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Tariff-Setting and Multinationals

by

Hartmut Egger, Peter Egger and David Greenaway

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Abstract
This paper provides an analysis of non-cooperative tariff-setting in the presence on foreign direct investment. We set up a two-country general equilibrium model with co-existence of exporters and horizontal multinational firms. For symmetric countries, analytical results are derived. The theoretical analysis is enriched by numerical simulation exercises to provide a concise picture of how asymmetries in the economic fundamentals of countries affect our analytical findings. The main hypotheses are confirmed by empirical results from panel regressions. In particular, our findings support the theoretically appealing idea that tariff rates are higher when horizontal multinational firms are prevalent.

Keywords: tariff-setting; monopolistic competition; multinationals

JEL classification: F12, F13, F23

Outline

Non-Technical Summary

Multinational enterprises (MNEs) have a central role in shaping the development of the world economy. Foreign direct investment (FDI) over the last few decades has grown spectacularly: annual inflows were $60 billion in 1982 and are now over $700 billion; whilst over the same period total stocks have grown from $800 billion to over $8,000 billion. This has resulted in 'multinationality' of firms becoming a key driver of the current wave of globalisation. Over this same period trade policy and changes in trade policy have also been centre stage. Even though average tariff levels in OECD countries have declined significantly since World War II trade policy and tariff levels remain controversial in some areas.

The presence of MNEs not only impacts on a country's economic prosperity, they also affect the fortunes of national exporting firms (NEs) by changing their competitive environment in both product and factor markets. In this regard, horizontal MNEs are of special interest for two reasons. First, the preponderance of FDI of developed countries in other, large developed economies indicates that this mode of FDI is important. There is implicit evidence for a dominance of horizontal, trade-cost-jumping FDI over vertical, low-cost-seeking FDI. Second, the mode of a firm's entry as a horizontal MNE versus an NE is characterized by what has become known as the *proximity-concentration trade-off* ie., the trade-off of serving foreign consumers locally through foreign plant production by saving trade costs at the expense of higher fixed costs (*proximity*) versus exporting from a single plant by saving fixed costs at the expense of trade costs (*concentration*). Tariffs affect this trade-off, which renders the analysis of trade policy in general equilibrium with MNEs an important issue. This our focus on in this paper.

The paper builds on previous research and studies non-cooperative tariff determination in a general equilibrium model of trade and horizontal MNEs. For this, we set up a two-sector, two-country model of imperfect competition, which explicitly distinguishes between the physical-capital-serving and the knowledge-capital-serving nature of headquarters for their foreign affiliates We thus account for human capital (or skilled labour) and physical capital as distinct endowment parameters. Like other general equilibrium models of MNEs, one sector is characterized by a large variety of monopolistically competitive firms (NEs and MNEs), while the second (homogeneous sector) serves as the numéraire.

In the empirical part of the paper, we bring our model to the data and assess its main theoretical predictions. For this, we use a spatial econometric approach that allows us to account for cross-country interdependencies. Such interdependencies are an important feature of the world economy but are typically paid scant attention in empirical analysis.

Our findings suggest that variations in trade-weighted tariffs are related in a systematic way to the hypotheses derived from our theoretical model. Specifically, we find that tariff rates are strategic complements in equilibrium. From our general equilibrium model with MNEs, we hypothesize that countries with abundant skilled labor will set higher import tariffs. This is consistent with our empirical evidence. Also the impact of investment costs and (inbound and outbound) FDI stocks give support to our theoretical analysis. Overall, we find that the impact of foreign economies' endowments and other characteristics should not be neglected.

1 Introduction

Multinational enterprises (MNEs) have a central role in shaping the development of the world economy. Foreign direct investment (FDI) over the last few decades has grown spectacularly: annual inflows were $60 billion in 1982 and are now over $700 billion; whilst over the same period total stocks have grown from $800 billion to over $8,000 billion. This has resulted in 'multinationality' of firms becoming a key driver of the current wave of globalisation. Over this same period trade policy and changes in trade policy have also been centre stage. Even though average tariff levels in OECD countries have declined significantly since World War II, and mostly so way before the wave of MNE activity, trade policy and tariff levels remain controversial in some areas.[1]

