reduce T_h. Average productivity $\tilde{\varphi}_h$ increases in response to incremental mutual recognition if and only if the the dispersion measure of the Pareto distribution is large enough, i.e.*

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{T}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h} < \frac{1}{\underline{\gamma}_h} \equiv \frac{1}{\sigma_h - 1}\sqrt{\frac{1}{1 + np_h^x}\frac{T_h - 1}{T_h}} \tag{23}$$

Proof. Follows immediately from totally differentiating (14). ■

At the extensive margin, the least productive firms are forced to exit (selection effect), while new exporters enter (adverse export selection effect). Only if the selection effect is large enough as compared to the adverse selection effect, $\tilde{\varphi}_h$ rises as stated in condition (23).

Input diversity. If the productivity distribution is not extremely skewed towards the least productive firms (i.e. if the shape parameter γ_h is sufficiently small), the number of input varieties lost through exposure to trade is overcompensated by additionally imported inputs, resulting in an increase in input diversity.

Lemma 2 ***(Input diversity)*** *Fix f_h^d and reduce T_h. Input diversity M_h increases in response to incremental mutual recognition if and only if the dispersion measure of the Pareto γ_h is sufficiently small, i.e.*

$$\frac{\hat{M}_h}{\hat{T}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h} > \frac{1}{\bar{\gamma}_h} \equiv \frac{1}{\sigma_h - 1}\frac{1}{1 + np_h^x}\frac{T_h - 1}{T_h}. \tag{24}$$

Proof. Follows immediately from totally differentiating (18). ■

Lemma 2 presents a necessary condition (24). Note that a simple sufficient condition is $T_h < 1$.

Industry productivity. Using (19) and Lemmata 1 and 2, average productivity and input diversity increase in response to a incremental mutual recognition, if the value γ_h is not too extreme, i.e., if

$$\bar{\gamma}_h > \gamma_h > \underline{\gamma}_h. \tag{25}$$

Then, industry productivity improves unambiguously regardless the degree of external economies of scale.

However, even if condition (25) is violated, industry productivity can actually increase, depending on the degree of external economies of scale. If $\tilde{\varphi}_h$ is falling and M_h rising, the degree of external economies of scale has to be sufficiently large for industry productivity to increase, and *vice versa*. There exists the following trade-off: If the shape parameter γ_h is sufficiently small unproductive firms have little relative mass. Hence, there is little potential for reallocation from the exiting, low-productivity firms to new exporters. Then average productivity declines. In contrast, input diversity increases, since more imported varieties are attracted than domestic ones are forced to exit. If, on the other hand, the shape parameter is γ_h is sufficiently large, the logic reverses, and average productivity increases whereas input diversity declines.

Consider that input diversity decreases in response to incremental mutual recognition, which means a violation of condition (24) in Lemma 2. Then, by condition (23) average productivity unambiguously rises, and the degree of external economies of scale has to be sufficiently small. The negative diversity effect is always offset for the empirically relevant cases $\eta_h \leq 1$.

Turn now to the case where average productivity declines in response to incremental mutual recognition, i.e. a violation of condition (23) in Lemma 1. Then, by (24) industry diversity always increases, and $\eta_h / (\sigma_h - 1)$ has to be sufficiently large to generate an increase in industry productivity, which is always true for the special Melitz case ($\eta_h = 1$). These results are summarized in the following Proposition.

Proposition 2 ***(Incremental mutual recognition)*** *Let υ_h^* be the threshold degree of external economies of scale*

$$\upsilon_h^* \equiv \frac{1}{\gamma_h - \bar{\gamma}_h} \left(\frac{\gamma_h}{\sigma_h - 1} - \frac{\bar{\gamma}_h}{\gamma_h} \right).$$

(i) Violation of condition (24). A decrease in input diversity in response to incremental mutual recognition is overcompensated by an increase in average productivity, if and only if the degree

of external economies of scale is below the threshold value υ_h^*, *i.e.*

$$\frac{\eta_h}{\sigma_h - 1} < \upsilon_h^*, \tag{26}$$

where $\upsilon_h^* > 1/(\sigma_h - 1)$.

(ii) Violation of condition (23). A decrease in average productivity in response to incremental mutual recognition is overcompensated by an increase in input diversity, if and only if the degree of external economies of scale is above the threshold value υ_h^*, *i.e.*

$$\frac{\eta_h}{\sigma_h - 1} > \upsilon_h^*, \tag{27}$$

where $0 < \upsilon_h^* < 1/(\sigma_h - 1)$.

Proof. The conditions follow from equation (19). ■

3.3 Comparing lower variable trade costs and TBT reform

As with incremental mutual recognition, lower variable trade costs induce an upward-shift in the ZCP. The reason for this effect is the same as before. Hence, tariff liberalization (or any reduction in variable trade costs) has similar effects on the cutoff productivity levels as lower T_h with f_h^d fixed. However, lower trade costs on net benefit incumbent exporters, as additional competitive pressure is over-compensated by lower trade costs.[18] It follows, that the direction of market share reallocation is unequivocally towards more productive firms. Note, however, that the sales function depicted in Figure 3 does not suffice to determine the effect on average productivity, which depends on the masses of firms engaged in exporting relative to purely domestic ones. It turns out that the productivity effect is *a priori* ambiguous and depends on T_h, which governs the size of the selection and export selection effect.

If $T_h > 1$, imported inputs are on average more productive (they have to cover higher fixed market entry costs). This implies lower prices and, in turn, given CES preferences, results in higher expenditure. Thus, more than one domestically produced input has to be displaced in

[18] This result holds for all productivity distributions.

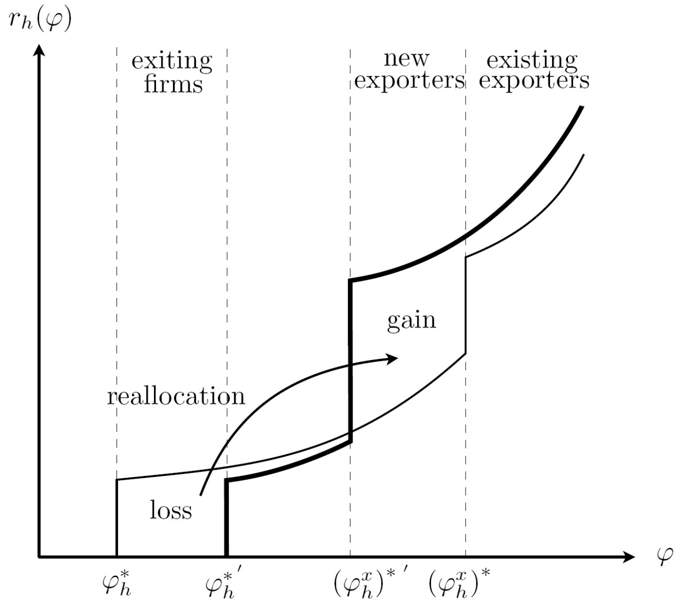

Figure 3: Within-industry reallocation of market shares as response to variable trade cost liberalization.

order to import one additional input variety, and input diversity drops.[19] Reallocation of market shares towards more productive firms and the reduced availability of the least productive inputs, result in higher average productivity. If $T_h < 1$, we end up with higher input diversity. It turns out that in this case average productivity actually declines.[20]

For the empirical relevant case $T_h > 1$, input diversity drops at the lower end of the productivity distribution, resulting in an increase in average productivity. As mentioned above, the condition under which average productivity increases is less strict:

Lemma 3 ***(Average productivity)*** *Average productivity increases in response to variable trade cost liberalization if and only if the dispersion measure of the Pareto distribution is small*

[19]A similar explanation has been put forward by Baldwin and Forslid (2006).

[20]$T_h >$ (<) 1 is a necessary condition for input diversity to decrease (rise), whereas for average productivity to increase (drop) it is a sufficient condition. The necessary condition would be less strict and depend on the skewness of the productivity distribution.

enough, i.e.

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{\tau}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h} > -\frac{1}{\sigma_h - 1}\frac{1}{1+np_h^x}\frac{T_h - 1}{T_h}. \tag{28}$$

Proof. Follows from totally differentiating (14). ■

Condition (28) clearly holds if M_h decreases, i.e. $T_h > 1$. However, average productivity also rises if the selection effect is sufficiently large, shifting input production to more productive firms.

