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Anna Bohnstedt[1]

Spillovers from Foreign Exporters

Abstract

We develop a general equilibrium model of international trade with heterogeneous firms that accounts for productivity spillovers transmitted by foreign exporters. Everything else equal, stronger spillovers increase welfare. We embed the model framework into a trade policy scenario where countries strategically set inter-country variable trade costs for the trading partner. In the strategic Nash-equilibrium policy, governments trade-off welfare gains from protectionism and those which are due to spillovers from foreign exporters. The equilibrium degree of protectionism is decreasing in the strength of the spillover. Policy coordination induces welfare gains, but these gains can be hump-shaped in the spillover strength.

JEL Classification: F1, L25

Keywords: Spillovers; heterogeneous firms

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1 University of Duisburg-Essen. – The author thanks Florian Mayneris, Michael Pflüger, Jens Südekum, and the audiences at various seminar presentations for very helpful comments. – All correspondence to Anna Bohnstedt, Mercator School of Management, University of Duisburg-Essen, Lotharstr. 65, 47057 Duisburg, Germany. E-Mail: anna.bohnstedt@uni-due.de.

1 Introduction

There is substantial diffusion of modern technologies[1] across countries. Actually, countries adopt up to three-fourth of innovative ideas from abroad, and these ideas considerably contribute to domestic (productivity) growth (see e.g., Eaton and Kortum (1999) and Keller (2009)). Thereby, the literature identifies various channels through which technological expertise diffuses, and highlights the role of internationally active firms as an important transmitter of knowledge. The most prominent, and empirically well discussed, channels are foreign direct investment (FDI) and trade (see e.g., Gong and Keller (2003) and Keller (2004) who review the importance of different transmission channels).[2] In the past, slightly more attention was paid to foreign firms that decide to relocate production to the domestic country, i.e., for the case of FDI. The empirical evidence for the importance of this channel is rather mixed (see e.g., Crespo and Fontoura (2007) for a survey), however, recent studies find a positive effect of the presence of multinational firms on domestic productivity due to FDI spillovers (see e.g., Keller and Yeaple (2009)). International diffusion of technology via trade is also widely discussed in the literature and can be further subdivided into import-related and export-related technology diffusion. While there is strong empirical evidence for import-related spillovers (see e.g., Bas and Strauss-Kahn (2011), Bas (2009), Keller (2002a), Acharya and Keller (2008), and Acharya and Keller (2009)), the empirical literature finds weak or no effect of learning-by-exporting (see e.g., Clerides et al. (1998)).

Our paper focuses on trade as transmission channel. In particular, we connect to the strong empirical evidence on the relevance of import-related technology diffusion and theoretically model productivity enhancing spillovers conveyed by foreign firms that serve the domestic market via exports. While we do not provide a micro-foundation for technology spillovers, we explore the implications of existing import-related spillovers for strategic trade policy. Precisely, we provide a general equilibrium model of international trade, where firms are heterogeneous in their marginal costs à la Melitz (2003), and which accounts for spillovers from foreign exporters.[3] The productivity enhancing spillover is modeled as an overall increase in a country's technological potential as introduced in

[1] The term "technology" includes all kinds of knowledge, for instance, product, process, and distribution specific technologies as well as management and marketing skills (see Blomstroem and Kokko (1998)).

[2] Recently also other cross-border actions like communication are analyzed as a possible channel for the diffusion of technology. For instance, studies suggest that language skills have a positive effect on the diffusion of ideas across countries (see e.g., Keller (2002b)).

[3] Note that we use a Melitz (2003) framework with heterogeneous firms since in a standard Krugman model with homogeneous firms either all firms or no firm would export, depending on the level of variable inter-country trade costs. With heterogeneous firms, countries' can maximize welfare with respect to the mass of foreign exporters in their country since the mass is a continuous function with respect to variable trade costs.

Bohnstedt et al. (2011). In their model, a higher technological potential yields a higher expected productivity draw for each single firm. Our model can clearly explain that if productivity spillovers, modeled as an increase in a country's technological potential, exist, this increases welfare. Hence, the focus of the paper are the general equilibrium repercussions of spillovers from foreign exporters in a Melitz (2003)-type model.

In this heterogeneous firms framework with spillovers, we analyze a basic strategic trade policy scenario in which governments' can strategically set the trading partners' inter-country variable trade costs. That is, countries can influence how easily foreign exporters can access the domestic market, or in other words countries choose their degree of protectionism and accessibility, respectively. In a world without spillovers, countries have a clear incentive for protectionism since it stimulates market entry in the own country and softens foreign competition.

In a strategic Nash-equilibrium this results in prohibitively high trade costs because both countries want to become the "protectionism leader".[4] However, in a framework with productivity enhancing spillovers from foreign exporters, protectionism excludes countries from the benefits of these spillovers. High trade costs translate into weaker spillovers since there are less foreign exporters active in the domestic market, which negatively affects the domestic country's welfare. Consequently, countries that increase variable trade costs for foreign exporters face a trade-off between welfare gains from protectionism and welfare losses due to weaker trade-induced spillovers. In a strategic Nash-equilibrium policy countries set trade costs which are not prohibitively high. Furthermore, we find that inter-country trade costs are decreasing in the strength of the spillover. That is, countries set lower trade costs for the trading partner, and hence open up to trade, the stronger the positive effect of the spillover is. In our model countries choose their degree of protectionism and accessibility, respectively, by setting inter-country variable trade costs for the trading partner. Although the nature of this choice variable is not exactly the one of a tariff,[5] the results given above can comparably be found in contributions on optimal tariffs in the new trade literature (see e.g., Gros (1987) and Venables (1987)) and in the "new new" trade literature (see e.g., Felbermayr et al. (2012)). These studies also find an equilibrium tariff which is neither prohibitively high, nor equal to zero.

[4]The unilateral incentive for protectionism in order to maximize welfare is a well-known result in the relevant literature, see e.g., Melitz and Ottaviano (2008), Pflueger and Russek (2011a), and Ossa (2011). However, note that Felbermayr and Jung (2012) show that this result hinges on the assumption of a homogeneous goods sector. Without the outside sector both countries would benefit from unilateral trade liberalization modeled as a reduction in iceberg-type trade costs.

[5]Since the choice variable of countries' in our model, inter-country variable trade costs, generates no tariff revenue, and since explicit import tariffs are not legal according to the trade principles of the World Trade Organization (WTO), the nature of this variable is best explained by comparing it to a non-tariff barrier to trade, like e.g., legal or technical requirements on imported products.

In a cooperative scenario, where countries jointly maximize total welfare, countries aim for a bilateral dismantling of variable inter-country trade costs. Intuitively, the existence of spillovers magnifies the incentive for perfect trade liberalization since governments want to maximize the benefits from spillovers and do not have an incentive for protectionism. This result matches with the fact that there are constant efforts by the World Trade Organization (WTO) to reduce trade barriers.

From a policy maker's perspective, these are important results since they identify an additional welfare enhancing channel of trade liberalization, namely spillovers from foreign exporters to the domestic country. There are potential welfare gains from supranational coordination of trade policies. This is because the cooperative scenario internalizes the welfare enhancing effects of spillovers while in the strategic scenario the incentive for protectionism hinders countries to take full advantage of spillovers from foreign exporters. Comparing the welfare levels between the cooperative solution and the Nash-equilibrium policy, we find that welfare gains from policy coordination can be hump-shaped in the strength of the spillover. Stronger spillovers first open up a technological gap, which increases the welfare difference, before welfare levels finally converge. In that case, welfare gains from policy coordination are largest with intermediate spillovers.

1.1 Related Literature

First, our model is related to the heterogeneous firms literature, especially the seminal contribution on heterogeneous firms by Melitz (2003).[6] In particular, the model is closely related to research dealing with asymmetric countries in a Melitz (2003) framework (see e.g., Pflueger and Russek (2011a), Demidova (2008), and Falvey et al. (2005) for recent studies). As in Demidova (2008), we consider a country's technology distribution to be country-specific. However, in contrast to her paper, we allow for endogenous technology differences across countries, which are determined by productivity spillovers from foreign exporters. Furthermore, our paper is loosely related to the heterogeneous firms literature which studies various policy instruments that are transmitted via trade, e.g., entry subsidies (see Pflueger and Suedekum (2009)), FDI subsidies (see Chor (2009)), research investments (see Bohnstedt et al. (2011)) or default risks (see Pflueger and Russek (2011b)).

Second, our paper is related to the endogenous trade policy literature. A huge litera-

[6]The huge literature on heterogeneous firms (see, e.g., Melitz (2003), Melitz and Ottaviano (2008), and Behrens et al. (2009)) was motivated by newly available firm-level empirical studies. Starting in the nineties, various scholars (see, e.g., Bernard and Jensen (1999), Aw et al. (2000), and Clerides et al. (1998)) documented that even in narrowly defined industries firms differ substantially in such dimensions as productivity, firm size, and export status.

ture focuses on the interests of special lobbying groups (see e.g., Grossman and Helpman (1994)) while our model is more closely related to the research which studies trade policy regimes that maximize national welfare. For example Gros (1987) has studied optimal tariffs in a strategic Nash-equilibrium for the Krugman (1980) model of monopolistic competition. Recently scholars have started to discuss tariffs in the context of heterogeneous firms models (see e.g., Felbermayr et al. (2012), Cole and Davies (2009), and Demidova and Rodriguez-Clare (2009)). In a small economy setting, Demidova and Rodriguez-Clare (2009) show that there actually exists an optimal tariff, which reduces the mark-up distortion of monopolistic competition between foreign and domestic varieties. Although Felbermayr et al. (2012) use CES preferences as in Melitz (2003) while Cole and Davies (2009) use quasi-linear preferences as in Melitz and Ottaviano (2008), those heterogeneous firms frameworks yield quite similar predictions. In a heterogeneous firms framework, a country's unilaterally chosen tariff results in a lower average firm productivity compared to the cooperative solution, which in turn implies potential welfare gains from bilateral cooperation. We do not explicitly study tariffs but our paper is closely related to this literature and to the results. Rather than studying tariffs, we simply assume that countries influence inter-country variable trade costs of foreign exporters, who convey productivity spillovers to the domestic country. We do also rule out any potential welfare effects from redistribution of tariffs.