The presence of MNEs not only impacts on a country's economic prosperity as measured by GDP per capita. MNEs also affect the fortunes of national exporting firms (NEs) by changing their competitive environment in both product and factor markets. In this regard, horizontal MNEs are of special interest for two reasons. First, the preponderance of FDI of developed countries in other, large developed economies indicates that this mode of FDI is important. There is implicit evidence for a dominance of horizontal, trade-cost-jumping FDI (Markusen, 1984, Markusen and Venables, 1998, 2000) over vertical, low-cost-seeking FDI (Helpman, 1984, Helpman and Krugman, 1985).[2] Second, the mode of a firm's entry as a horizontal MNE versus an NE is characterized by what has become known as the *proximity-concentration trade-off* (Brainard, 1993, 1997). ie., the trade-off of serving foreign consumers locally through foreign plant production by saving trade costs at the expense of higher fixed costs (*proximity*) versus exporting from a single plant by saving fixed costs at the expense of trade costs (*concentration*). Tariffs affect this trade-off, which renders the analysis of trade policy in general equilibrium with MNEs an important issue. This our focus on in this paper.

A large part of the literature on trade policy analyses non-cooperative, best-response tariff setting, mostly in a static framework. Johnson (1953) and Horwell (1966) are two pioneering studies and Burbidge and Myers (2004) is a more recent example. By contrast, Bagwell and Staiger (1997a, 1997b) pursue a dynamic approach with an infinite repetition of a static tariff

[1] For instance, see the lively debate about tariff barriers on trade in steel and bananas between the United States and the European Union.
[2] For recent empirical support on this issue see Carr, Markusen and Maskus (2001) as well as Markusen and Maskus (2002).

game to determine the outside options of trade negotiations.[3] Economists have also analysed the impact of national political factors (Hillman and Ursprung, 1988; Grossman and Helpman, 1994) on non-cooperative tariff-setting.[4] However, only a few studies have investigated the determination of tariffs with MNEs. In this regard, at least three valuable attempts should be mentioned: Hillman and Ursprung (1993) assume trade policy to be an outcome of political competition between national and multinational firms; Ludema (2002) analyses the formation of preferential trade agreements in a model of endogenous plant location; and Collie and Vandenbussche (2003) study optimum non-cooperative tariffs in a Cournot-type model with MNEs. However, these models do not consider income effects associated with trade policy.

This paper builds on previous research and studies non-cooperative tariff determination in a general equilibrium model of trade and horizontal MNEs. For this, we set up a two-sector, two-country model of imperfect competition[5]. The model has some similarities with Markusen and Venables (2000). However, we explicitly distinguish between the physical-capital-serving and the knowledge-capital-serving nature of headquarters for their foreign affiliates (see Lipsey, 2002, and Bergstrand and Egger, 2005, on this notion). In doing so, we account for human capital (or skilled labour) and physical capital as distinct endowment parameters. Like other general equilibrium models of MNEs, one sector is characterized by a large variety of monopolistically competitive firms (NEs and MNEs), while the second (homogeneous sector) serves as the numéraire.

Given weak empirical evidence of a sizeable impact of political considerations on trade policy[6] and for the sake of simplicity, we abstain from modelling political factors. The proposed framework is simple enough to render analytical solutions for Nash tariff-setting feasible under symmetry. However, to get a concise picture of how asymmetries in the economic fundamentals impact on reaction functions, we augment our theoretical analysis by insights based on numerical simulation.

In the empirical part of the paper, we bring our model to the data and assess its main theoretical predictions. For this, we use a spatial econometric approach that allows us to

[3] In their footnote 9, Baier and Bergstrand (2003) refer to this as an "ideal approach". Among others, Krugman (1991) and Bond and Syropoulos (1996) analyze Nash tariffs in case of preferential trade agreements.
[4] Bagwell and Staiger (1999) build on Baldwin (1987) in elaborating on the issue that political influences do not offer a way out of the Prisoner's Dilemma of static non-cooperative trade policy games.
[5] See Venables, 1985, for such a model on endogenous trade policy without MNEs
[6] Goldberg and Maggi (1999, page 1151) provide evidence that, in fact, "*the magnitude of political considerations in the government's objective is small.*"

account for cross-country interdependencies. Such interdependencies are an important feature of the world economy but are typically paid scant attention in empirical analysis. By referring to important shortcomings in the related empirical literature, Grossman and Helpman (1995) have noted that "*none of the studies includes any regressors relating to foreign political and economic conditions and thus they assume that international interdependence is unimportant or that foreign industry conditions are uncorrelated with those at home*", an assumption at odds with insights of general equilibrium models of trade.