Proposition 3 ***(Lower variable trade costs)*** *Let ψ_h^* be the threshold degree of external economies of scale*

$$\psi_h^* \equiv \frac{1}{\sigma_h - 1} + \frac{1}{\gamma_h}\frac{T_h}{T_h - 1}\left(1 + np_h^x\right).$$

(i) Assume $T_h > 1$, so that input diversity decreases and average productivity increases. Then industry productivity goes up if and only if the degree of external economies of scale is below the threshold value ψ_h^*, i.e.

$$\frac{\eta_h}{\sigma_h - 1} < \psi_h^*. \tag{29}$$

(ii) Assume $T_h < 1$ and a violation of condition (28), so that input diversity increases and average productivity decreases. Then industry productivity increases if and only if the degree of external economies of scale is above the threshold value ψ_h^*, i.e.

$$\frac{\eta_h}{\sigma_h - 1} > \psi_h^*. \tag{30}$$

Proof. The conditions follow from totally differentiating (18). ■

Conditions (29) and (30) always hold if respectively $\eta_h \leq 1$, and $\eta_h \geq 1$. Hence, in the special Melitz case ($\eta_h = 1$), industry productivity always increases in response to variable trade cost liberalization. In contrast, incremental mututal recognition reduces the market shares of existing exporters, thereby inducing reallocation of market shares towards less productive firms, and $T_h > 1$ is not sufficient to guarantee an increase in average productivity.

There are three interesting corollaries that follow from the comparison between TBT reform and variable trade cost reductions. First, in the empirically relevant case $T_h > 1$ and $\eta_h \leq 1$, lower variable trade costs unambiguously improves industry productivity, while the effect of TBT reform is still ambiguous. However, in both situations, total export sales increase.[21] Hence, there is no clear link between increased trade openness and industry (or even economy-wide) productivity measures. This theoretical result rationalizes the low degree of robustness that empirical cross-country analyses of the openness-productivity (or more often: GDP per capita) link suffer from; see, e.g., Rodríguez and Rodrik (2000).

Second, the effect of lower trade costs is conditioned by the importance of competitive disadvantage of foreign firms as measured by T_h. We have seen above, that – if $T_h > 1$ – lower variable trade costs may lead to a fall in industry productivity. In other words: industries can be hurt by reductions in tariffs or transportation costs if the degree of fixed-cost protection is too high. This allows two policy conclusions: first, before engaging in variable trade cost reforms, countries should lower TBTs. Only countries with sufficiently low TBTs benefit from the (exogenous) downward trend in transportation costs. Hence, productivity gains from technical progress in transportation can be tapped only if TBTS are low enough.

Third, there seems to be substantial resistance against TBT reforms. Gwartney, Lawson, Sobel, and Leason (2007) argue that the EU25 countries have failed on average to decrease regulatory costs to importers. Our paper allows two interpretations of this result. First, based on efficiency considerations, TBT reform is not desirable per se, at least not under arbitrary parameter constellations. Second, TBT reform – even if it leads to industry productivity gains – inflicts losses to the vast majority of firms due to the implied reallocation of resources towards new exporters – by nature a relatively small fraction out of all domestic firms. Hence, it may not be overly surprising that total resistance against TBT reform is strong, and, in particular, stronger than against lower variable trade cost reductions, which tend to be beneficial for incumbent exporters.

[21] Total sales abroad are given by $X_h^{cif} = nM_h^x r^x(\tilde{\varphi}_h^x)$. Recall that $M_h^x = p_h^x M_h^d$. Using (4), (17) and (18) one finds that $X_h^{cif} = L_h n p_h^x T_h / (1 + n p_h^x T_h)$, and $\partial X_h^{cif} / \partial T_h < 0$.

4 Numerical exercise at the industry level

In this chapter, we use estimates of the key parameters of our model from the literature or calibrate them according to the model. Since there is substantial cross-industry variation of parameters, we do a separate analysis for 14 industries. The numerical exercise serves several purposes. First, it allows to calibrate the degree of external economies of scale, $\eta_h / (\sigma_h - 1)$, and the level of competitive disadvantage of importers, T_h. Second, it enables us to check the inequalities derived in the theoretical section of this paper and to empirically sort out the ambiguous effects of different trade liberalization scenarios, industry by industry. Finally, the exercise allows to compute the productivity gains (or losses) relative to *status quo* achieved by setting $T_h = 1$, i.e., to a situation, where technical requirements are harmonized.

4.1 Calibration

Several studies quantify the elasticity of substitution and productivity dispersion on industry level for US and European data. However, we do not have estimates from a *structural* econometric approach, in which σ_h and γ_h are separately identified under the relevant regularity conditions that have to hold in the present theoretical framework.[22]

Corcos, Del Gatto, Mion, and Ottaviano (2007) estimate industry-level *dispersion measures* γ_h using European data.[23] Their estimates of γ_h are on average close to 2. Chaney (2007) shows that *elasticities of substitution* obtained from standard gravity models are distorted under the presence of heterogeneous firms. Therefore, we draw on estimates of the shape parameter of the sales distribution $\varsigma_h = \gamma_h - (\sigma_h - 1)$ obtained from Helpman, Melitz, and Yeaple (2004) to back out the values of σ_h given the estimates of γ_h.[24] Our sources for ς_h and γ_h both are consistent with heterogeneous firm models and use the same European firm-level data (Amadeus). Since ς_h is close to 1 for all industries, the values of σ_h cluster around 2.[25] Table 1 reports our findings

[22] For example, $\gamma_h > \sigma_h - 1$.

[23] They estimate firm-level productivities using the Levinsohn and Petrin (2003) estimator, and fit a Pareto distribution for each industry. For all industries the regression fit (the adjusted R squared) is close to 1.

[24] In other words: we take γ_h and ς_h as data and calibrate σ_h.

[25] Our values of σ_h seem low; however, the are consistent with other estimates, e.g., those by Acemoglu and

Table 1: Parameter description (preferred specification)

	Data				Calibration				
Industry	τ_h	p^x_h	η_h	γ_h	σ_h	T_h	$\frac{\eta_h}{\sigma_h-1}$	$\frac{\eta^{min}}{\sigma_h-1}$	$\frac{\eta^{max}}{\sigma_h-1}$
Chemicals	1.09	0.55	0.62	1.81	1.31	1.08	1.98	1.25	2.51
Rubber and plastics	1.12	0.44	0.7	2.37	2.51	1.42	0.46	0.26	0.52
Leather and footwear	1.09	0.26	0.63	2.35	2.51	2.08	0.42	0.26	0.52
Lumber and wood	1.15	0.12	0.56	2.45	2.55	3.07	0.36	0.25	0.5
Paper products	1.14	0.45	0.78	1.97	1.94	1.29	0.83	0.41	0.83
Textile	1.11	0.24	0.59	2.25	2.29	1.97	0.46	0.3	0.61
Apparel	1.09	0.24	0.59	1.8	1.91	1.89	0.64	0.43	0.85
Non-ferrous metals	1.06	0.53	0.71	2.21	1.87	1.23	0.82	0.45	0.9
Machinery except electrical	1.06	0.27	0.39	2.35	2.24	1.86	0.32	0.32	0.63
Electrical machinery	1.06	0.29	0.39	1.93	1.84	1.64	0.47	0.47	0.93
Road vehicles	1.1	0.33	0.55	2.06	1.35	1.17	1.56	1.11	2.22
Transport equipment	1.05	0.33	0.65	2.06	1.67	1.39	0.97	0.58	1.16
Scientific/measuring equip.	1.05	0.13	0.42	1.84	1.34	1.43	1.22	1.13	2.27
Optical/photographic equip.	1.05	0.13	0.42	1.84	1.5	1.69	0.83	0.77	1.55

Notes. τ_h from Hanson and Xiang (2004); η_h from Ardelean (2007). T_h calibrated to meet export participation rate p^x_h from Eaton, Kortum, Kramarz (2004). n calibrated to meet openness of 40%. σ_h imputed from shape parameters estimated by Corcos, Del Gatto, Mion, and Ottaviano (2007) and sales dispersion measures from Helpman, Melitz, and Yeaple (2004) for 14 sectors.[26]

Ardelean (2007) provides the first industry-level estimates of the parameter that governs the external scale effect. She identifies η_h by decomposing the price index into a traditional part and the extensive margin, following Feenstra (1994), and exploiting cross-importer variation. For all industries, she rejects the standard assumption of $\eta_h = 1$. On average, her estimate of η_h is 0.58. Given the importance of this parameter, and the fact that the available estimates are for the US (while our calibration targets Europe), we run three scenarios. (A) uses the estimates found by Ardelean and allows for industry variation. (B) disallows for industry variation and sets η_h for all industries to the lowest available estimate found in Ardelean $\eta^{\min}$. (C) is similar to (B) but sets $\eta_h = \eta^{\max}$. Note that even in (B) and (C) the elasticity of A_h with respect to input variety $(\eta_h / (\sigma_h - 1))$ still exhibits industry-level variance.