Third, there is the theoretical literature on the micro-foundation of spillovers. The model on export spillovers by Krautheim (2007) is based on a network approach, where firms exporting to the same country share information, which reduces firms fixed export costs and alleviates market access. In the corresponding literature on FDI spillovers, various micro-foundations that have been proposed. For instance, suppliers (resalers) in upstream (downstream) markets can benefit from productivity spillovers (through linkages) of multinationals as argued by Markusen and Venables (1999). Another strand of the literature focuses on "learning" (see e.g., Glass and Saggi (2002), Fosfuri et al. (2001), and Markusen and Rutherford (2004)), which is more closely related to our approach since in our model spillovers from foreign exporters yield an overall increase in the domestic country's technological potential. However, note that our modeling of spillovers does not explain from which source spillovers originate, and through which channels they rise a country's technological potential.

The rest of this paper is organized as follows. In section 2 we consider an open economy version of a heterogeneous firms model setup à la Melitz (2003), without explicitly modeling spillovers. In section 3 we derive the comparative static results with respect to variable trade costs and a country's technological potential. Section 4 introduces productivity enhancing spillovers from foreign exporters and derives the Nash-equilibrium as well as the cooperative policy, and offers a welfare comparison for the two policy regimes. Finally, section 5 briefly considers the case of asymmetric countries and section 6 concludes.

2 The model

We consider an open economy setting with two countries r and s that are asymmetric with respect to inter-country trade costs and their technological potential. In all other dimensions the countries are assumed to be identical. Precisely, each economy is populated by L workers and each worker inelastically supplies one unit of labor. In each country labor is the only factor of production and perfectly mobile across two industries: a homogeneous goods sector A with constant returns to scale and perfect competition, and a manufacturing industry C, which is monopolistically competitive and consists of a continuum of differentiated varieties. Each variety is produced by a single firm under increasing returns to scale and firms are heterogeneous in their productivities, i.e., marginal costs as modeled in Melitz (2003). In the A-sector there are zero trade costs. This ensures factor price equalization, provided both sectors are active in both countries after trade. In sector C there are two types of trade costs. First, there are per-period fixed costs of exporting, f_x, that arise if a firm decides to serve the market in the other country. Second, there are inter-country variable trade costs, which are modeled as standard iceberg-type trade costs, i.e., for one unit of output to arrive, a firm needs to ship $\tau_{rs} > 1$ units from country r to country s.

2.1 Preferences

In each country the preferences of a household h are defined over the homogeneous good, which is used as the numeraire, and over the set of differentiated varieties Ω, which consists of domestic and foreign varieties. Utility is represented by a quasi-linear, logarithmic function with constant elasticity of substitution (CES) subutility over the set of varieties

$$U = \beta \ln C_h + A_h \quad \text{with} \quad C_h = \left(\int_{z \in \Omega} q_h(z)^{\rho} \, \mathrm{d}z \right)^{1/\rho},$$

where $0 < \rho < 1$, $\beta > 0$, and domestic and foreign varieties enter the utility function symmetrically. The household's consumption of a variety z is given by $q_h(z)$. The elasticity of substitution between any two varieties is given by $\sigma \equiv 1/(1-\rho) > 1$. The CES price index for the bundle of varieties in country r can then be derived in the standard way and reads as $P_r = \left(\int_{z \in \Omega} p(z)^{1-\sigma} \, \mathrm{d}z \right)^{1/(1-\sigma)}$, where $p(z)$ denotes the price of a variety z. Utility maximization implies per-capita expenditures $P_r C_h = \beta$ and $A_h = y_h - \beta$ for the manufacturing aggregate and the homogeneous good, respectively, where y_h stands for the household's income. We drop the subscript h from now on as all households are identical. Using the CES price index P_r we can express demand and revenue for a single variety z. For a domestic variety z, i.e., a variety that is produced and sold in country r at the price p_r, demand and revenue are given by $q_r(z) = \beta L p_r(z)^{-\sigma} P_r^{\sigma-1}$ and $r_r(z) = \beta L (P_r/p_r(z))^{\sigma-1}$, respectively. Moreover, an export variety z from country r that is sold in country s at price p_{xr} yields a demand and revenue of $q_{xr}(z) = \beta L p_{xr}(z)^{-\sigma} P_s^{\sigma-1}$ and $r_{xr}(z) = \beta L (P_s/p_{xr}(z))^{\sigma-1}$, respectively.

2.2 Production and Firm Behavior

In sector A one unit of labor is needed to produce one unit of output. As the price for that good is normalized to one and since workers are perfectly mobile across sectors, this implies that the wage is also equal to one. In the manufacturing industry C, a firm needs $l = \overline{f} + q/\varphi$ units of labor to produce q units of output. The overhead costs are $\overline{f} = f$ if a firm is only active domestically while a firm that additionally serves the export market faces overhead costs $\overline{f} = f + f_x$, with $f_x > f$. While the overhead costs are the same for each firm (for a given export status), firms are heterogeneous in their productivity φ. Furthermore, the firm-specific marginal costs are $1/\varphi$ for the production of a domestic variety while for an export variety that is produced in country r and sold in country s the iceberg-type variable trade costs yield marginal costs of τ_{rs}/φ.

With respect to the price setting behavior firms have zero mass and thus take the price index in each country as given. Since consumers have iso-elastic demands, firms charge prices which are constant mark-ups over firm-specific marginal costs. Firms from country r that sell varieties in their domestic market r set a price $p_r(\varphi) = 1/(\rho\varphi)$, sell the quantity $q_r(\varphi) = \beta L (\rho\varphi)^{\sigma} P_r^{\sigma-1}$, generate revenue $r_r(\varphi) = \beta L (\rho\varphi P_r)^{\sigma-1}$, and earn profits $\pi_r(\varphi) = r_r(\varphi)/\sigma - f$. Similarly, for the export market, if a firm from country r ships to country s, it charges a price $p_{xr}(\varphi) = \tau_{rs}/(\rho\varphi)$, sells the quantity $q_{xr}(\varphi) = \beta L (\rho\varphi/\tau_{rs})^{\sigma} P_s^{\sigma-1}$, has revenue $r_{xr}(\varphi) = \beta L (\rho\varphi P_s/\tau_{rs})^{\sigma-1}$, and earns additional export profits of $\pi_{xr}(\varphi) = r_{xr}(\varphi)/\sigma - f_x$. Due to the additional iceberg-type trade costs it is evident that for a given productivity φ, firms set a lower price, sell a larger quantity, generate higher revenue, and earn a higher variable profits in their own domestic market compared to their export market. Firms with a higher productivity φ charge a lower price, sell a larger quantity, generate a higher revenue, and earn higher profits in their domestic market as well as in their export market.

2.3 Entry and Exit

At each point of time there is a mass M_r^E of entrants, which enter the manufacturing industry in country r subject to a sunk entry cost f_e. Upon entry, they learn about their firm-specific productivity level φ, which is drawn from a common and known country-specific distribution $G_r(\varphi)$. In the following we assume productivities to be Pareto distributed with $G_r(\varphi) = 1 - \left(\varphi_r^{MIN}/\varphi\right)^k$ and with density $g_r(\varphi) = k\left(\varphi_r^{MIN}\right)^k \varphi^{-(k+1)}$, where $k > 1$ is the shape parameter and $\varphi_r^{MIN} > 0$ is the lower bound in country r.[7] As in Bohnstedt et al. (2011), we refer to the lower bound of the Pareto distribution, φ_r^{MIN}, as country r's technological potential. Comparing two Pareto distributions with different lower bounds, the productivity distribution with the higher technological potential, φ_r^{MIN}, first stochastically dominates the productivity distribution with the lower technological potential. Intuitively, a higher φ_r^{MIN} reflects a "right shift" of the Pareto distribution, which implies a higher expected productivity draw.

After learning about the idiosyncratic productivity draw, each firm decides whether to serve the domestic market only, to serve the domestic market as well as the export market, or to exit the market and never start production. There are two productivity threshold levels, called cutoff productivities, which induce this partitioning of firms and are endogenously determined later in the equilibrium. The cutoff productivity to serve the domestic market is denoted by φ_r^* while the cutoff productivity to serve the export market is given by φ_{xr}^*. Intuitively, firms from country r with a productivity draw $\varphi_r < \varphi_r^*$ will decide to exit the market because they cannot cover the per-period fixed costs f to start production for the domestic market. Firms with a productivity draw $\varphi_r^* < \varphi_r < \varphi_{xr}^*$ will serve the domestic market only and those firms with a productivity draw $\varphi_r > \varphi_{xr}^*$ are able to cover the additional fixed costs of exporting f_x and decide to serve the domestic market as well as the export market. The above described partitioning of firms in country r occurs if the additional costs of starting an export activity are sufficiently high compared to the costs of starting production in the domestic market, which is fulfilled since we have assumed $f_x > f$ before.

As in Melitz (2003), every active firm can then be hit by a bad shock with probability $\delta > 0$ at each point of time, which is assumed to be uncorrelated with the firms' productivity draws.[8] If this shock occurs, the firm must shut down. In a stationary equilibrium without time discounting, the mass of entrants which successfully enter country r equals

[7] The Pareto distribution is the commonly used distribution to replicate firm heterogeneity (see e.g., Bernard et al. (2003) or Melitz and Ottaviano (2008)) since it fits empirical firm size distributions very well (see Axtell (2001)).

[8] See Pflueger and Russek (2011b) for a Melitz-type model that studies heterogeneity in the probability of insolvency.

the mass of firms which are forced to exit $p_r^{in} M_r^E = \delta M_r$, where $p_r^{in} = 1 - G_r(\varphi_r^*)$ is the ex ante survival probability of entrants. The endogenous productivity distribution among surviving firms, $\mu_r(\varphi)$, is thus equal to $\mu_r(\varphi) = g_r(\varphi) / (1 - G_r(\varphi_r^*)) = k (\varphi_r^*)^k \varphi_r^{-(k+1)}$ if $\varphi > \varphi_r^*$ and equal to zero otherwise, i.e., it also follows a Pareto distribution with shape parameter k on the domain $[\varphi_r^*, \infty)$ with mean $\tilde{\varphi}_r$.