Even though well-respected empirical evidence points to a limited role for political factors in a government's objective function when deciding upon trade policy and although political variables are not given attention in our theoretical model, one might want to reduce and at best eliminate their influence on the outcome in a regression analysis. Unfortunately, lack of available data prevents us from explicitly controlling for political factors. Even empirical research that aims at explicitly estimating the role of these factors is faced with this limitation. As Goldberg and Maggi (1999, 1140) note, a rigorous analysis "*…would need data on political organization of countries other than the United States. Such data are generally not available.*" However, since we can exploit information from panel data, we are able to control for all time-invariant, country-specific influences.

Our findings suggest that the variation in trade-weighted tariffs is related in a systematic way to the hypotheses derived from our theoretical model. Specifically, we find that tariff rates are strategic complements in equilibrium. From our general equilibrium model with MNEs, we hypothesize that countries with abundant skilled labor will set higher import tariffs. This is consistent with our empirical evidence. Also the impact of investment costs and (inbound and outbound) FDI stocks give support to our theoretical analysis. Overall, we find that the impact of foreign economies' endowments and other characteristics should not be neglected. This underpins the importance of the warning in Grossman and Helpman (1995) that ignoring international interdependence in empirical work on this issue potentially leads to biased parameter estimates.

The remainder of the paper is organized as follows. The next section lays out the structure of our general equilibrium model. In Section 3 we provide an analytical discussion of best-response tariffs in the symmetric equilibrium, and in Section 4 we discuss optimum non-cooperative tariffs for the case of asymmetrically endowed economies by means of numerical analysis. Sections 5 and 6 contain the empirical analysis and provide several extensions to check robustness. The last section concludes with a short summary of the most important insights.

2 A General Equilibrium Model of Trade and Horizontal Multinationals

We consider a model of two countries and two sectors. In the industrial *X*-sector differentiated goods are supplied under monopolistic competition, while firms in the *Y*-sector are perfectly competitive and produce a homogeneous good. Preferences of consumers are represented by a Cobb-Douglas utility function:

$$U = X^{\alpha} \left(Y^{D}\right)^{1-\alpha}, \;\; 0 < \alpha < 1, \tag{1}$$

where $X := \left[\sum_k \left(x_k^D \right)^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)}$, $\varepsilon > 1$, is a CES-index.[7] Production technologies in the two sectors are represented by $x = L$ and $Y = L$, respectively, where *L* is low-skilled labour. In addition, production in the *X*-sector requires fixed set-up costs through the use of physical capital *K* and high-skilled non-production labour *S*. (In the following, we use the terms *high-skilled labour* and *human capital* interchangeably.) We choose good *Y* as the numéraire and, thus, obtain $w_{Li} = w_{Lj} = 1$ under diversification in the production of both economies (which is assumed from now on). Export of industrial output is impeded by iceberg transport costs. These are accounted for by parameter $t>1$ below. Moreover, there may be tariffs on international transactions of industrial goods. Following Venables (1987) and Ludema (2002), trade in the numéraire good is not subject to any trade frictions.

We consider two types of firms, exporters and horizontal multinationals. To headquarter a firm in a particular economy requires one unit of physical capital and one of human capital. Local production can start immediately, without further investment. However, if a firm sets up a second production plant abroad, $g-1$ (with $g \geq 2$) units of physical capital have to be invested as a fixed factor input before production can be started[8]. In addition, we assume that firms with headquarters in country *i* are restricted to country *i*'s endowment with physical and human capital, when setting up production plants. All firms of a particular type which are

[7] Country indices are neglected for the moment. x_k^D denotes the quantity of variety *k*, consumed by the representative consumer of a particular economy. And Y^D is the respective quantity of the homogeneous good.
[8] Multinational firms have a fixed plant cost disadvantage but save on transport costs, when serving the foreign market.

headquartered in the same country are symmetric. Hence, we can skip firm indices in the following analysis.