We take data on industry transport costs from Hanson and Xiang (2004). Using data on freight rates for U.S. imports from Feenstra (1996), they identify the implicit U.S. industry freight rate (insurance and freight charges/import value), and regress it on log distance to the origin country. Transport cost for an industry are reported as the projected industry freight rate from these coefficient estimates evaluated at median distance in their sample of importers and exporters.[27]

Finally, we calibrate the competitive disadvantage of importers T_h such that the model replicates the export participation rates p_h^x by industry reported by Eaton, Kortum, and Kramarz (2004) for European firms.[28] Equation (13) shows that our choice of τ_h, γ_h and σ_h and the observed values of p_h^x directly imply T_h.[29] Our calibration yields values of T_h varying between 1 and 3, in all industries strictly above unity (see Table 1). This finding is well in line with the other calibration exercises in the literature, e.g., Ghironi and Melitz (2005). The calibration

Ventura (2002). We conduct some robustness analysis with respect to σ_h below.

[26] Table 4 in the Appendix reports how data organized in different industry classifications has been mapped into our sectoral structure (which is essentially that of Corcos, Del Gatto, Mion, and Ottaviano, 2007).

[27] We are grateful to Gordon Hanson for providing those estimates.

[28] More specifically, their data is from France.

[29] We also use information on openness (40%), the average transportation costs, and the average T_h to calibrate the number of trading partners n.

reveals interesting cross-industry variance in the incidence of fixed cost protection T_h. The chemical and transport equipment industries exhibit fairly low levels of T_h, while leather and footwear or apparel seem much more strongly protected.[30]

4.2 Sorting out the ambiguities

We may now use the results of our calibration exercise to check the inequalities derived in the theoretical section of the paper. Our calibration yields $T_h > 1$ in all industries. Hence, our theoretical results imply that variable trade cost liberalization always leads to an increase in average productivity and to a reduction in input diversity. Given that $\eta_h < 1$ for all industries, the loss in input diversity has a modest negative impact on industry productivity A_h so that the positive effect on the average productivity $\tilde{\varphi}_h$ dominates. In case of TBT reform, the results presented in Table 1 do not suffice to sort out the ambiguities. Therefore, the following discussion focuses on our two TBT liberalization scenarios. Table 2 answers whether industry productivity A_h and its components $(M_h, \tilde{\varphi}_h)$ increase with TBT reform. The left panel discusses the case of T-neutral deregulation, while the right panel looks at incremental mutual recognition.

T-neutral deregulation. We have shown analytically that T-neutral deregulation unambiguously leads to a fall in average productivity $\tilde{\varphi}_h$ and to a rise in input diversity M_h. However, the effect on industry productivity A_h is ambiguous and crucially depends on the elasticity of A_h with respect to M_h relative to the dispersion measure γ_h (see Proposition 1). Allowing for cross-industry variation in η_h, column (A) in the left panel of Table 2 shows that T-neutral deregulation improves industry productivity in most of the industries, except for those where industry externalities are unimportant due to a high value of σ_h (leather and footwear, lumber and wood) or due to low values for η_h (machinery except electric, electric machinery). In contrast to column (A), where industry values for η_h are used, in (B) the parameter η_h is set for all industries to the minimum level $\eta^{\min}$ found by Ardelean. In (C) it is set to the maximum level $\eta^{\max}$. Not surprisingly, with (B) the outlook worsens, while it improves with (C). Hence,

[30] The literature mainly offers aggregate calibration exercises. We seem to be the first to run an industry-level simulation.

Table 2: Do industry productivity A_h and its components rise under TBT reform?

	T-neutral deregulation			Incremental mutual recognition				
	Increase in			Increase in				
	A_h	A_h	A_h	$\tilde{\varphi}_h$	M_h	A_h	A_h	A_h
	(A)	(B)	(C)	–	–	(A)	(B)	(C)
Industry								
Chemicals	YES	YES	YES	NO	YES	YES	YES	YES
Rubber and plastics	YES	NO	YES	NO	YES	YES	NO	YES
Leather and footwear	NO	NO	YES	NO	YES	YES	NO	YES
Lumber and wood	NO	NO	YES	YES	YES	YES	YES	YES
Paper products	YES	NO	YES	NO	YES	YES	NO	YES
Textile	YES	NO	YES	NO	YES	YES	YES	YES
Apparel	YES	NO	YES	NO	YES	YES	YES	YES
Non-ferrous metals	YES	NO	YES	NO	YES	YES	YES	YES
Machinery except electrical	NO	NO	YES	NO	YES	YES	YES	YES
Electrical machinery	NO	NO	YES	NO	YES	YES	YES	YES
Road vehicles	YES	YES	YES	YES	YES	YES	YES	YES
Transport equipment	YES	YES	YES	NO	YES	YES	YES	YES
Scientific/equipm.	YES	YES	YES	YES	YES	YES	YES	YES
Optical/photographic equip.	YES	YES	YES	YES	YES	YES	YES	YES

Notes. In scenario (A), the external scale parameter η_h varies across industries according to estimates from Ardelean (2007). In scenario (B), η_h does not vary across industries and is set at the minimum value found in the estimates. Scenario (C), uses the maximum value instead. Average productivity $\tilde{\varphi}_h$ and input diversity M_h are not affected by η_h. In case of domestic deregulation, they respectively fall and rise unambiguously. See Table 1 for further details on the specification.

whether T-neutral deregulation improves industry productivity crucially depends on the importance of scale economies. In our preferred setup (A), the picture is mixed: some industries benefit while others do not.

Incremental mutual recognition. For incremental mutual recognition, the effects on average productivity and input diversity are both ambiguous from a theoretical point of view (see Lemmata 1 and 2) and depend on model parameters in a fairly complicated fashion. Table 2 shows that TBT reform improves input diversity in all industries. Regarding the effect on average productivity, the picture is different. Incremental mutual recognition leads to reallocation of resources from efficient incumbent exporters and inefficient domestic producers to new exporters. It turns out that the latter effect dominates the former one in most industries. In line with condition (23), average productivity $\tilde{\varphi}_h$ only goes up for industries with low export participation rates (lumber and wood, road vehicles, scientific/measuring equipment, and optical/photographic equipment). In those special cases, industry productivity rises regardless of η_h.

In the other cases, the size of the scale effect is important again. Only if it is large enough does the positive industry diversity effect offset the negative average productivity effect (see condition (27)). Specification (A), which exploits the industry variation in Ardelean's estimates, shows that industry productivity increases in all industries. This optimistic outlook materializes a fortiori if η_h is set to $\eta^{\max}$. The picture is reversed for three industries (rubber and plastics, leather and footwear, and paper products) if we use $\eta^{\min}$. Hence, we are fairly confident that incremental mutual recognition indeed improves industry productivity.

4.3 Quantifying the effects of TBT reform: the case of harmonization

Rather than evaluating the sign of a marginal TBT reform, we now quantify the productivity gains and losses associated to the harmonization of technical standards, i.e., to a reduction of $\tilde{f}_x$ such that foreign firms face the same licensing costs than domestic firms. This scenario stops short from full mutual recognition, since foreign firms still have to license their goods market by market. More specifically, assume the domestic and foreign fixed distribution cost are identical.[31] Then the comparative disadvantage of importers T_h is only driven by differences in the regulatory component. We simulate the effects of a discrete cut of T_h to the level of harmonization, i.e. a reduction to $T_h = 1$. This scenario is technologically feasible for all industries since the sorting condition $\tau_h^{1-\sigma_h} T_h > 1$ continues to hold, given any level of variable trade costs τ_h.[32]

One could expect that industry productivity unambiguously rises. However, *a prioiri* this

[31]In the present model, this is a natural assumption since countries are symmetric.

[32]It *may* be feasible to reduce beyond harmonization and eliminate $\tilde{f}_h^x$ such that T_h goes below unity. However, since we have no data on the components of f_h^d and f_h^x, we cannot calibrate the lowest feasible level of $\bar{f}_h^d$. Also note that our numerical analysis does not require calibration of f_h^e or δ_h since those parameters drop out when comparing equilibrium outcomes at $T_h = 1$ to those obtained under the benchmark calibration.

is not the case, since their are industry externalities at work. The decentralized equilibrium does not necessarily feature the efficient industry diversity if $\eta_h \neq 1$.[33] Neither do producers internalize the effect of entry on the external economies of scale in the industry nor on the profits of incumbent producers. If $\eta_h < 1$, there is over-supply of varieties, if $\eta_h > 1$ (which is empirically implausible) there is under-supply. Only in the special case where $\eta_h = 1$ does the planner solution coincide with the decentralized equilibrium. High regulatory costs reduce entry and thereby mitigate the distortion due to external economies of scale. However, TBTs are certainly not the first-best policy to cope with oversupply of varieties, since they do not generate any income (unlike entry taxes).

Clearly, the cut to $T_h = 1$ is tremendous for industries with a high degree of competitive disadvantage of imports (lumber and wood) and relatively small for industries with low protection to start with (chemicals). In any case, the reduction in T_h induces more firms to export, thereby implying $\Delta\% p_h^x > 0$. Second, since less productive firms start to export, this comes along with a deterioration of their average productivity level ($\Delta\% \tilde{\varphi}_h < 0$).[34] Third, due to increased competition the least productive input producers are forced to exit, thereby decreasing the mass of firms operating domestically ($\Delta\% M_h^d < 0$). However, input diversity clearly rises ($\Delta\% M_h > 0$).[35] The increase is relatively large in industries with high initial T_h.