2.4 Equilibrium

The open economy equilibrium can be determined by the free entry condition (FEC) and the zero cutoff profit condition (ZCPC). Both conditions establish a relationship between ex ante expected profits $\overline{\pi}_r$ and the cutoff productivity φ_r^*. Firms will enter the productivity lottery and bear the entry costs f_e until the value of entry, $v^E = E\left[\sum_{t=0}^{\infty} (1-\delta)^t \pi(\varphi)\right] - f_e$, equals zero. The FEC for country r then reads as

$$\overline{\pi}_r = \delta f_e \left(\frac{\varphi_r^*}{\varphi_r^{MIN}} \right)^k \qquad \text{(FEC)}$$

and represents the ex ante expected profit conditional on successful entry. The ZCPC accounts for the fact that firms can serve the domestic market and, if sufficiently productive, the export market. Ex ante expected profits for a firm located in country r (conditional on survival) can be written in the following way $\overline{\pi}_r = \pi_r(\widetilde{\varphi}_r) + p_r^x \pi_{xr}(\widetilde{\varphi}_{xr})$, where $p_r^x = (\varphi_r^*/\varphi_{xr}^*)^k$ is the probability to be an exporter among all active firms from country r, $\pi_{xr}(\widetilde{\varphi}_{xr})$ is the corresponding expected export profit level, $\widetilde{\varphi}_r$ is the average productivity among all active domestic firms, and $\widetilde{\varphi}_{xr}$ is the average productivity among all exporting firms from country r. Using $\widetilde{\varphi}_r/\varphi_r^* = \widetilde{\varphi}_{xr}/\varphi_{xr}^* = \left(\frac{k}{k+1-\sigma}\right)^{1/(\sigma-1)}$, which holds under the Pareto distribution, the ZCPC in country r (with $r \neq s$) can be rewritten as follows

$$\overline{\pi}_r = \frac{f(\sigma-1)}{k+1-\sigma} \left[1 + \phi_r \left(\frac{\varphi_r^*}{\varphi_s^*} \right)^k \right], \qquad \text{(ZCPC)}$$

where

$$\phi_r \equiv \frac{1}{(\tau_{rs})^k} \left(\frac{f}{f_x} \right)^{\frac{(k+1-\sigma)}{(\sigma-1)}} \qquad (1)$$

is a country-specific measure of trade openness, with $0 < \phi_r < 1$. In our model this trade openness parameter indicates how easy domestic firms can access the foreign export market and hence the degree of protectionism in the foreign country. As it gets clear from (1), trade openness ϕ_r can be influenced by inter-country variable trade costs τ_{rs}. Higher variable trade costs indicate a higher degree of protectionism in the destination country and hamper export market accessibility. Intuitively, with higher trade costs it is harder for domestic firms to serve the export market. For example $\tau_{rs} > \tau_{sr}$ implies $\phi_s > \phi_r$, i.e., export market accessibility for firms from country s is better than for firms from country r. Nevertheless, assuming symmetry in the variable trade costs with $\phi = \phi_r = \phi_s$ means that $\phi = \phi_r = \phi_s = 1$ captures free trade while with $\phi = \phi_r = \phi_s = 0$ we have autarky. Substituting the FEC into the ZCPC then leads to a system of two equations, which can be solved for the equilibrium cutoff productivities. The cutoff productivity in country r is given by

$$\varphi_r^* = \left[\frac{\chi\left(1 - \phi_r\phi_s\right)}{\chi - \phi_r}\right]^{\frac{1}{k}} \cdot \Gamma \cdot \varphi_r^{MIN} \quad \text{and} \quad \varphi_s^* = \left[\frac{1 - \phi_r\phi_s}{1 - \phi_s\chi}\right]^{\frac{1}{k}} \cdot \Gamma \cdot \varphi_s^{MIN}, \tag{2}$$

where $\Gamma = \left[\left(f\left(\sigma - 1\right)\right) / \left(\delta f_e\left(k + 1 - \sigma\right)\right)\right]^{1/k}$.[9] The term $\chi = \left(\varphi_s^{MIN} / \varphi_r^{MIN}\right)^k$, with $0 < \chi < 1$, measures the relative technological potential of country s.

As in Bohnstedt et al. (2011) we need to impose that the technological asymmetry is sufficiently small relative to the degree of export market accessibility, namely $\chi_r > \phi_s$, to ensure that $\varphi_r^* > 0$. Provided this condition and since $\Gamma \cdot \varphi_r^{MIN}$ determines the cutoff productivity under autarky we also have $\varphi_r^* > \Gamma \cdot \varphi_r^{MIN}$. That is, both countries have a higher cutoff in the open economy than under autarky, which is the selection effect of trade emphasized by Melitz (2003). Furthermore, domestic and export cutoffs are linked as $\varphi_{xs}^* = \Lambda_s \varphi_r^*$ with $\Lambda_s \equiv \tau_{sr}\left(f_x/f\right)^{1/(\sigma-1)} > 1$.

To complete the description of the equilibrium we need to determine the share of the workforce, γ, that is employed in the manufacturing sector in each country. In the Appendix we derive the conditions which ensure that both sectors in both countries are active after trade, i.e., $0 < \gamma < 1$. Using those conditions, it is then straightforward to derive the equilibrium masses of entrants (M_r^E), surviving firms (M_r), exporting firms (M_{xr}), and consumption variety ($M_{tr} = M_r + M_{xs}$) for both countries - also see the Appendix. The CES price index in country r is given by $P_r = M_{tr}^{1/(1-\sigma)} / \left(\rho\widetilde{\varphi}_{tr}\right)$, where $\widetilde{\varphi}_{tr}$ is the average productivity among all (domestic and foreign) firms active in market r. Finally, indirect utility as a measure for welfare in country r can be written as follows

$$V_r = 1 + \beta \cdot \ln \varphi_r^* + \frac{\beta}{\sigma - 1} \ln L + \kappa_1, \tag{3}$$

where $\kappa_1 = \beta(\ln(\beta\rho) - 1) + \beta/(\sigma - 1)\ln(\beta/\sigma f)$ is a constant. Welfare in country r is sufficiently described by the domestic cutoff productivity φ_r^*, which in turn depends on the country's technological potential φ_r^{MIN} and on the degree of both market accessibilities, as can be seen from (2). Note that a higher cutoff φ_r^* in country r increases welfare.

[9] For consistency we need to assume that $\Gamma > 1$.

3 Some Comparative Statics

Ultimately, we are interested in the endogenous determination of trade policies. To illustrate through what channels countries may have an incentive to become the "protectionism leader" or the "technological leader", we first derive the comparative static results with respect to unilateral changes in inter-country variable trade costs and a country's technological potential.

3.1 Trade Costs

First, consider an initial situation where the two countries r and s have identical variable inter-country trade costs $\tau_{rs} = \tau_{sr} = \tau_0$ and hence a common degree of export market accessibility $\phi_r = \phi_s = \phi_0$.[10] Country s then experiences an exogenous increase in its variable trade costs τ_{sr}, whereas the variable trade costs for country r, τ_{rs}, remain unchanged. This causes a disparity in the export market accessibility between the two countries, namely $\phi_r = \phi_0 > \phi_s$. For country s it is now harder to export to country r since it has to bear higher variable trade costs than before. In other words country r becomes the "protectionism leader" while country s is the "accessibility leader". Proposition 1 summarizes the main comparative static results, which are proven in the Appendix. Note that we have to assume that country asymmetries are moderate such that both sectors in both countries are active after trade, i.e., $0 < \gamma_r < 1$ and $0 < \gamma_s < 1$.

Proposition 1 *Comparing the "old equilibrium" with $\phi_r = \phi_s = \phi_0$ and the "new equilibrium" with $\phi_r = \phi_0 > \phi_s$, we find that i) $M_r^E > M_0^E > M_s^E$ for the mass of entrants, ii) $M_r > M_0 > M_s$ for the mass of surviving firms, iii) $M_{xr} > M_{x0} > M_{xs}$ for the mass of exporting firms, iv) $p_r^x > p_0^x > p_s^x$ for the exporting probability, v) $M_{tr} > M_{t0} > M_{ts}$ for consumption diversity, vi) $\widetilde{\varphi}_r > \widetilde{\varphi}_0 > \widetilde{\varphi}_s$ for the average productivity of domestic firms, and finally vii) $V_r > V_0 > V_s$ for welfare.*

If country r exogenously becomes the "protectionism leader" this yields a positive change in the average productivity, consumption diversity, and welfare in that country. Proposition 1 also illustrates the incentive for country s (the "accessibility leader") to increase protection of the domestic market since average productivity, consumption diversity, and welfare actually decrease in absolute terms when a variable trade cost gap opens up.

Furthermore, the incentive for country r to become the "protectionism leader" in-

[10] The subscript "0" denotes the degree of export market accessibility of both countries in the initial situation.

creases the more integrated the economies are. Formally, we consider the relative cutoff productivity $(\varphi_r^*/\varphi_s^*)$ as a measure for relative welfare. Since it is beneficial for country r to become the protectionism leader we have $\partial(\varphi_r^*/\varphi_s^*)/\partial\tau_{sr} > 0$. In the Appendix we additionally show that $\partial^2(\varphi_r^*/\varphi_s^*)/(\partial\tau_{rs}\partial\tau_{sr}) < 0$. In words, the increase in relative welfare and consequently the incentive to become the protectionism leader is larger, the more integrated countries are (formally, the lower the initial level $\tau_{rs} = \tau_0$). The economic intuition is as follows. If country r becomes the protectionism leader, this implies greater expected profits from serving the domestic market r and the foreign export market s. This in turn stimulates market entry and yields tougher selection in country r. In the accessibility leader country s, where exporters have to bear higher variable trade costs $\tau_{sr} > \tau_{rs}$, lower expected profits decrease market entry and imply looser selection. These considerations are amplified by trade liberalization.