Demand in country *i* for a single variety of the differentiated good is given by

$$x_{ii}^D = \frac{\alpha E_i p_{ii}^{-\varepsilon}}{P_i} \quad \text{and} \quad x_{ji}^D = \frac{\alpha E_i p_{ji}^{-\varepsilon} b_{ji}^{-\varepsilon}}{P_i}, \tag{2}$$

where x_{ii}^D is a variety produced and consumed in country *i*, while x_{ji}^D is produced in *j* and exported to *i*. Variable b_{ji} represents country *i*'s ad-valorem tariff on imports of the industrial good from country *j*. p_{ji} denotes the producer price and $p_{ji}b_{ji}$ the respective tariff-including consumer price of a variety produced in country *j* and consumed in country *i*. $E_i = L_i + w_{Ki}K_i + w_{Si}S_i + (b_{ji} - 1)p_{ji}n_j x_{ji}^D$ is total income (equal to total expenditures) of country *i* and $P_i = p_{ii}^{1-\varepsilon}\left(h_i + h_j + n_i\right) + \left(p_{ji}b_{ji}\right)^{1-\varepsilon} n_j$ is a price index. n_i, n_j and h_i, h_j are the numbers of exporters and horizontal multinationals of countries *i* and *j*, respectively. Each firm produces one variety so the number of monopolistically competitive firms equals the number of varieties. Profit maximization leads to a constant price mark-up and, therefore, to prices $p_{ii} = p_{jj} = \varepsilon / \left(\varepsilon - 1\right)$ and $p_{ij} = p_{ji} = t\varepsilon / \left(\varepsilon - 1\right)$ if both sectors are active in the two countries, i.e., if $w_{Li} = w_{Lj} = 1$.

In equilibrium, goods markets are cleared, implying[9]

$$x_{ii} = x_{ii}^D \quad \text{and} \quad x_{ji} = t x_{ji}^D = x_{ii}\tau b_{ji}^{-\varepsilon}, \tag{3}$$

according to (2), where $\tau = t^{1-\varepsilon}$ is a transformed measure of iceberg transport costs. In addition, zero-profit conditions of country *i* firms are represented by

$$\pi_{ni} = \frac{1}{\varepsilon - 1}\left[x_{ii} + \tau b_{ij}^{-\varepsilon} x_{jj}\right] - w_{Ki} - w_{Si} = 0, \tag{4}$$

$$\pi_{hi} = \frac{1}{\varepsilon - 1}\left[x_{ii} + x_{jj}\right] - g_i w_{Ki} - w_{Si} = 0, \tag{5}$$

if $w_{Li} = w_{Lj} = 1$. Finally, we assume that all factor inputs are inelastically supplied in perfectly competitive and internationally segmented markets. Then, the factor market clearing conditions in country *i* are given by[10]

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[9] Of course, also $Y_i + Y_j = Y_i^D + Y_j^D$ holds in equilibrium, with Y_i, Y_j being homogeneous goods supply of countries *i* and *j*, respectively.

$$L_i = \left(h_i + h_j + n_i\right) x_{ii} + n_i \tau b_{ij}^{-\varepsilon} x_{jj} + Y_i, \tag{6}$$

$$S_i = n_i + h_i, \tag{7}$$

$$K_i = n_i + g_i h_i. \tag{8}$$

From (4) and (5), we obtain

$$w_{Ki} = \frac{1}{\varepsilon - 1} \frac{1 - \tau b_{ij}^{-\varepsilon}}{g_i - 1} x_{jj}, \qquad w_{Si} = \frac{1}{\varepsilon - 1}\left[x_{ii} - x_{jj} \frac{1 - g_i \tau b_{ij}^{-\varepsilon}}{g_i - 1}\right] \tag{9}$$

for equilibrium factor prices. In addition,

$$h_i = \frac{K_i - S_i}{g_i - 1}, \qquad n_i = \frac{g_i S_i - K_i}{g_i - 1} \tag{10}$$

determine the equilibrium numbers of horizontal multinationals and exporters in country *i*, according to (7) and (8). (Equivalent expressions are obtained for quantities, factor prices, and firm numbers in *j*.) Positive factor prices w_{Ki}, w_{Si} and a positive number of both firm types require that countries are not too different and $S_i < K_i < g_i S_i$. This is assumed throughout our analysis.

In our model, the number of exporters and multinationals is determined by endowments of human and physical capital and the investment cost parameter g_i, according to (10). This implies that variety effects, as typically considered in models with monopolistic competition and CES preferences, do not arise as long as factor endowments and the investment cost parameter are fixed. As a consequence, general equilibrium mechanisms work through output adjustments (and not through variety effects). It is this (admittedly simplifying) assumption that allows us to account for income effects in an analytically solvable general equilibrium model with coexisting exporters and multinational firms in the industrial sector.