Finally, the total effect on industry productivity is dominated by the scale effect.[36] The increase is relatively large in industries with low value of σ_h (chemicals, road vehicles), and in industries with a positive average productivity effect (scientific and measuring equipment, and optical and photographic equipment). Table 3 summarizes the results.

[33] The welfare-theoretic results obtained by Benassy (1996) for arbitrary η_h and homogeneous firms continue to hold in the presence of productivity heterogeneity.

[34] An exception are industries with a low fraction of exporters to start with (scientific and measuring equipment, and optical and photographic equipment): there average productivity increases, overall leading to a large rise in industry productivity.

[35] From a social planner's perspective, there is over-supply of varieties also under T_h^* as $\eta_h < 1$. However, even if $\Delta\% M_h > 0$, the over-supply of varieties relative to the planner's solution is smaller for T_h^* than for T_h.

[36] An exception is the industry which features the lowest strength of external economies of scale effects (machinery except electrical).

Table 3: Productivity gains and losses from harmonization (preferred specification)

Industry	$\Delta\%T_h$	$\Delta\%M_h^d$	$\Delta\%p_h^x$	$\Delta\%\tilde{\varphi}_h$	$\Delta\%M_h$	$\Delta\%A_h$
Chemicals	-7.2	-24.5	54.4	-2.3	5.7	9.0
Rubber and plastics	-29.5	-14.3	73.0	-9.7	28.8	1.5
Leather and footwear	-51.8	-26.9	211.9	-16.7	61.1	1.7
Lumber and wood	-67.4	-37.3	488.2	-16.6	78.1	2.7
Paper products	-22.6	-19.3	70.6	-8.3	20.2	6.8
Textile	-49.3	-31.7	227.4	-14.9	53.2	3.4
Apparel	-47.2	-37.5	253.1	-16.0	48.9	8.3
Non-ferrous metals	-18.5	-22.1	68.2	-6.0	16.4	6.4
Machinery except electrical	-46.3	-34.8	225.7	-13.3	49.4	-1.6
Electrical machinery	-39.1	-39.1	214.7	-11.9	37.7	2.3
Road vehicles	-14.6	-43.0	151.4	-1.3	10.6	15.5
Transport equipment	-27.9	-40.2	173.1	-6.9	24.1	14.7
Scientific/measuring equip.	-30.2	-65.0	588.9	11.1	17.3	35.0
Optical/photographic equip.	-40.9	-61.8	586.7	3.8	27.7	27.2

Notes. In this scenario, we compare status quo industry productivity with the level that would obtain if regulatory fixed market access costs where as low for foreign firms than for domestic ones. $\Delta\%x = \Delta x/x * 100$. See Table 1 for further details.

4.4 Robustness

In our preferred calibration, we have avoided to draw on industry estimates of the elasticity of substitution σ_h which are derived in standard homogeneous-firms gravity models. As a robustness check we use data on σ_h from Hanson and Xiang (2004) (for the U.S.). We invert the logic in the above calibration, and now treat σ_h and ς_h as data. This allows to back out values of γ_h that are consistent with the theoretical model. Given that the estimates of σ_h in Hanson and Xiang are much larger than the ones derived under our preferred specification, we call this robustness check high-σ_h specification. Table 6 in the Appendix summarizes the parameters.[37] The major difference with respect to our preferred specification is that the elasticity of A_h with respect to M_h, i.e., $\eta_h/(\sigma_h - 1)$ is now much smaller since the values of σ_h are much bigger.

Table 7 in the Appendix reports the results for the local analysis. Regarding T-neutral deregulation, the negative diversity effect now dominates the positive average productivity ef-

[37] The number of symmetric trading partners n is calibrated to generate a trade openness of 40%.

fect. Allowing for industry variation in η_h (column (A)), only the paper industry features an improvement in industry productivity. Setting η_h to $\eta^{\min}$ for all industries obviously darkens the picture even further. Setting η_h to $\eta^{\max}$, in turn, only leads to a faint improvement: now benefiting industries include the chemical and wood industries along with the paper industry.

The results for the incremental mutual recognition scenario change, too. While it is still true that input diversity goes up in all industries, average productivity falls everywhere. Allowing for industry variation in η_h, the overall effect on industry productivity is negative, except for the wood and paper industries. If η_h is set to $\eta^{\min}$, the effect is negative for all industries. Using instead $\eta^{\max}$, the picture brightens up slightly with about half of all industries experiencing positive productivity effects.

The calibration of σ_h also drives the quantitative effects of TBT reform. While in terms of average productivity and input diversity the picture is quite the same as compared to our preferred specification[38], the scale effect is large enough to slightly overcompensate the loss in average productivity only for the industry with the highest strength of external economies of scale (paper products).

Given the model and the available data, the quantitative analysis of the productivity effects of TBT reform remains somewhat inconclusive. The reason is that estimates of σ_h found in the literature vary widely. However, those estimates are crucial for pinning down the overall productivity effects. Corsetti, Martin, and Pesenti (2007) also document strong sensitivity of results with respect to this elasticity, albeit in a homogeneous goods open-macro model. We believe that our preferred specification has key advantages over the strategy chosen in the robustness checks, since it is fully consistent with our heterogeneous firms setup. However, we will only be able to provide a definitive answer on the productivity effects of TBT reform once structural estimates of σ_h and γ_h are available.

[38] An exception is that all industries face a deterioration of average productivity.

5 Discussion and conclusions

5.1 Discussion

The present model highlights the input diversity and the average productivity effects of TBT reform. These two channels are thought of great interest in recent trade models. However, TBT deregulation can affect outcomes also through additional channels.

Resource saving effect. One may expect a direct *resource saving effect* of lower regulatory costs which may increase the amount of final output per worker in the industry. However, in our model, the resource-saving effect is exactly offset by additional entry so that TBT does not affect productivity through this channel. To see this, let F_h denote sector-h specific resources[39] devoted to fixed costs of entry f_h^e, fixed domestic costs f_h^d, and fixed foreign market costs f_h^x. Making use of the stationarity condition (17) and the free entry condition (15), one obtains $F_h = L_h/\sigma_h$. Hence, irrespectively of the absolute size of f_h^e,f_h^d, and f_h^x, a constant share of the industry-specific labor force is used for the payment of fixed costs.[40] The result is summarized in Lemma 4.

Lemma 4 *In a stationary equilibrium, the number of workers devoted to fixed costs of entry, domestic regulation, and fixed costs associated with the foreign market is a constant share* $1/\sigma_h$ *of the industry-specific labor force.*

Proof. In the Appendix. ■

Pro-competitive productivity gains. Additional entry may reduce the dead-weight loss associated to the existence of monopoly power. In our framework with constant elasticity of substitution between varieties, markups are constant and TBT reform does not lead to *pro-competitive*

[39]Recall: by choice of numeraire, $w_h = 1$.

[40]This result is specific to the CES production function but holds for general productivity distributions. Also, it hinges on free entry of firms. In the Chaney (2007) model, where the number of potential producers is fixed, there would be a resource saving effect. By allowing for free entry, the present paper takes a long-run perspective.

productivity gains. The paper of Melitz and Ottaviano (2008) addresses pro-competitive effects with heterogeneous firms in a model with a linear demand system. However, in that framework, there is no natural role for fixed foreign market access costs (and hence TBT as defined in our paper), since the partitioning of firms into exporters and domestic sellers is achieved by the structure of demand.

Between-industry reallocation. TBT reform potentially induces not only within-industry resource reallocation, but also reallocation between industries. This would require a theoretical framework like the one proposed by Bernard, Redding, and Schott (2007). However, in that model analytical results are hard to obtain, even for simple setups and with the Pareto assumption. This makes our task of 'sorting out' the intricacies unfeasible. Thus, we have based our analysis on the Melitz framework and relegate the (worthwhile) computational analysis of between-industry reallocation effects to future research.

Learning-by-exporting. Knowledge spillovers from international buyers and competitors may improve the productivity of exporters. The so-called learning-by-exporting hypothesis has been subject of intense empirical research, but has not encountered robust empirical support so far (see the survey by Wagner, 2007). This is why we have refrained from modeling a link between a firm's export status and its productivity.

5.2 Conclusion

This paper analyzes the reallocation and industry productivity effects of technical barriers to trade (TBT) reform in a single market with heterogeneous firms and variable and fixed trade costs. The model goes beyond existing versions of the Melitz (2003) model by explicitly parameterizing external scale effects. Our framework allows to disentangle the effect of a TBT reform on average productivity of input producers $\tilde{\varphi}_h$ and input diversity M_h, thereby making the industry productivity effect dependent on the strength of external economies of scale.