3.2 Technological Potential

Second, we study unilateral changes in the technological potential. Similar to the previous case, consider an initial situation where the two countries r and s have a common technological potential $\varphi_s^{MIN} = \varphi_r^{MIN} = \varphi_0^{MIN}$. Then country r experiences a technological improvement, whereas the technological potential in country s remains unchanged. This causes a technological disparity between the two countries, namely $\varphi_r^{MIN} > \varphi_s^{MIN} = \varphi_0^{MIN}$. In Proposition 2 we summarize the main comparative static results, which are proven in the Appendix.[11]

Proposition 2 *Comparing the "old equilibrium" with* $\varphi_r^{MIN} = \varphi_s^{MIN} = \varphi_0^{MIN}$ *and the "new equilibrium" with* $\varphi_r^{MIN} > \varphi_s^{MIN} = \varphi_0^{MIN}$*, we find that i)* $M_r^E > M_0^E > M_s^E$ *for the mass of entrants, ii)* $M_r > M_0 > M_s$ *for the mass of surviving firms, iii)* $M_{xr} > M_{x0} > M_{xs}$ *for the mass of exporting firms, iv)* $p_r^x > p_0^x > p_s^x$ *for the exporting probability, v)* $M_{tr} > M_{t0} > M_{ts}$ *for consumption diversity, vi)* $\widetilde{\varphi}_r > \widetilde{\varphi}_0 > \widetilde{\varphi}_s$ *for the average productivity of domestic firms, and finally vii)* $V_r > V_0 > V_s$ *for welfare.*

Country r benefits from an increase in its technological potential. Gains in productivity, consumption diversity, and welfare are a strong incentive to become the "technological leader". Average productivity, consumption diversity, and welfare in the laggard country actually decrease in absolute terms when a technological gap opens up, even if the technological potential in country s does not change. Hence country s has an incentive to "keep up" with the "technological leader". As it is shown in Bohnstedt et al. (2011), the

[11] Again we have to assume moderate country asymmetries such that $0 < \gamma_r < 1$ and $0 < \gamma_s < 1$.

incentive to become the "technological leader" is also amplified by trade integration. The economic intuition is that the technological difference yields a competitive advantage for the firms from the leading country. Precisely, the market in country r is characterized by tougher selection than the market in country s. Therefore firms from country s find it harder to export to the market in r than vice versa. The incentive for entry in country s reduces, which loosens selection even more. This, in turn, boosts the expected exporting profits for firms from country r. The more integrated countries are, the stronger are these general equilibrium repercussions.

4 Spillovers from foreign Exporters and Strategic Trade Policy

In the following we distinguish between two different policy regimes. First, we consider a strategic Nash-equilibrium, where both countries independently choose their trade policy. Second, we analyze the cooperative solution, where the countries jointly determine their trade policy in order to maximize total welfare. In both scenarios the choice variable of each country is the variable trade costs exporters from the other country have to bear if they decide to export. Formally, country r sets variable trade costs for country s exporters, τ_{sr}, while the choice variable in country s is τ_{rs}. For instance, consider the case where country r sets τ_{sr} and country s sets τ_{rs} such that $\tau_{sr} > \tau_{rs}$. Then exporters from country s are relatively hindered compared to exporters from country r.

Intuitively, each country influences its degree of market accessibility by setting variable trade costs for foreign exporters. Although, explicit import tariffs to hinder foreign exporters are not legal according to WTO rules[12], there is a wide range of non-tariff barriers to trade, which have become of increasing importance over the last decades. Especially technical barriers, which impose certain requirements on imported products, heavily affect tariff lines (see e.g., UNCTAD (2005)). These technical barriers are perceived as a relevant obstacle from foreign markets (see e.g., OECD (2005)) and have a negative effect on trade integration (see Chen and Novy (2011)). Non-tariff barriers to trade, like the technical measure described above, are country-specific and represent a fraction of variable trade costs that can surely be influenced by each country's trade policy. They determine the inter-country variable trade costs in our model and have a direct effect on the degree of market accessibility and protectionism, respectively. Furthermore the consideration that inter-country variable trade costs are basically determined by non-tariff

[12] One of the principles of the WTO trading system is trade without discrimination. That is, countries are not allowed to discriminate between their trading partners and thus have to treat every member of the WTO equally.

barriers is intuitive since in our model no tariff revenue is generated.

4.1 Spillovers from foreign Exporters

We now introduce spillovers into the model framework. As motivated in the introduction, foreign exporters are a transmitter of knowledge and technology, which ultimately yields productivity gains in the domestic country. In order to model these positive spillovers from foreign exporters to domestic firms, we assume that spillovers from foreign exporters increase the domestic country's technological potential. Formally, a larger mass of exporters from country s, M_{xs}, increases the technological potential φ_r^{MIN} in country r with

$$\varphi_r^{MIN}\left(M_{xs}\right) = \exp\left\{\alpha \cdot M_{xs}\right\}, \tag{4}$$

where $\alpha \geq 0$. As stated in Proposition 2, an increase in the technological potential of a country increases the average productivity, which in our model represents the productivity enhancing effect of spillovers conveyed by foreign exporters. Note that in autarky the technological potential in country r is normalized to one since $M_{xs} = 0$ and hence $\varphi_r^{MIN}(0) = 1$. If there is bilateral trade it follows that $M_{xs} > 0$ and the technological potential is higher compared to the autarkic scenario. Everything else equal, productivity spillovers from country s to country r are stronger, the higher α or the larger the mass of exporters M_{xs} is.[13]

4.2 Nash-Equilibrium Policy

We now consider the strategic scenario where country r chooses τ_{sr} such that welfare in country r, V_r, is maximized while country s independently sets τ_{rs} in order to maximize V_s. The maximization problem for country r is given by

$$\max_{(\tau_{sr})} V_r = 1 + \beta \cdot \ln \varphi_r^* + \frac{\beta}{\sigma - 1} \ln L + \kappa_1$$

and the corresponding first-order condition (FOC) can be written as

$$\frac{\partial V_r}{\partial \tau_{sr}} \Big|_{\tau=\tau_{sr}=\tau_{rs}} = \underbrace{\frac{\beta\,\phi^2}{\tau\left(1-\phi^2\right)}}_{\text{protectionism}} + \underbrace{\overbrace{\frac{\beta}{(1-\phi)} \frac{\varphi_r^{MIN\prime}(\alpha,\beta)}{\varphi^{MIN}}}^{\text{direct}} - \overbrace{\frac{\beta\,\phi}{(1-\phi)} \frac{\varphi_s^{MIN\prime}(\alpha,\beta)}{\varphi^{MIN}}}^{\text{indirect}}}_{\text{spillover}} = 0. \tag{5}$$

[13] The technical assumption of an exponential relationship allows for closed form solutions but does not alter the qualitative results.

Note that $\varphi^{MIN}(\tau = \tau_{sr} = \tau_{rs}) = \varphi_r^{MIN} = \varphi_s^{MIN}$ since there is symmetry between countries in the Nash-equilibrium, and that $\varphi_r^{MIN'}$ and $\varphi_s^{MIN'}$ are the corresponding partial derivatives of φ_r^{MIN} and φ_s^{MIN} with respect to τ_{sr}. The FOC can be split into three summands, which identify the different effects how inter-country variable trade costs influence welfare. Recall that higher variable trade costs indicate a higher degree of protectionism.

First, consider the summand which is labeled as "protectionism". It is unambiguously positive and reflects country r's incentive to become the "protectionism leader" by raising variable trade costs for foreign exporters τ_{sr}. In case of zero spillovers[14], a country's protectionism incentive is grounded on the general equilibrium repercussions as spelled out in Proposition 1. The protectionism leader induces stronger market entry in the own domestic market since firms in the more protected country expect higher profits in the domestic market as well as in the export market. A higher mass of entrants then induces tougher selection and eventually raises welfare. Consequently, without productivity spillovers from foreign exporters the resulting Nash-equilibrium would be $\tau_{rs} = \tau_{sr} \to \infty$. In this autarkic scenario, countries set infinitely high transport costs to protect their domestic market from foreign competition and realize welfare gains as proposed in Proposition 1.

The second effect labeled as "spillover" is negative and reflects the welfare losses from protecting domestic firms from foreign competition. Intuitively, a higher degree of protectionism weakens the welfare enhancing effects of productivity spillovers transmitted by foreign exporters. The two summands are negative since $\varphi_r^{MIN'} < 0$ and $\varphi_s^{MIN'} > 0$. That is, an increase in the variable trade costs of foreign exporters, τ_{sr}, decreases welfare in country r, which represents the incentive for country r to become the "accessibility leader". In the following we further decompose the "spillover" effect into a "direct" and an "indirect" effect.

Analytically, the "direct" effect is the reduction in the technological potential of the domestic country r, φ_r^{MIN}, which is welfare decreasing as spelled out in Proposition 2. By setting high variable trade costs for foreign exporters from country s, τ_{sr}, the domestic country r hinders those exporters to serve the domestic market in country r. Intuitively, it is then less profitable to export and the mass of foreign exporters, M_{xs}, decreases. This in turn decreases the technological potential since it positively depends on the mass of foreign exporters as it gets clear from (4). The "indirect" effect is the increase in the technological potential of country s, φ_s^{MIN}, since more exporters from country r, M_{xr}, are active in country s. Intuitively, decreasing expected profits for country s firms yields less entrants in country s and softens competition for country r exporters. Hence, the mass of

[14]Note that if $\alpha = 0$ in (4) this implies $\varphi_r^{MIN'} = \varphi_s^{MIN'} = 0$ and the second and third summand in (5) are zero.

exporters from country r, M_{xr}, increases. The resulting higher technological potential in country s is, everything else equal, welfare decreasing for country r, which is also stated in Proposition 2. Note that both effects are amplified in the strength of the spillover while the protectionism incentive is independent of α.