We find that – under the parameter constellations obtained in our industry-level calibration exercise – lower TBTs lead to reallocation of market shares from more to less productive firms, potentially negatively affecting industry productivity for a wide range of parameter constellations. However, input diversity usually goes up: To the danger of oversimplification, the aggregate industry-level productivity effect is positive whenever the externality linked to input diversity is strong enough. Our calibration exercise shows that this is indeed the case for all industries. The aggregate effect, however, is sensitive to details of the calibration, while the adverse effect on the productivity of the average firm is fairly robust.

Our analysis has a number of interesting implications: First, while variable trade cost and TBT liberalization both increase the openness of industries, the relation between openness and productivity is unclear. This may rationalize existing empirical results. Second, whether reductions in variable trade costs improve aggregate productivity depends on the level of TBTs. This interdependence calls for an integrative approach in trade policy. Third, our analysis suggests that TBT reform typically is harder to achieve politically than tariff reform. The reason is that, under a range of parameter constellations, existing exporters would lose market share from lower TBTs but gain from lower variable trade costs.

The present paper suggests an array of interesting extensions. First, we have studies a model of symmetric countries. This is probably defendable on grounds of carving out the general driving forces and sorting out the ambiguities. For a relevant analysis of trade policy, however, a model with asymmetric countries is needed. However, whenever the number of countries goes beyond two, analytical results become hard to come by.

Second, we have treated trade costs as exogenous. It would be interesting to study the strategic setting of TBTs in an asymmetric two-country model. A key challenge is how to deal with the complex adjustment dynamics, that we have ignored in the present model, but which are probably important in any political-economy analysis.

Third, given the ambiguous effects of different types of trade liberalization on aggregate productivity, better estimates of the key parameters governing the model would be highly welcome. This calls for structural estimation and identification of the key parameters in trade models with heterogeneous firms: the shape parameter, the elasticity of substitution, and the degree of external economies of scale.

References

[1] Acemoglu, D. and J. Ventura (2002). The World Income Distribution. Q*uarterly Journal of Economics* **117**(2), 659-694.

[2] Ardelean, A. (2007). How Strong is Love of Variety? Mimeo: Purdue University.

[3] Axtell, R. (2001). Zipf Distribution of U.S. Firm Sizes. *Science* **293**: 1818-20.

[4] Baldwin, R.E., and R. Forslid (2006). Trade Liberalization with Heterogeneous Firms. *NBER Working Paper* 12192.

[5] Benassy, J.-P. (1996). Taste for Variety and Optimum Production Patterns in Monopolistic Competition. *Economics Letters* 52: 41-47.

[6] Bernard, A., J.S. Redding, and P.K. Schott (2005). Products and Productivity. *NBER Working Paper* 11575.

[7] Bernard, A., J.S. Redding, and P.K. Schott (2007). Comparative Advantage and Heterogeneous Firms. *Review of Economic Studies* **74**(1): 31-66.

[8] Blanchard, O., and F. Giavazzi (2003). Macroeconomic Effects of Regulation and Deregulation in Goods and Labor Markets. *The Quarterly Journal of Economics* **118**(3): 879-907.

[9] Chaney, T. (2007). Distorted Gravity: The Intensive and Extensive Margins of International Trade. *American Economic Review*, forthcoming.

[10] Chen, N. (2004). Intra-national versus International Trade in the European Union: Why do National Borders Matter? *Journal of International Economics* **63**: 93-118.

[11] Conway, P., V. Janod, G. Nicoletti (2005). Product Market Regulation in OECD Countries: 1998 To 2003. *OECD Economics Department Working Paper* No. 419.

[12] Corcos, G., M. Del Gatto, G. Mion, and G.I.P. Ottaviano (2007). Productivity and Firm Selection: Intra- vs International Trade. *CORE Discussion Paper* No. 2007/60

[13] Corsetti, G., P. Martin, and P. Pesenti (2007). Productivity, Terms of Trade and the 'Home Market Effect'. *Journal of International Economics* **73**:99-127.

[14] Delgado, J. (2006). Single Market Trails Home Bias. *Bruegel Policy Brief* 2006/05. Brussels.

[15] Del Gatto, M., G. Mion, and G.I.P. Ottaviano (2007). Trade Integration, Firm Selection and the Costs of Non-Europe. *Working Paper CRENoS* 200703.

[16] Dixit, A.K., and J.E. Stiglitz (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review*: **67**(3): 297-308.

[17] Eaton, J., S. Kortum, and F. Kramarz (2004). Dissecting Trade: Firms, Industries, and Export Destinations. *American Economic Review* **94**(2): 150-154.

[18] Egger, H., and U. Kreickemeier (2007). Firm Heterogeneity and the Labour Market Effects of Trade Liberalisation. *CESifo Working Paper* No. 2000.

[19] Feenstra, R. (1994). New Product Varieties and the Measurement of International Prices. *American Economic Review:* **84**(1): 157-177.

[20] Feenstra, R. (1996). U.S. Imports, 1972-1994: Data and Concordances. *NBER Working Paper* 5515.

[21] Felbermayr, G., and J. Pratt (2007). Product Market Regulation, Firm Selection and Unemployment. *IZA Discussion Paper* No. 2754.

[22] Francois, J., H. van Meijl, and F. van Tongeren (2005). Trade Liberalization in the Doha Development Round. Economic Policy **20**(42): 349-391.

[23] Ghironi, F., and M.J. Melitz (2005). International Trade and Macroeconomic Dynamics with Heterogeneous Firms. *Quarterly Journal of Economics* **120**(3): 865-915.

[24] Gibson, M.J. (2006). Trade Liberalization, Reallocation, and Productivity. Mimeo: University of Minnesota.

[25] Gwartney, J., R. Lawson, R.S. Sobel, and P.T. Leeson (2007). Economic Freedom of the World 2007 Annual Report. Fraser Institute, Vancouver.

[26] Hanson, G., and C. Xiang (2004). The Home-Market Effect and Bilateral Trade Patterns. *American Economic Review* **94**(4): 1108-1129.

[27] Helpman, E. (2006). Trade, FDI, and the Organization of Firms. *Journal of Economic Literature* **44**(3): 589-630.

[28] Helpman, E., M.J. Melitz, and S.R. Yeaple (2004). Export Versus FDI with Heterogeneous Firms. *American Economic Review* **94**(1): 300-316.

[29] Ilzkovitz, F., A. Dierx, V. Kovacs, and N. Sousa (2007). Steps. Towards a Deeper Economic Integration: The Internal Market in the 21st Century. European Economy, *Economic Papers* No. 271, European Commission.

[30] Keuschnigg, C., and W. Kohler (1996). Austria in the European Union: Dynamic Gains from Integration and Integration and Distributional Implications. *Economic Policy* **22**:155-211.

[31] Krugman, P.R. (1980). Scale Economies, Product Differentiation, and the Pattern of Trade. *American Economic Review* **70**(5): 950-959.

[32] Levinsohn, J., and A. Petrin (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies* **70**: 317-342.

[33] Melitz, M.J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica* **71**(6): 1695-1725.

[34] Melitz, M.J., and G.I.P Ottaviano (2008). Market Size, Trade, and Productivity. *Review of Economic Studies* **75**: 295-316.

[35] Rodríguez, F. and D. Rodrik (2000). Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence. In: B.S. Bernanke and K. Rogoff (eds.). *NBER Macroeconomics Annual 2000.* MIT Press.

[36] Smith, A., and A.J. Venables (1988). Completing the Internal Market in the European Community. Some Industry Simulations. *European Economic Review* **32**: 1501-1521.

[37] Wagner, J. (2007). Exports and Productivity: A Survey of the Evidence from Firm Level Data. *The World Economy* **30**(1): 60-82.

[38] World Trade Organization (2007). Twelfth Annual Review of the Implementation and Operation of the TBT Agreement. Geneva

A Data description and robustness checks

Industry concordance. For calibration, we use data from different sources categorized at different industry classifications. We therefore propose a concordance to map the several variables of interest into a unique industry classification (see Table 5). If two categories of the source classification fall into one class of our classification, we compute the mean, in case of more than two, we use the median.[41]

Table 4: Industry concordance

Parameter(s)	γ	η_h	ς_h	τ_h, σ_h	p_h^x
Industry	Ottaviano	HS	BEA	SITC	SIC
Chemicals	9	28-31	281,283,284,287	51-56	28
Rubber and plastics	10	39	305,308	57,58	30
Leather and footwear	4	64	310	61,85	31
Lumber and wood	5	45	240	63	24
Paper products	6	48	262, 265	64	26
Textile	2	50-52	220	65	22
Apparel	3	61,62	230	84	23
Non-ferrous metals	12	74-81	335	68	33
Machinery except electrical	14	84	354	73	35
Electrical machinery	15	84	351-353,355-366	71,72,74-77	35,36
Road vehicles	17	87	371	78	37
Transport equipment	17	86,88	379	79	37
Scientific/measuring equip.	16	90,91	381	87	38
Optical/photographic equip.	16	90,91	386	88	38

Industry sales dispersion. The industry sales dispersion measure is obtained from Helpman, Melitz, and Yeaple (2004). Using data on European firms from the Amadeus database for 1994, they compute the standard deviation of the logarithm of firm sales, which – given the Pareto assumption – is equivalent to $\varsigma_h = \gamma_h - (\sigma_h - 1)$; see Table 6.

[41] We have also tried the mean throughout, which yields identical results.

Table 5: Industry sales dispersion

Industry	ς_h
Chemicals	1.5
Rubber and plastics	0.86
Leather and footwear	0.84
Lumber and wood	0.9
Paper products	1.03
Textile	0.96
Apparel	0.89
Non-ferrous metals	1.34
Machinery except electrical	1.11
Electrical machinery	1.1
Road vehicles	1.71
Transport equipment	1.39
Scientific and measuring equipment	1.5
Optical and photographic equipment	1.34

Table 6: Parameter description (high-σ_h specification)

	Data				Calibration				
Industry	τ_h	p_h^x	η_h	σ_h	γ_h	T_h	$\frac{\eta_h}{\sigma_h - 1}$	$\frac{\eta^{min}}{\sigma_h - 1}$	$\frac{\eta^{max}}{\sigma_h - 1}$
Chemicals	1.09	0.55	0.62	5.94	6.44	1.03	0.12	0.08	0.16
Rubber and plastics	1.12	0.44	0.7	5.8	5.66	1.16	0.15	0.08	0.16
Leather and footwear	1.09	0.26	0.63	8.07	7.91	1.82	0.09	0.06	0.11
Lumber and wood	1.15	0.12	0.56	3.99	3.89	3.35	0.19	0.13	0.26
Paper products	1.14	0.45	0.78	4.25	4.28	1.19	0.24	0.12	0.24
Textile	1.11	0.24	0.59	7.82	7.78	1.7	0.09	0.06	0.11
Apparel	1.09	0.24	0.59	5.61	5.5	2.18	0.13	0.08	0.17
Non-ferrous metals	1.06	0.53	0.71	6.66	7	1.24	0.13	0.07	0.14
Machinery except electrical	1.06	0.27	0.39	8.09	8.2	2.07	0.06	0.06	0.11
Electrical machinery	1.06	0.29	0.39	8.2	8.29	1.98	0.05	0.05	0.11
Road vehicles	1.1	0.33	0.55	7.11	7.82	1.36	0.09	0.06	0.13
Transport equipment	1.05	0.33	0.65	7.4	7.79	1.79	0.1	0.06	0.12
Scientific/measuring equip.	1.05	0.13	0.42	6.72	7.22	3.77	0.07	0.07	0.14
Optical/photographic equip.	1.05	0.13	0.42	8.13	8.47	3.85	0.06	0.05	0.11

Notes. σ_h and τ_h from Hanson and Xiang (2004); η_h from Ardelean (2006). T_h calibrated to meet export participation rate p_h^x from Eaton, Kortum, Kramarz (2004). n calibrated to meet openness of 40%. γ_h computed from ς using σ_h from Hanson and Xiang.

Table 7: Do industry productivity A_h and its components rise under TBT reform? (High σ_h specification)

	T-neutral deregulation			Incremental mutual recognition				
	Increase in			Increase in				
	A_h	A_h	A_h	$\tilde{\varphi}_h$	M_h	A_h	A_h	A_h
	(A)	(B)	(C)	–	–	(A)	(B)	(C)
Industry								
Chemicals	NO	NO	YES	NO	YES	NO	NO	YES
Rubber and plastics	NO	NO	NO	NO	YES	NO	NO	NO
Leather and footwear	NO	NO	NO	NO	YES	NO	NO	NO
Lumber and wood	NO	NO	YES	NO	YES	YES	NO	YES
Paper products	YES	NO	YES	NO	YES	YES	NO	YES
Textile	NO	NO	NO	NO	YES	NO	NO	NO
Apparel	NO	NO	NO	NO	YES	NO	NO	YES
Non-ferrous metals	NO	NO	NO	NO	YES	NO	NO	NO
Machinery except electrical	NO	NO	NO	NO	YES	NO	NO	NO
Electrical machinery	NO	NO	NO	NO	YES	NO	NO	NO
Road vehicles	NO	NO	NO	NO	YES	NO	NO	YES
Transport equipment	NO	NO	NO	NO	YES	NO	NO	YES
Scientific/measuring equip.	NO	NO	NO	NO	YES	NO	NO	YES
Optical/photographic equip.	NO	NO	NO	NO	YES	NO	NO	YES

Notes. In scenarios (A), the external scale parameter η_h varies across industries according to estimates from Ardelean (2007). In scenario (B) η_h does not vary across industries and is set at the minimum value found in the estimates. Scenario (C) uses the maximum value instead. Average productivity $\tilde{\varphi}_h$ and input diversity M_h are not affected by η_h. In case of domestic deregulation, they respectively fall and rise unambiguously. See Table 1 for further details on the specification.

B Guide to calculations

B.1 Theoretical framework

Export cutoff productivity. Evaluating (5) and (6) at φ_h^* and $(\varphi_h^*)^x$ and solving for r_h^d respectively yields $r_h^d(\varphi_h^*) = \sigma_h f_h^d$ and $r_h^d[(\varphi_h^*)^x] = \sigma_h f_h^d \tau_h^{\sigma_h - 1} T_h$. Divding $r_h^d(\varphi_h^*)$ and $r_h^d[(\varphi_h^*)^x]$

Table 8: Productivity gains and losses from harmonization (high-σ_h specification)

Industry	$\Delta\%T_h$	$\Delta\%M_h^d$	$\Delta\%p_h^x$	$\Delta\%\tilde{\varphi}_h$	$\Delta\%M_h$	$\Delta\%A_h$
Chemicals	-2.6	-0.6	3.5	-0.3	1.8	-0.1
Rubber and plastics	-14.1	-1.8	19.6	-1.7	10.5	-0.3
Leather and footwear	-44.9	-4.6	94.9	-4.3	41.8	-1.2
Lumber and wood	-70.1	-21.4	382.0	-12.1	76.6	-2.2
Paper products	-16.1	-3.7	26.0	-2.7	12.4	0.1
Textile	-41.0	-4.6	82.7	-3.6	34.2	-1.2
Apparel	-54.2	-9.9	153.7	-7.7	58.0	-2.2
Non-ferrous metals	-19.1	-3.6	29.9	-2.1	16.0	-0.2
Machinery except electrical	-51.7	-7.7	131.9	-5.1	55.3	-2.8
Electrical machinery	-49.5	-7.1	119.9	-4.8	52.3	-2.6
Road vehicles	-26.4	-5.4	48.0	-2.3	20.4	-0.6
Transport equipment	-44.1	-8.6	102.9	-4.5	44.8	-0.9
Scientific/equip.	-73.5	-21.7	433.8	-8.0	96.2	-3.4
Optical/photographic equip.	-74.0	-16.2	395.7	-7.3	98.9	-3.4

Notes. $\Delta\%x = \Delta x/x * 100$. See Table 1 for further details.

using (4) then leads to expression (11)

$$\frac{r_h^d\left(\varphi_h^*\right)}{r_h^d\left[\left(\varphi_h^*\right)^x\right]} = \left(\frac{\varphi_h^*}{\left(\varphi_h^*\right)^x}\right)^{\sigma_h-1} = \frac{\sigma_h f_h^d}{\sigma_h f_h^d \tau_h^{\sigma_h-1} T_h}$$
$$\Rightarrow \quad \left(\varphi_h^*\right)^x = \varphi_h^* \tau_h T_h^{\frac{1}{\sigma_h-1}}$$

Average sales-weighted productivity level of domestically produced inputs. Under Pareto, the average sales-weighted productivity level of domestically produced inputs (7) is given by

$$\begin{aligned}\left(\tilde{\varphi}_h^d\right)^{\sigma_h-1} &= \frac{1}{1-G\left(\varphi_h^*\right)}\int_{\varphi_h^*}^{\infty}\varphi^{\sigma_h-1}g_h\left(\varphi\right)d\varphi \\ &= \gamma_h\left(\varphi_h^*\right)^{\gamma_h}\int_{\varphi_h^*}^{\infty}\varphi^{\sigma_h-\gamma_h-2}d\varphi \\ &= \frac{\gamma_h}{\gamma_h-\left(\sigma_h-1\right)}\left(\varphi_h^*\right)^{\sigma_h-1}.\end{aligned} \tag{31}$$

Average sales-weighted productivity level of imported inputs. Correspondingly, under Pareto the average sales-weighted productivity level of imported components is

$$\left(\tilde{\varphi}_h^x\right)^{\sigma_h-1} = \frac{1}{1-G\left[\left(\varphi_h^x\right)^*\right]}\int_{\left(\varphi_h^x\right)^*}^{\infty}\left(\varphi\right)^{\sigma_h-1}g_h\left(\varphi\right)d\varphi \tag{32}$$
$$= \frac{\gamma_h}{\gamma_h-\left(\sigma_h-1\right)}\left[\left(\varphi_h^x\right)^*\right]^{\sigma_h-1}:$$

Plugging in the entry cutoff productivity level (11) and recalling (31), we find that $\left(\tilde{\varphi}_h^x\right)^{\sigma_h-1} = \tau_h T_h^{\frac{1}{\sigma_h-1}}\tilde{\varphi}_h^d$.