In order to determine the Nash-equilibrium, we can solve (5) for τ^{Nash}, which can be written as

$$\tau^{Nash} = \left[\frac{(\zeta_1 - \zeta_2)^{\frac{1}{3}} + (\zeta_1 + \zeta_2)^{\frac{1}{3}} - (\alpha\beta\,(1 + k - \sigma))^2 + (\sigma f_x)^2 - \alpha\beta\sigma f_x\,(k + 1 - \sigma)}{3\alpha\beta\sigma\,(1 + k - \sigma)\, f^{\frac{k+1-\sigma}{1-\sigma}} f_x^{\frac{k}{\sigma-1}}} \right]^{\frac{1}{k}}, \quad (6)$$

where the terms ζ_1 and ζ_2 are stated in the Appendix.[15] For a given mass of exporters, the strength of the spillover is solely determined by α and we can numerically show that τ^{Nash} monotonically decreases in α. That is, if the "spillover" effect in (5) becomes more important, countries will further decrease their strategic variable trade costs in order to benefit from spillovers transmitted by foreign exporters. We summarize in Proposition 3.

Proposition 3 *In a strategic Nash-equilibrium countries independently choose variable trade costs τ^{Nash} that trade-off the gains from protectionism with the gains from spillovers transmitted by foreign exporters. We find that i) the more important spillovers are (higher α), the lower are the strategic trade costs τ^{Nash}. It follows that ii) if spillovers are sufficiently weak both countries set prohibitively high variable trade costs such that they find themselves in an autarkic scenario and iii) if the strength of the spillover is sufficiently strong, i.e., $\alpha \to \infty$, this implies $\tau^{Nash} \to 1$ and countries choose minimal variable trade costs.*

Furthermore, numerical simulations indicate that for a given strength of the spillover, a higher preference for varieties β increases the incentive to open up to trade since with lower strategic trade costs more foreign varieties enter the domestic market.

4.3 Cooperative Policy

We now consider the cooperative scenario where both countries jointly maximize total

[15] For consistency we have to assume $\tau^{Nash} \geq 1$.

welfare, which is given by $\Omega \equiv V_r + V_s$. The FOC can be written as

$$\frac{\partial \Omega}{\partial \tau_{sr}} \mid_{\tau=\tau_{sr}=\tau_{rs}} = -\underbrace{\frac{\beta\,\phi}{\tau\,(1+\phi)}}_{\text{selection}} + \underbrace{\overbrace{\frac{\beta\,\varphi_r^{MIN'}(\alpha,\beta)}{\varphi^{MIN}}}^{\text{direct}} + \overbrace{\frac{\beta\,\varphi_s^{MIN'}(\alpha,\beta)}{\varphi^{MIN}}}^{\text{indirect}}}_{\text{spillover}} < 0 \tag{7}$$

and is unambiguously negative. As in the strategic Nash-equilibrium scenario the FOC can be split into three summands which identify the different welfare effects.

The first term represents the classic "selection" effect à la Melitz (2003) and is unambiguously negative. Bilateral trade liberalization yields tougher selection in both markets. Intuitively, the new foreign exporting firms are on average more productive than the domestic firms that quit production. This in turn increases the average productivity in both markets and is welfare increasing in both countries. If there are zero spillovers (i.e., $\alpha = 0$ in (4)) the welfare enhancing selection effect would imply minimal variable trade costs such that countries cooperatively choose $\tau^{Coop} = 1$.

Second, consider the "spillover" effect. Bilaterally increasing variable trade costs yields less exporters in both countries such that the technological potential decreases in both countries. Formally, the terms $\varphi_s^{MIN'}$ and $\varphi_r^{MIN'}$ are negative which implies that the "spillover" effect is unambiguously negative. As in the case of the strategic Nash-equilibrium, we can disentangle the "spillover" effect in an "direct" and "indirect" effect, where the direct (indirect) effect represents the decrease in technological potential in the home (foreign) country r (s). Since both the welfare enhancing selection effect and productivity spillovers from foreign exporters are maximized if there are minimal variable trade costs countries cooperatively choose $\tau^{Nash} = 1$. We summarize in Proposition 4.

Proposition 4 *Countries that cooperatively choose variable trade costs that maximize total welfare Ω choose $\tau^{Coop} = 1$. This maximizes both the gains from tougher selection à la Melitz (2003) and the increase in the technological potential due to productivity spillovers from foreign exporters.*

4.4 Spillovers from foreign Exporters and Welfare Comparison

In order to understand the welfare gains from policy coordination in our model, in the following we compare the Nash-equilibrium policy and the cooperative solution. The analysis starts with a comparison of the policy regime induced differences in the technological potential and continues with a welfare comparison for both policy regimes.

Formally, the difference in the technological potentials is given by $\tilde{\Delta}^{\varphi^{MIN}} = \varphi^{MIN}(\tau = \tau^{Coop}) - \varphi^{MIN}(\tau = \tau^{Nash})$. To simplify the notation, consider the following monotonic transformation of $\tilde{\Delta}^{\varphi^{MIN}}$ given by

$$\Delta^{\varphi^{MIN}} \equiv \alpha \cdot M_x(\tau = \tau^{Coop}) - \alpha \cdot M_x(\tau = \tau^{Nash}), \quad (8)$$

and where $\Delta^{\varphi^{MIN}}$ can be interpreted as the endogenously determined technological difference between the cooperative policy and the Nash-equilibrium policy.[16] Note that $\Delta^{\varphi^{MIN}} \geq 0$ since in the cooperative policy the mass of foreign exporters is larger than in the Nash-equilibrium, i.e., $M_x(\tau = \tau^{Coop}) \geq M_x(\tau = \tau^{Nash})$. Intuitively, the cooperative solution internalizes the welfare enhancing effects of productivity spillovers from foreign exporters and hence maximizes the mass of exporters while in the Nash-equilibrium policy the strategic incentive for protectionism hinders countries to take full advantage of productivity spillovers transmitted by foreign exporters. From this result regarding the mass of foreign exporters it gets clear that, irrespectively of the strength of the spillover, α, the technological potential given by (4) is higher in the cooperative policy than in the strategic Nash-equilibrium policy, i.e., $\varphi^{MIN}(\tau = \tau^{Coop}) \geq \varphi^{MIN}(\tau = \tau^{Nash})$.

The impact of the spillover strength, α, on the technological difference $\Delta^{\varphi^{MIN}}$ can be determined by

$$\frac{\partial \Delta^{\varphi^{MIN}}}{\partial \alpha} = M_x(\tau = \tau^{Coop}) - M_x(\tau = \tau^{Nash}) - \alpha \cdot \frac{\partial M_x}{\partial \tau^{Nash}} \cdot \frac{\partial \tau^{Nash}}{\partial \alpha}, \quad (9)$$

where the sign is ambiguous. Figure 1 illustrates the actual relationship between $\Delta^{\varphi^{MIN}}$ and α, which is humped-shaped.[17] The economic intuition is as follows. Consider the spillover in the cooperative policy given by $\alpha \cdot M_x(\tau = \tau^{Coop})$. It increases linearly in α since with $\tau^{Coop} = 1$ the mass of foreign exporters is constant. In contrast, the mass of exporters in the Nash-equilibrium policy, $M_x(\tau = \tau^{Nash})$, positively depends on α. This is the case since a higher α yields a lower τ^{Nash}, as derived in Proposition 3, which implies a higher mass of exporters. For low levels of α, such that $\alpha < \alpha^*$, the spillover in the Nash-equilibrium increases less than proportional and for high levels of α, such that $\alpha > \alpha^*$, it increases more than proportional.[18] Formally, for $\alpha < \alpha^*$ the marginal increase in the technological potential in the cooperative solution is larger than in the Nash-equilibrium policy. Intuitively, an increase in the strength of the spillover yields a

[16] An alternative approach would be to consider $\tilde{\Delta}^{\varphi^{MIN}}$. The following results are qualitatively similar to this approach while the terms become unnecessarily larger.

[17] To understand this humped-shaped relationship analytically, note that $\alpha \to 0$ implies $\partial \Delta^{\varphi^{MIN}} / \partial \alpha = M_x(\tau = \tau^{Coop}) > 0$ while for $\alpha \to \infty$ it follows $\partial \Delta^{\varphi^{MIN}} / \partial \alpha = -\alpha(\partial M_x / \partial \tau^{Nash})(\partial \tau^{Nash} / \partial \alpha) < 0$.

[18] The threshold α^* is implicitly given by $\partial \Delta^{\varphi^{MIN}} / \partial \alpha = 0$.

relatively low increase in the Nash-equilibrium policy mass of exporters since the spillover is relatively weak compared to the protectionism incentive as can be seen from (5). In contrast to this, for $\alpha > \alpha^*$ the spillover in (5) is relatively strong. This implies that an increase in the spillover strength yields a relatively high increase in $M_x(\tau = \tau^{Nash})$ and $\Delta^{\varphi^{MIN}}$ eventually decreases. We can conclude that sufficiently strong spillovers yield the convergence of the strategic and cooperative trade policy, i.e., $\tau^{Nash} \rightarrow \tau^{Coop} = 1$, which closes the technological gap ($\Delta^{\varphi^{MIN}} \rightarrow 0$). Figure 2 illustrates this relationship between both technological potentials, i.e., $\varphi^{MIN}(\tau = \tau^{Nash})$ and $\varphi^{MIN}(\tau = \tau^{Coop})$, and the strength of the spillover α. Note that the technological difference, and hence the welfare gains from policy coordination, is largest if spillovers are intermediate, i.e., $\alpha = \alpha^*$.