Average sales-weighted productivity of inputs Plugging in (12) into (14), and using $M_h = \left(1+np_h^x\right)M_h^d$, we obtain the following expression

$$\left(\tilde{\varphi}_h\right)^{\sigma_h-1} = \frac{1}{M_h}\left[M_h^d\left(\tilde{\varphi}_h^d\right)^{\sigma_h-1} + nM_h^x\left(\tau^{-1}\tilde{\varphi}_h^x\right)^{\sigma_h-1}\right] \tag{33}$$
$$= \frac{1}{1+np_h^x}\left[\left(\tilde{\varphi}_h^d\right)^{\sigma_h-1} + np_h^x\left(\tau^{-1}\tilde{\varphi}_h^x\right)^{\sigma_h-1}\right]$$
$$= \frac{1+np_h^xT}{1+np_h^x}\left[\left(\tilde{\varphi}_h^d\right)\right]^{\sigma_h-1}. \tag{34}$$

Average profit. By using (5), (6), (7), and (12) we can compute average profits.

$$\bar{\pi}_h = \pi_h^d\left(\tilde{\varphi}_h^d\right) + np_h^x\pi_h^x\left(\tilde{\varphi}_h^x\right) \tag{35}$$
$$= \frac{r_h^d\left(\tilde{\varphi}_h^d\right)}{\sigma_h} - f_h^d + np_h^x\left(\frac{\tau_h^{1-\sigma_h}r_h^d\left(\tilde{\varphi}_h^x\right)}{\sigma_h} - f_h^x\right)$$
$$= f_h^d\left[\left(\frac{\tilde{\varphi}_h^d}{\varphi_h^*}\right)^{\sigma_h-1} - 1\right] + np_h^xf_h^d\left[\left(\frac{\tau_h^{-1}\tilde{\varphi}_h^x}{\varphi_h^*}\right)^{\sigma_h-1} - T_h\right]$$
$$= f_h^d\frac{\sigma_h-1}{\gamma_h-\left(\sigma_h-1\right)} + np_h^xf_h^x\frac{\sigma_h-1}{\gamma_h-\left(\sigma_h-1\right)}$$
$$= f_h^d\frac{\sigma_h-1}{\gamma_h-\left(\sigma_h-1\right)}\left(1+np_h^xT_h\right). \tag{36}$$

Given equation (13), the average profit line is horizontal in the $\left(\bar{\pi}_h, \varphi_h^*\right)$ −space.

Entry cutoff productivity level. Plugging in (36) and $p_h^{in} = \left(\varphi_h^*\right)^{-\gamma_h}$ into the free entry condition (15), and using $p_h^{in} = \left(\varphi_h^*\right)^{-\gamma_h}$ and (13), one can solve for the entry productivity cutoff level

$$f_h^e \delta_h \left(\frac{\varphi_h^*}{\varphi_h^0}\right)^{\gamma_h} = f_h^d \left(\frac{\sigma_h - 1}{\gamma_h - (\sigma_h - 1)}\right)^{\sigma_h - 1} [1 + n\tau p_h^x T]$$

$$\Leftrightarrow \varphi_h^* = \left\{\frac{\sigma_h - 1}{\gamma_h - (\sigma_h - 1)} \frac{f_h^d}{f_h^e \delta_h} [1 + n\tau p_h^x T]\right\}^{\frac{1}{\gamma_h}}.$$

Input diversity. Recall that $r_h^d(\varphi_h^*) = \sigma_h f_h^d$. It follows from (4) that $r_h^d(\varphi) = \left(\frac{\varphi}{\varphi_h^*}\right)^{\sigma_h - 1} \sigma_h f_d$. Evaluating r^d at $\tilde{\varphi}_h$, and using $R_h = L_h$, input diversity is given by

$$M_h = \frac{R_h}{r^d(\tilde{\varphi}_h)} = \frac{L_h}{\sigma_h f_h^d} \left(\frac{\varphi_h^*}{\tilde{\varphi}_h}\right)^{\sigma_h - 1}.$$

Price index. By inserting optimal pricing of monopolists and the definition of average productivity (8) in the definition of the price index (3) we obtain

$$P_h = M_h^{-\frac{\eta_h}{\sigma_h - 1}} p(\tilde{\varphi}_h) \quad (37)$$

$$= M_h^{-\frac{\eta_h}{\sigma_h - 1}} / \rho\tilde{\varphi}_h. \quad (38)$$

B.2 Industry productivity effects of TBT reforms

B.2.1 T-neutral deregulation

Entry cutoff level. Differentiating the entry cutoff level (16) with respect to f_h^d, holding everthing else constant, we obtain

$$\hat{\varphi}_h^* / \hat{f}_h^d = 1/\gamma_h.$$

Export cutoff level. From equation (11) it can immediately seen that

$$\widehat{(\varphi_h^x)^*} / \hat{f}_h^d = \hat{\varphi}_h^* / \hat{f}_h^d$$

Average productivity. It follows from (14) along with (7) that average productivity changes according to

$$\widehat{\widetilde{\varphi}}_h/\hat{f}_h^d = \widehat{\widetilde{\varphi}}_h^d/\hat{f}_h^d = \hat{\varphi}_h^*/\hat{f}_h^d.$$

Industry productivity. Plugging $\hat{\varphi}_h^*/\hat{f}_h^d$ into (19), we find

$$\frac{\hat{A}_h}{\hat{f}_h^d} = -\left(\frac{\eta_h}{\sigma_h - 1} - \frac{1}{\gamma_h}\right).$$

B.2.2 Incremental mutual recognition

Entry cutoff level From totally differentiating (16) one obtains

$$\frac{\hat{\varphi}_h^*}{\hat{T}_h} = -\frac{\gamma_h - (\sigma_h - 1)}{\gamma_h (\sigma_h - 1)} \frac{n p_h^x T_h}{1 + n p_h^x T_h}. \tag{39}$$

Export cutoff level Totall differentiating (11) and using (39) yields

$$\begin{aligned} \frac{\widehat{(\varphi_h^x)^*}}{\hat{T}_h} &= \frac{\hat{\varphi}_h^*}{\hat{T}_h} + \frac{1}{\sigma_h - 1} \\ &= \frac{1}{\sigma_h - 1}\left[1 - \frac{\gamma_h - (\sigma_h - 1)}{\gamma_h} \frac{n p_h^x T_h}{1 + n p_h^x T_h}\right]. \end{aligned}$$

Since $[\gamma_h - (\sigma_h - 1)]/\gamma_h < 1$ and $n p_h^x T_h / (1 + n p_h^x T_h)$, we have $\widehat{(\varphi_h^x)^*}/\hat{T}_h > 0$.

Fraction of exporters. Differentiating (13) with respect to T_h, we obtain

$$\frac{\hat{p}_h^x}{\hat{T}_h} = -\frac{\gamma_h}{\sigma_h - 1}. \tag{40}$$

Average productivity of domestic producers. It follows from (7) that

$$\frac{\widehat{\widetilde{\varphi}}_h^d}{\hat{T}_h} = \frac{\hat{\varphi}_h^*}{\hat{T}_h}. \tag{41}$$

Average productivity. Differentiating (14), we obtain

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{T}_h} = \frac{\widehat{\tilde{\varphi}}_h^d}{\hat{T}_h} + \frac{1}{\sigma_h - 1} \frac{np_h^x T_h}{1 + np_h^x T_h} \left(\frac{\hat{p}_h^x}{\hat{T}_h} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x} + 1 \right).$$

Using (40), (41), and (39), we get

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{T}_h} = \frac{np_h^x T_h}{1 + np_h^x T_h} \left(\frac{1}{\gamma_h} - \frac{\gamma_h}{(\sigma_h - 1)^2} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x} \right). \tag{42}$$

Then

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{T}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h^2} < \frac{1}{\underline{\gamma}_h^2} = \frac{1}{(\sigma_h - 1)^2} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x},$$

which can never hold if $T_h < 1$.

Input diversity. From inserting (39) and (42) into $\hat{M}_h/\hat{T}_h = (\sigma_h - 1) \left(\widehat{\tilde{\varphi}}_h/\hat{T}_h - \widehat{\tilde{\varphi}}_h/\hat{T}_h \right)$, we get

$$\frac{\hat{M}_h}{\hat{T}_h} = \frac{np_h^x T_h}{1 + np_h^x T_h} \left(\frac{\gamma_h}{\sigma_h - 1} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x} - 1 \right). \tag{43}$$

Then

$$\frac{\hat{M}_h}{\hat{T}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h} > \frac{1}{\bar{\gamma}_h} = \frac{1}{\sigma_h - 1} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x},$$

which always holds if $T_h < 1$.

Industry productivity. Plugging (43) and (42) into (19), we have

$$\begin{aligned}
\frac{\hat{A}_h}{\hat{T}_h} &= \frac{1}{\sigma_h - 1}\frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h\left(\eta_h-1\right)+\frac{\sigma_h-1-\eta_h\gamma_h}{\gamma_h}\right)\\
&= \frac{1}{\sigma_h - 1}\frac{np_h^x T_h}{1+np_h^x T_h}\left(\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\eta_h-\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h+\frac{\sigma_h-1}{\gamma_h}\right)\\
&= \frac{1}{\sigma_h - 1}\frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\eta_h-\frac{\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-\frac{\sigma_h-1}{\gamma_h}}{\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1}\right)\\
&= \frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\frac{\eta_h}{\sigma_h-1}-\frac{1}{\sigma_h-1}\frac{\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-\frac{\sigma_h-1}{\gamma_h}}{\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1}\right)\\
&= \frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\frac{\eta_h}{\sigma_h-1}-\frac{1}{\sigma_h-1}\frac{\frac{\gamma_h}{\bar{\gamma}_h}-\frac{\sigma_h-1}{\gamma_h}}{\frac{\gamma_h}{\bar{\gamma}_h}-1}\right)\\
&= \frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\frac{\eta_h}{\sigma_h-1}-\frac{1}{\sigma_h-1}\frac{\gamma_h-\frac{\bar{\gamma}_h}{\gamma_h}\left(\sigma_h-1\right)}{\gamma_h-\bar{\gamma}_h}\right)\\
&= \frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\frac{\eta_h}{\sigma_h-1}-\frac{\frac{\gamma_h}{\sigma_h-1}-\frac{\bar{\gamma}_h}{\gamma_h}}{\gamma_h-\bar{\gamma}_h}\right)\\
&= \frac{np_h^x T_h}{1+np_h^x T_h}\left(\frac{\gamma_h}{\sigma_h-1}\frac{T_h-1}{T_h}\theta_h-1\right)\left(\frac{\eta_h}{\sigma_h-1}-\upsilon_h^*\right)
\end{aligned}$$

Then

$$\hat{A}_h/\hat{T}_h < 0 \Leftrightarrow \begin{cases} \bar{\gamma}_h > \gamma_h > \underline{\gamma}_h & \\ \gamma_h < \underline{\gamma}_h \text{ and } & \frac{\eta_h}{\sigma_h-1} > \upsilon_h^* \\ \gamma_h > \bar{\gamma}_h \text{ and } & \frac{\eta_h}{\sigma_h-1} < \upsilon_h^* \end{cases}$$

B.2.3 Comparing tariff and TBT liberalization

Entry cutoff productivity. From totally differentiating (16) one obtains

$$\frac{\hat{\varphi}_h^*}{\hat{\tau}_h} = -\frac{np_h^x T_h}{1+np_h^x T_h} < 0.$$

Export cutoff level Accordingly, totally differentiating (11) yields

$$\begin{aligned}
\frac{\widehat{\left(\varphi_h^x\right)^*}}{\hat{\tau}_h} &= \frac{\hat{\varphi}_h^*}{\hat{\tau}_h}+1\\
&= \frac{1}{1+np_h^x T_h} > 0.
\end{aligned}$$

Fraction of exporters. From differentiating (13) we obtain

$$\frac{\hat{p}_h^x}{\hat{\tau}_h} = -\gamma_h. \tag{44}$$

Average productivity. From totally differentiating (14) we obtain

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{\tau}_h} = \frac{\widehat{\tilde{\varphi}}_h^d}{\hat{\tau}_h} - \frac{\gamma_h}{\sigma_h - 1} \frac{np_h^x}{1 + np_h^x} \frac{T_h - 1}{1 + np_h^x T},$$

where we have used (44). Using (7), we see that $\widehat{\tilde{\varphi}}_h^d / \hat{\tau}_h = \widehat{\varphi}_h^* / \hat{\tau}_h$. Then totally differentiating (16) and (14) yields respectively

$$\frac{\widehat{\varphi}_h^*}{\hat{\tau}_h} = -\frac{np_h^x T_h}{1 + np_h^x T_h} \tag{45}$$

and

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{\tau}_h} = -\frac{np_h^x T_h}{1 + np_h^x T_h} \left(1 + \frac{\gamma_h}{\sigma_h - 1} \frac{1}{1 + np_h^x} \frac{T_h - 1}{T_h} \right). \tag{46}$$

Then

$$\frac{\widehat{\tilde{\varphi}}_h}{\hat{\tau}_h} < 0 \Leftrightarrow \frac{1}{\gamma_h} > -\frac{1}{\sigma_h - 1} \frac{1}{1 + np_h^x} \frac{T_h - 1}{T_h}.$$

Input diversity. From totally differentiating (18), we get

$$\frac{\widehat{M}_h}{\hat{\tau}_h} = (\sigma_h - 1) \left(\frac{\widehat{\varphi}_h^*}{\hat{\tau}_h} - \frac{\widehat{\tilde{\varphi}}_h}{\hat{\tau}_h} \right).$$

Plugging in (45) and (46) yields

$$\frac{\widehat{M}_h}{\hat{\tau}_h} = \frac{\gamma_h (T_h - 1)}{1 + np_h^x T_h} \frac{np_h^x}{1 + np_h^x}. \tag{47}$$

Industry productivity. Inserting (46) and (47) into (19) yields

$$\frac{\hat{A}_h}{\hat{\tau}_h} < 0 \Leftrightarrow \eta_h \frac{\gamma_h}{\sigma_h - 1} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x} < 1 + \frac{\gamma_h}{\sigma_h - 1} \frac{T_h - 1}{T_h} \frac{1}{1 + np_h^x}. \tag{48}$$

Let $\psi_h^* \equiv \frac{1}{\sigma_h - 1} + \frac{1}{\gamma_h} \frac{T_h}{T_h - 1} (1 + np_h^x)$. Then condition (48) implies $\eta_h / (\sigma_h - 1) < \psi_h^*$ for $T_h > 1$ and $\eta_h / (\sigma_h - 1) > \psi_h^*$ for $T_h < 1$ respectively.

B.2.4 Discussion

Resource saving effect. Using the free entry condition (15), the stationarity condition (17), and the expression for average profits (36), the total amount of labor devoted to fixed costs is given by

$$\begin{aligned} F_h &= M_h^d f_h^d + n M_h^x f_h^x + M_h^e f_h^e \\ &= M_h^d f_h^d \left(1 + n p_h^x T_h\right) + \frac{p_h^{in}}{\delta_h} \bar{\pi}_h M_h^e \\ &= M_h^d f_h^d \left(1 + n p_h^x T_h\right) + \bar{\pi}_h M_h^d \\ &= f_h^d M_h^d \left(1 + n p_h^x T_h + \bar{\pi}_h / f_h^d\right) \\ &= f_h^d M_h^d \left(1 + n p_h^x T_h + \frac{\sigma_h - 1}{\gamma_h - (\sigma_h - 1)} \left(1 + n p_h^x T_h\right)\right) \\ &= f_h^d M_h^d \left(1 + n p_h^x T_h\right) \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \end{aligned}$$

Dividing both sides by R_h, using $M_h = M_h^d \left(1 + n p_h^x\right)$, plugging in the expression for r^d evaluated at $\tilde{\varphi}_h$ into the expression for input diversity, and using the expressions for average productivity (14) and (7), we find that a fixed share of aggregate revenues is devoted to the payment of fixed costs.is actually constant

$$\begin{aligned} \frac{F_h}{R_h} &= \frac{1}{\sigma_h} \frac{1 + n p_h^x T_h}{1 + n p_h^x} \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \left(\frac{\varphi_h^*}{\tilde{\varphi}_h}\right)^{\sigma_h - 1} \\ &= \frac{1}{\sigma_h} \frac{1 + n p_h^x T_h}{1 + n p_h^x} \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \left(\frac{\varphi_h^*}{\tilde{\varphi}_h}\right)^{\sigma_h - 1} \frac{1 + n p_h^x}{1 + n p_h^x T} \frac{\gamma_h - (\sigma_h - 1)}{\gamma_h} \\ &= \frac{1}{\sigma_h}. \end{aligned}$$