The difference in welfare levels between the cooperative solution and the Nash-equilibrium policy is given by $\Delta^W \equiv V^{Coop}(\tau = \tau^{Coop}) - V^{Nash}(\tau = \tau^{Nash})$ and simplifies to

$$\Delta^W = \beta\, \Delta^{\varphi^{MIN}} + \beta\, \ln\left(\frac{1+\phi(\tau = \tau^{Coop})}{1+\phi(\tau = \tau^{Nash})}\right). \tag{10}$$

The expression Δ^W is positive since welfare in the cooperative solution is higher than in the Nash-equilibrium.[19] We are now again interested in how the strength of the spillover influences the welfare difference Δ^W and hence we consider

$$\frac{\partial \Delta^W}{\partial \alpha} = \beta \cdot \frac{\partial \Delta^{\varphi^{MIN}}}{\partial \alpha} - \frac{\beta}{1+\phi(\tau = \tau^{Nash})} \cdot \frac{\partial \phi(\tau = \tau^{Nash})}{\partial \alpha}. \tag{11}$$

Note that a higher α decreases the Nash-equilibrium trade costs τ_{Nash}, which in turn implies a higher trade openness, i.e., $\partial\phi(\tau = \tau^{Nash})/\partial\alpha > 0$. If α is sufficiently high, such that $\partial\Delta^{\varphi^{MIN}}/\partial\alpha < 0$, welfare levels in the cooperative solution and in the Nash-equilibrium converge when the spillover strength increases, i.e., $\partial\Delta^W/\partial\alpha < 0$. For low levels of α, such that $\alpha < \alpha^*$, the situation is ambiguous. The trade induced effect, $\partial\phi(\tau = \tau^{Nash})/\partial\alpha > 0$, still decreases the welfare difference. However, the technological difference increases, i.e., $\partial\Delta^{\varphi^{MIN}}/\partial\alpha > 0$, which in turn increases the welfare difference. It depends on concrete parameter values which effect dominates. If the "trade effect" dominates the "technology effect", the welfare difference decreases in the strength of the spillover even for low levels of α. If the "technology effect" dominates the "trade effect", welfare levels diverge for low levels of α and welfare gains from supranational coordination are largest if spillovers are intermediate but lower than α^*. Proposition 5 summarizes.

[19] Formally, the welfare difference is positive since $\Delta^{\varphi^{MIN}} \geq 0$ and $\tau^{Nash} \geq \tau^{Coop}$, which implies $\phi(\tau = \tau^{Nash}) < \phi(\tau = \tau^{Coop})$.

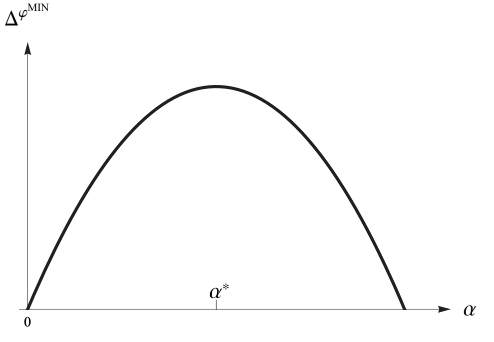

Figure 1: Difference in the technological potentials: $\Delta^{\varphi^{MIN}}(\alpha)$

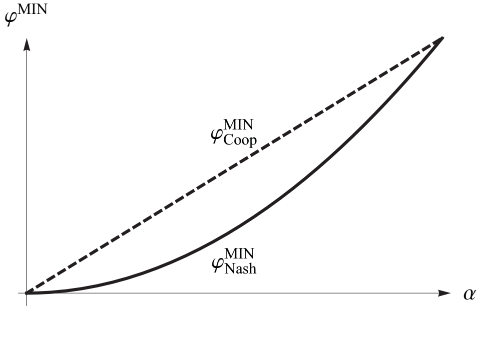

Figure 2: $\varphi^{MIN}_{Coop} \equiv \varphi^{MIN}(\tau = \tau^{Coop})$ and $\varphi^{MIN}_{Nash} \equiv \varphi^{MIN}(\tau = \tau^{Nash})$

Proposition 5 *i) The technological difference between the cooperative policy and the Nash-equilibrium policy is a humped-shaped relationship in* α*. For relatively weak (strong) spillovers, a marginal increase in* α *opens up (closes) the technological gap* $\Delta^{\varphi^{MIN}}$*. ii) The welfare difference* Δ^W *between the two policies is decreasing (hump-shaped) in* α *if the "trade effect" ("technology effect") dominates. iii) Sufficiently strong spillovers* ($\alpha \to \infty$) *yield the convergence of both trade policies* ($\tau^{Nash} \to \tau^{Coop} = 1$)*, technological potentials* ($\varphi^{MIN}(\tau = \tau^{Nash}) \to \varphi^{MIN}(\tau = \tau^{Coop})$)*, and welfare levels* ($V(\tau = \tau^{Nash}) \to V(\tau = \tau^{Coop})$)*.*

To develop economic intuition for the interesting result that welfare gains from policy coordination can be hump-shaped in the strength of the spillover, it is helpful to better understand the "trade effect" and the "technology effect". Both effects determine the impact of increasing spillovers on the welfare difference between the Nash-equilibrium policy and the cooperative solution. The "trade effect" unambiguously decreases the welfare difference. Stronger spillovers result in lower strategic trade costs and a better market accessibility, respectively, which eventually increases welfare in the Nash-equilibrium policy. The "technology effect" captures the difference in the technological potentials between both policy regimes. The impact of stronger spillovers on the technological difference is hump-shaped as can be seen from figure 1. An increase in the strength of the spillover first opens up a technological gap, which closes after reaching a certain threshold level. Thereby a larger technological difference increases the welfare difference while the convergence of technological potentials decreases the welfare difference. Thus, if the "technology effect" dominates the "trade effect", the hump-shaped relationship between stronger spillovers and the technological difference carries over to the welfare difference. This in turn implies that welfare gains from policy coordination are hump-shaped in the strength of the spillover and largest if spillovers are intermediate.

5 Asymmetric Countries

We now briefly discuss the case of two asymmetric countries that exogenously differ in either country size or their technological potentials, and where the population size in country r is denoted by L_r and the technological potential in country r is denoted by φ_r^{MIN}. Welfare in country r can be written as

$$W_r = L_r \left(1 + \beta \cdot \ln \varphi_r^* \left(\varphi_r^{MIN} \right) + \frac{\beta}{\sigma - 1} \ln L_r + \kappa_1 \right) \tag{12}$$

while the cutoffs are still given by (2). We cannot solve explicitly for the strategic Nash-equilibrium policy in closed form. However, using (12) we can numerically derive the strategic inter-country variable trade costs τ_{sr}^{Nash} and τ_{rs}^{Nash} that solve $\partial W_r/\partial\tau_{sr} = 0$ and $\partial W_s/\partial\tau_{rs} = 0$, respectively, see the Appendix for details.

If we assume country r to be the larger ($L_r > L_s$) or technologically advanced ($\varphi_r^{MIN} > \varphi_s^{MIN}$) country, respectively, the numerical simulations show that country r sets lower strategic variable trade costs than country s. In the Nash-equilibrium it follows $\tau_{sr}^{Nash} < \tau_{rs}^{Nash}$. Furthermore, we find that for both countries the strategic variable trade costs decrease in the strength of the spillover α, which is in line with Proposition 3 and confirms that even in the case of asymmetric countries stronger spillovers constitute an incentive to open up for trade. In figure 3 and figure 4 we plot τ_{sr}^{Nash} and τ_{rs}^{Nash} as a function of α for both an asymmetry in country size and an asymmetry in the technological potential. The economic intuition for $\tau_{sr}^{Nash} < \tau_{rs}^{Nash}$ is as follows. For a given level of variable trade costs that is identical across countries, country r is characterized by a relatively larger mass of exporters. As it gets clear from (4), this rises the technological potential in country s relatively stronger. To balance this effect, country r provides a better export market accessibility for foreign firms by setting relatively lower variable trade costs. Moreover, our numerical simulations indicate that country r is characterized by a higher welfare level than country s and that welfare in both countries increases in the strength of the spillover.

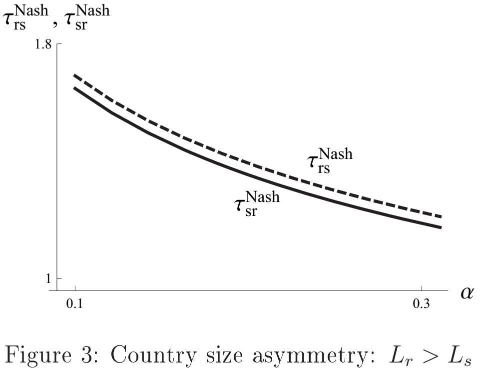

Figure 3: Country size asymmetry: $L_r > L_s$

Comparing the strategic scenario with the cooperative scenario, we find that country r has higher potential welfare gains from supranational coordination of trade policies. To develop economic intuition for this result, recall that in the Nash-equilibrium country r sets the lower strategic variable trade costs. This implies that for country r spillovers are more important than for country s. Since in the cooperative solution productivity enhancing spillovers from foreign exporters are maximized, country r benefits relatively

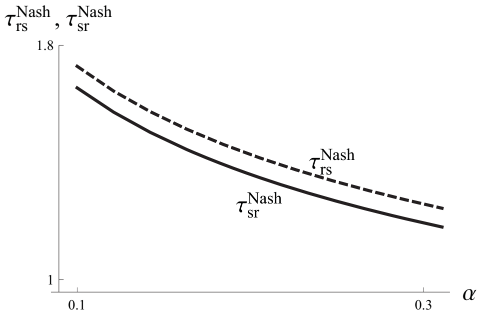

Figure 4: Technological potential asymmetry: $\varphi_r^{MIN} > \varphi_s^{MIN}$

more from policy coordination in the cooperative solution.

6 Conclusion

We have developed a model of international trade that explicitly accounts for spillovers conveyed by foreign exporters. These productivity enhancing spillovers are modeled as an increase in a country's technological potential, which is eventually welfare increasing. In a strategic trade policy scenario, countries maximize welfare with respect to the degree of market accessibility, which effects the mass of foreign exporters in their country. Choice variable is the inter-country trade cost for the trading partner. Higher trade costs account for the incentive to protect the domestic market from foreign competition but translate into lower spillovers. Consequently, governments trade off welfare gains from protectionism and welfare losses due to lower spillovers. Comparing the welfare enhancing effects of spillovers from foreign exporters in a strategic Nash-equilibrium policy with those in a cooperative policy scenario, we find that coordinating trade policies maximizes the welfare enhancing effects of spillovers and a selection effect à la Melitz (2003). Hence, there exist potential welfare gains from supranational coordination of trade policies. Interestingly, we find that these welfare gains can be hump-shaped in the strength of the spillover. If the "technology effect" dominates the "trade effect", with stronger spillovers the welfare difference between the cooperative solution and the Nash-equilibrium policy first increases before the welfare levels converge.

For asymmetric countries our numerical simulations indicate that the larger or the technologically advanced country, respectively, sets lower strategic variable trade costs, and that the strategic trade costs in both countries decrease in the strength of the spillover. Comparing the strategic and the cooperative scenario, we find that the larger or technologically advanced country, respectively, has higher potential welfare gains from coordination of trade policies.

For policy makers our model identifies an additional welfare enhancing channel of trade liberalization, namely spillovers from foreign exporters. We are the first to study such import-related productivity spillovers in a general equilibrium model of heterogeneous firms. This is important since the related literature mainly focuses on the role of FDI in transmitting knowledge and technology spillovers.

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Appendix

Open Economy Equilibrium. To characterize the open economy we first have to impose a balanced trade condition. This allows us to derive the conditions under which both sectors in both countries are active after trade. From the perspective of country r trade is balanced if

$$p_r^x M_r r_{xr}(\tilde{\varphi}_{xr}) = p_s^x M_s r_{xs}(\tilde{\varphi}_{xs}) + (1-\beta)L_r - (1-\gamma_r)L_r$$

holds. On the LHS we have manufacturing exports while on the RHS we first have manufacturing imports, and second the difference between consumption and production of the homogeneous good. Following Pflueger and Russek (2010), we now substitute for $M_r = \gamma_r L_r/\bar{r}_r$, where $\bar{r}_r = r_r(\tilde{\varphi}_r) + p_r^x r_{xr}(\tilde{\varphi}_{xr})$ and $\beta(L_r + L_s) = \gamma_r L_r + \gamma_s L_s$. Solving for γ_r and γ_s then yields

$$\gamma_r = \frac{\beta \bar{r}_r}{r_r(\tilde{\varphi}_r)} \frac{(1-\phi_s/\xi)}{(1-\phi_s\phi_r)} \quad \text{and} \quad \gamma_s = \frac{\beta \bar{r}_s}{r_s(\tilde{\varphi}_s)} \frac{(1-\phi_r\xi)}{(1-\phi_s\phi_r)},$$

where $\xi \equiv (L_r/L_s)(\varphi_s^*/\varphi_r^*)^k$. Both sectors in both countries are active if $0 < \gamma_r < 1$ and $0 < \gamma_s < 1$. Three conditions must be satisfied to secure this: i.) country size differences must be moderate, ii.) differences in variable trade costs must be moderate, and iii.) differences in the technological potentials must be moderate. Using γ_r and γ_s, the masses of firms are immediately implied by $M_r\bar{r}_r = \gamma_r L$ and $M_s\bar{r}_s = \gamma_s L$, respectively. The term $r_r(\varphi_r^*)$ follows from the ZCPC and is given by $\varphi_r^* = \sigma k f/(k+1-\sigma)$. Using this we get

$$M_r = \frac{(k+1-\sigma)\beta L_r}{\sigma k f}\left[\frac{1-\phi_s/\xi}{1-\phi_r\phi_s}\right] \quad \text{and} \quad M_s = \frac{(k+1-\sigma)\beta L_s}{\sigma k f}\left[\frac{1-\phi_r\xi}{1-\phi_r\phi_s}\right].$$

The mass of exporting firms is then $M_{xr} = p_r^x M_r$ and the mass of entrants following can be derived according to $M_r^E = \delta M_r(\varphi_r^*/\varphi_r^{MIN})^k$. The consumption variety available in country r is $M_{tr} = M_r + M_{xs}$. The price level can be rewritten as $P_r = M_{tr}^{1/(1-\sigma)} p_r(\tilde{\varphi}_{tr})$, where

$$\tilde{\varphi}_{tr} = \left\{(1/M_{tr})\left(M_r\tilde{\varphi}_r^{\sigma-1} + M_{xr}\tau_{sr}^{1-\sigma}\tilde{\varphi}_{xr}^{\sigma-1}\right)\right\}^{1/(\sigma-1)}$$

can be interpreted as the average productivity of all active firms (domestic and foreign) that serve consumers in country r.

Proposition 1. The following results are sufficient to prove Proposition 1. To simplify the notation we define

$$\nu_1 = 2\left(ff_x\right)^{\frac{2(k-1+\sigma)}{\sigma-1}}\left(\tau_{rs}\tau_{sr}\right)^k + \left(f^{\frac{k}{\sigma-1}}f_x\right)^3\left(f^{\frac{k}{\sigma-1}}f_x - 2ff_x^{\frac{k}{\sigma-1}}\tau_{rs}^k\right) + \left(\tau_{rs}\tau_{sr}^2\right)^k\left(f_x^{\frac{k}{\sigma-1}}f\right)^3\left(f^{\frac{k}{\sigma-1}}f_x\tau_{rs}^k - 2f_xf^{\frac{k}{\sigma-1}}\right) > 0$$

and

$$\nu_2 = \left(ff_x^{\frac{k}{\sigma-1}}\tau_{sr}^k - f^{\frac{k}{\sigma-1}}f_x\right)^2\left(\left(ff_x^{\frac{k}{\sigma-1}}\right)^2\left(\tau_{rs}\tau_{sr}\right)^k - \left(f^{\frac{k}{\sigma-1}}f_x\right)^2\right)^2 > 0.$$

$$(i)\quad \frac{\partial M_r^E}{\partial \tau_{sr}} = \frac{\beta\left(\sigma-1\right)\tau_{sr}^{k-1}\left(ff_x\right)^{\frac{k+1-\sigma}{\sigma-1}}}{\sigma f_e\left(f^{\frac{k}{\sigma-1}}f_x - ff_x^{\frac{k}{\sigma-1}}\tau_{sr}^k\right)^2} > 0$$

$$\frac{\partial M_s^E}{\partial \tau_{sr}} = -\frac{\beta\left(\sigma-1\right)\tau_{sr}^{k-1}\left(ff_x\right)^{\frac{k+1-\sigma}{\sigma-1}}}{\sigma f_e\left(f^{\frac{k}{\sigma-1}}f_x - ff_x^{\frac{k}{\sigma-1}}\tau_{sr}^k\right)^2} < 0$$

$$(ii)\quad \frac{\partial M_r}{\partial \tau_{sr}} = \frac{\beta\left(k+1-\sigma\right)f^{\frac{k}{\sigma-1}}f_x^{\frac{k+1-\sigma}{\sigma-1}}\tau_{sr}^{k-1}\nu_1}{\sigma\nu_2} > 0$$

$$\frac{\partial M_s}{\partial \tau_{sr}} = -\frac{2\beta\left(k+1-\sigma\right)\tau_{sr}^{k-1}\tau_{rs}^kf_x^{\frac{2(k+\sigma-1)}{\sigma-1}}f^{\frac{2k+\sigma-1}{\sigma-1}}}{\sigma\left(\left(f_xf^{\frac{k}{\sigma-1}}\right)^2 - \left(\tau_{rs}\tau_{sr}\right)^k\left(ff_x^{\frac{k}{\sigma-1}}\right)^2\right)^2} < 0$$

$$(iii)\quad \frac{\partial M_{xr}}{\partial \tau_{sr}} = \frac{2\beta\left(k+1-\sigma\right)\tau_{sr}^{k-1}\tau_{rs}^kf^{\frac{2(k+\sigma-1)}{\sigma-1}}f_x^{\frac{2k+\sigma-1}{\sigma-1}}}{\sigma\left(\left(f_xf^{\frac{k}{\sigma-1}}\right)^2 - \left(\tau_{rs}\tau_{sr}\right)^k\left(ff_x^{\frac{k}{\sigma-1}}\right)^2\right)^2} > 0$$

$$\frac{\partial M_{xs}}{\partial \tau_{sr}} = -\frac{\beta\left(k+1-\sigma\right)f^{\frac{k+1-\sigma}{\sigma-1}}f_x^{\frac{k}{\sigma-1}}\tau_{sr}^{k-1}\nu_1}{\sigma\nu_2} < 0$$

$$(iv)\quad \frac{\partial p_r^x}{\partial \tau_{sr}} = \frac{kf^{\frac{2k}{\sigma-1}}f_x^{\frac{k+1-\sigma}{1-\sigma}}\tau_{sr}^{-(k+1)}}{ff_x^{\frac{k}{\sigma-1}}\tau_{rs}^k - f^{\frac{k}{\sigma-1}}f_x} > 0$$

$$\frac{\partial p_s^x}{\partial \tau_{sr}} = \frac{fk\tau_{sr}^{-(k+1)}\tau_{rs}^{-k}\left(f_x - f^{\frac{k-1-\sigma}{1-\sigma}}f_x^{\frac{k}{\sigma-1}}\tau_{rs}^k\right)}{\left(f_x - f^{\frac{k-1-\sigma}{1-\sigma}}f_x^{\frac{k}{\sigma-1}}\tau_{sr}^k\right)^2} < 0$$

$$(v)\quad \frac{\partial M_{tr}}{\partial \tau_{sr}} = \frac{\beta\left(k+1-\sigma\right)\left(f_x-f\right)\left(f f_x\right)^{\frac{k}{\sigma-1}}\,\tau_{sr}^{k-1}\nu_1}{\sigma\nu_2} > 0$$

$$\frac{\partial M_{ts}}{\partial \tau_{sr}} = \frac{2\left(f-f_x\right)\left(k+1-\sigma\right)\tau_{sr}^{k-1}\tau_{rs}^{k}\left(f f_x\right)^{\frac{2k+\sigma-1}{\sigma-1}}\,f^{\frac{2k+\sigma-1}{\sigma-1}}}{\sigma\left(\left(f_x f^{\frac{k}{\sigma-1}}\right)^2-\left(\tau_{rs}\tau_{sr}\right)^k\left(f f_x^{\frac{k}{\sigma-1}}\right)^2\right)^2} < 0$$

$$(vi)\quad \frac{\partial \tilde{\varphi}_r}{\partial \tau_{sr}} = \left(\frac{k}{k+1-\sigma}\right)^{\frac{1}{\sigma-1}}\frac{\partial \varphi_r^*}{\partial \tau_{sr}} > 0$$

$$\frac{\partial \tilde{\varphi}_s}{\partial \tau_{sr}} = \left(\frac{k}{k+1-\sigma}\right)^{\frac{1}{\sigma-1}}\frac{\partial \varphi_s^*}{\partial \tau_{sr}} < 0$$

since

$$\frac{\partial \varphi_r^*}{\partial \tau_{sr}} = \frac{\varphi^{MIN}\nu_1\left(f f_x^{\frac{k}{\sigma-1}}\tau_{rs}^k - f^{\frac{k}{\sigma-1}}f_x\right)^{-1/k}\left(\left(\tau_{rs}\tau_{sr}\right)^k\left(f f_x^{\frac{k}{\sigma-1}}\right)^2-\left(f^{\frac{k}{\sigma-1}}f_x\right)^2\right)^{\frac{1-k}{k}}}{\left(f_e\delta\left(k+1-\sigma\right)\left(\sigma-1\right)\right)^{1/k}\tau_{rs}^2 f^{\frac{2k}{\sigma-1}}f_x^{\frac{3-2\sigma}{\sigma-1}}} > 0$$

$$\frac{\partial \varphi_s^*}{\partial \tau_{sr}} = -\frac{\varphi^{MIN}\nu_1\left(f f_x^{\frac{k}{\sigma-1}}\tau_{rs}^k - f^{\frac{k}{\sigma-1}}f_x\right)\left(\left(\tau_{rs}\tau_{sr}\right)^k\left(f f_x^{\frac{k}{\sigma-1}}\right)^2-\left(f^{\frac{k}{\sigma-1}}f_x\right)^2\right)^{\frac{1-k}{k}}}{\left(f_e\delta\left(k+1-\sigma\right)\left(\sigma-1\right)\right)^{1/k}\tau_{rs}\tau_{sr}^{k-1}f^{\frac{k-1+\sigma}{\sigma-1}}f_x^{\frac{k-2+\sigma}{\sigma-1}}\left(f f_x^{\frac{k}{\sigma-1}}\tau_{sr}^k - f^{\frac{k}{\sigma-1}}f_x\right)^{\frac{k+1}{k}}} < 0$$

Finally, it follows from (3) that welfare V_r increases in φ_r^* and decreases in φ_s^*. Result (vi) thus implies that (vii) $\partial V_r/\partial \tau_{sr} > 0$ and $\partial V_s/\partial \tau_{sr} < 0$.

Proposition 2. The following results are sufficient to prove Proposition 2.

$$
\begin{aligned}
(i) \quad & \frac{\partial M_r^E}{\partial \varphi_r^{MIN}} = \frac{(\sigma-1)\,\beta\phi\chi\left(1-4\phi\chi+\chi^2+\phi^2\left(1+\chi^2\right)\right)}{\sigma f_e \varphi_r^{MIN}\left(\phi-\chi\right)^2\left(1-\phi\chi\right)^2} > 0 \\
& \frac{\partial M_s^E}{\partial \varphi_r^{MIN}} = -\frac{(\sigma-1)\,\beta\phi\chi\left(1-4\phi\chi+\chi^2+\phi^2\left(1+\chi^2\right)\right)}{\sigma f_e \varphi_r^{MIN}\left(\phi-\chi\right)^2\left(1-\phi\chi\right)^2} < 0 \\
(ii) \quad & \frac{\partial M_r}{\partial \varphi_r^{MIN}} = \frac{\beta\left(1+k-\sigma\right)\phi\chi}{f\sigma\varphi_r^{MIN}\left(1-\phi\chi\right)^2} > 0 \\
& \frac{\partial M_s}{\partial \varphi_r^{MIN}} = -\frac{\beta\left(1+k-\sigma\right)\phi\chi}{f\sigma\varphi_r^{MIN}\left(\phi-\chi\right)^2} < 0 \\
(iii) \quad & \frac{\partial M_{xr}}{\partial \varphi_r^{MIN}} = \frac{\beta\left(1+k-\sigma\right)\phi\chi}{f_x\sigma\varphi_r^{MIN}\left(\phi-\chi\right)^2} > 0 \\
& \frac{\partial M_{xs}}{\partial \varphi_r^{MIN}} = -\frac{\beta\left(1+k-\sigma\right)\phi\chi}{f_x\sigma\varphi_r^{MIN}\left(1-\phi\chi\right)^2} < 0 \\
(iv) \quad & \frac{\partial p_r^x}{\partial \varphi_r^{MIN}} = \frac{k\left(1-\phi^2\right)\chi}{\Lambda^k\varphi_r^{MIN}\left(\phi-\chi\right)^2} > 0 \\
& \frac{\partial p_s^x}{\partial \varphi_r^{MIN}} = -\frac{k\left(1-\phi^2\right)\chi}{\Lambda^k\varphi_r^{MIN}\left(1-\phi\chi\right)^2} < 0 \\
(v) \quad & \frac{\partial M_{tr}}{\partial \varphi_r^{MIN}} = \frac{\left(f_x-f\right)\left(k+1-\sigma\right)\phi\chi}{f f_x\sigma\varphi_r^{MIN}\left(1-\phi\chi\right)^2} > 0 \\
& \frac{\partial M_{ts}}{\partial \varphi_r^{MIN}} = -\frac{\left(f_x-f\right)\left(k+1-\sigma\right)\phi\chi}{f f_x\sigma\varphi_r^{MIN}\left(\phi-\chi\right)^2} < 0 \\
(vi) \quad & \frac{\partial \tilde{\varphi}_r}{\partial \varphi_r^{MIN}} = \left(\frac{k}{k+1-\sigma}\right)^{\frac{1}{\sigma-1}}\frac{\partial \varphi_r^*}{\partial \varphi_r^{MIN}} > 0 \\
& \frac{\partial \tilde{\varphi}_s}{\partial \varphi_r^{MIN}} = \left(\frac{k}{k+1-\sigma}\right)^{\frac{1}{\sigma-1}}\frac{\partial \varphi_s^*}{\partial \varphi_r^{MIN}} < 0
\end{aligned}
$$

since

$$
\begin{aligned}
\frac{\partial \varphi_r^*}{\partial \varphi_r^{MIN}} &= \Gamma\cdot\left(1-\phi^2\right)^{\frac{1}{k}}\left(\frac{\chi}{(\chi-\phi)}\right)^{\frac{k+1}{k}} > 0 \\
\frac{\partial \varphi_s^*}{\partial \varphi_r^{MIN}} &= -\Gamma\cdot\phi\left(1-\phi^2\right)^{\frac{1}{k}}\left(\frac{\chi}{(1-\phi\chi)}\right)^{\frac{k+1}{k}} < 0.
\end{aligned}
$$

Finally, it follows from (3) that welfare V_r increases in φ_r^* and decreases in φ_s^*. Result (vi) thus implies that (vii) $\partial V_r/\partial \varphi_r^{MIN} > 0$ and $\partial V_s/\partial \varphi_r^{MIN} < 0$.

Footnote 8. We have to show that

$$\frac{\partial^2(\varphi_r^*/\varphi_s^*)}{\partial\tau_{rs}\partial\tau_{sr}} = -\left(\frac{f_x}{\tau_{rs}}\right)^2 f^{\frac{2k}{\sigma-1}} \left(\frac{\varphi_r^{MIN}}{\varphi_s^{MIN}}\right) \left(\frac{f\tau_{rs}^k f_x^{\frac{k}{\sigma-1}}(\varphi_s^{MIN})^k - f^{\frac{k}{\sigma-1}} f_x(\varphi_r^{MIN})^k}{f\tau_{sr}^k f_x^{\frac{k}{\sigma-1}}(\varphi_r^{MIN})^k - f^{\frac{k}{\sigma-1}} f_x(\varphi_s^{MIN})^k}\right)^{\frac{k-1}{k}} < 0$$

is negative.

Strategic Nash-Equilibrium. The terms ζ_1 and ζ_2 are given by

$$\begin{aligned}
\zeta_1 \quad &= \quad -27(\alpha\beta\sigma^2 f_x^2(k+1-\sigma))^2 \\
&\quad +18(\alpha\beta\sigma f_x(k+1-\sigma))^2((\alpha\beta(k+1-\sigma))^2 + \alpha\beta\sigma f_x(k+1-\sigma) - \sigma^2 f_x^2) \\
&\quad -2((\alpha\beta(k+1-\sigma))^2 + \alpha\beta\sigma f_x(k+1-\sigma) - \sigma^2 f_x^2)^3 \quad \text{and} \\
(\zeta_2)^2 \quad &= \quad (27(6(\alpha\beta\sigma f_x(k+1-\sigma))^2 - (\alpha\beta(k+1-\sigma))^2 + \alpha\beta\sigma f_x(k+1-\sigma) - \sigma^2 f_x^2)^2)^3 \\
&\quad +27(\alpha\beta\sigma^2 f_x^2(k+1-\sigma))^2 \\
&\quad -18(\alpha\beta\sigma f_x(k+1-\sigma))^2((\alpha\beta(k+1-\sigma))^2 + \alpha\beta\sigma f_x(k+1-\sigma) - \sigma^2 f_x^2) + \\
&\quad 2((\alpha\beta(k+1-\sigma))^2 + \alpha\beta\sigma f_x(k+1-\sigma) - \sigma^2 f_x^2)^3)^2.
\end{aligned}$$

Numerical Approach. Welfare in country r is given by (12) and the cutoffs are given by (2). We derive $\partial W_r/\partial\tau_{sr}$ and $\partial W_s/\partial\tau_{rs}$, which for themselves depend on φ_r^{MIN} and φ_s^{MIN}. We then have four equations: The two first-order-conditions $\partial W_r/\partial\tau_{sr} = 0$ and $\partial W_s/\partial\tau_{rs} = 0$ and the assumed functional form of the spillover for each country, i.e., φ_r^{MIN} and φ_s^{MIN} as given by (4). We then solve those four equations for our four unknowns φ_r^{MIN}, φ_s^{MIN}, τ_{sr}, and τ_{rs}.