For tractability, we assume that countries *i* and *j* do not differ in their physical capital requirements for setting up a multinational firm, i.e., $g_i = g_j \equiv g$. Moreover, countries are presumed to exhibit identical endowments of physical and human capital, i.e., $K_j = K_i \equiv K$ and $S_j = S_i \equiv S$, while they may differ in their endowments of low-skilled labour, i.e., $L_i = \lambda \bar{L}$, $L_j = \left(1 - \lambda\right) \bar{L}$ and $\lambda \in \left(0,1\right)$.

[10] According to (3), $x_{ij} = x_{jj} \tau b_{ij}^{-\varepsilon}$ has been considered in (6).

3 Best-Response Tariff-Setting

Welfare in country *i* is given by the utility of the representative consumer determined in (1). Noting $\left(1-\alpha\right)E_i = Y_i^D$ and using $E_i = P_i p_{ii}^{\varepsilon} x_{ii} / \alpha$, according to (2) and (3), welfare in country *i* as a function of tariff rates b_{ji}, b_{ij} can be written as

$$U_i\left(b_{ji}, b_{ij}\right) = \left(\frac{1-\alpha}{\alpha}\frac{\varepsilon}{\varepsilon-1}\right)^{1-\alpha}\left[2h + \left(1+\tau b_{ji}^{1-\varepsilon}\right)n\right]^{1+\alpha/(\varepsilon-1)} x_{ii}\left(b_{ji}, b_{ij}\right). \tag{11}$$

Differentiating (11) with respect to b_{ji} yields

$$\frac{\partial U_i}{\partial b_{ji}} = \frac{U_i}{b_{ji}}\left\{\frac{\partial x_{ii}}{\partial b_{ji}}\frac{b_{ji}}{x_{ii}} - \frac{\left(\varepsilon - 1 + \alpha\right)n\tau b_{ji}^{1-\varepsilon}}{2h + n\left(1+\tau b_{ji}^{1-\varepsilon}\right)}\right\}. \tag{12}$$

Egger, Egger, and Greenaway (2005) show that given $\varepsilon \geq 2$ there exists, for any $b_{ij} \geq 1$, a unique best-response tariff rate $b_{ji} \in \left(1, \infty\right)$ that solves $\partial U_i / \partial b_{ji} = 0$, according to (12), and, thus, maximizes welfare of country *i*. Based on this finding, we can characterize the main properties of the reaction functions in Lemma 1.

Lemma 1. *Consider* $\varepsilon \geq 2$ *and diversification in the production pattern of both economies. Then, reaction functions* $b_{ji} = b_{ji}^*\left(b_{ij}\right)$ *and* $b_{ij} = b_{ij}^*\left(b_{ji}\right)$ *are continuous and twice differentiable. Moreover, best-response tariff rates are independent of L-endowments.*

Proof. See Appendix. ■

With the results in Lemma 1 at hand, we can solve for the non-cooperative Nash equilibrium in tariff rates. The main findings are summarized Proposition 1.

Proposition 1. *Consider* $\varepsilon \geq 2$ *and diversification in the production pattern of both economies. Then, there exists a unique and symmetric Nash equilibrium in tariff rates* $b_{ij}^n = b_{ji}^n = b^n \in \left(1, \infty\right)$ *and the two reaction functions are positively (non-negatively) sloped in Nash equilibrium (i.e.,* $db_{ji}^*\left(\cdot\right)/db_{ij}\Big|_{b_{ji}^n, b_{ij}^n} \geq 0$ *and* $db_{ij}^*\left(\cdot\right)/db_{ji}\Big|_{b_{ji}^n, b_{ij}^n} \geq 0$*, respectively).*

Proof. See Appendix. ■

The results of Lemma 1 and Proposition 1 are depicted in Figure 1. The reaction functions are constructed using numerical simulation. In particular, Figure 1 illustrates that reaction functions are non-monotonic in general, but positively sloped in the Nash equilibrium. Hence, from Proposition 1 and Figure 1 we can conclude that tariff rates are strategic complements in the non-cooperative equilibrium.

Lemma 1 also shows that changes in the country-specific endowments with factor L do not influence non-cooperative tariff-setting, as long as diversification in the pattern of production is guaranteed. In all other respects, countries are assumed to be identical. In a next step, we will relax some of the strong symmetry assumptions underlying the results in Lemma 1 and Proposition 1. Asymmetries in (physical and human) capital endowments and the investment cost parameter g are of particular interest, since the focus of our paper is on the role of foreign direct investment (which directly depends on these fundamentals) for non-cooperative tariff-setting. To investigate asymmetries, we have to apply numerical simulation techniques, as the complexity of the model makes an analytical discussion difficult (if not impossible).

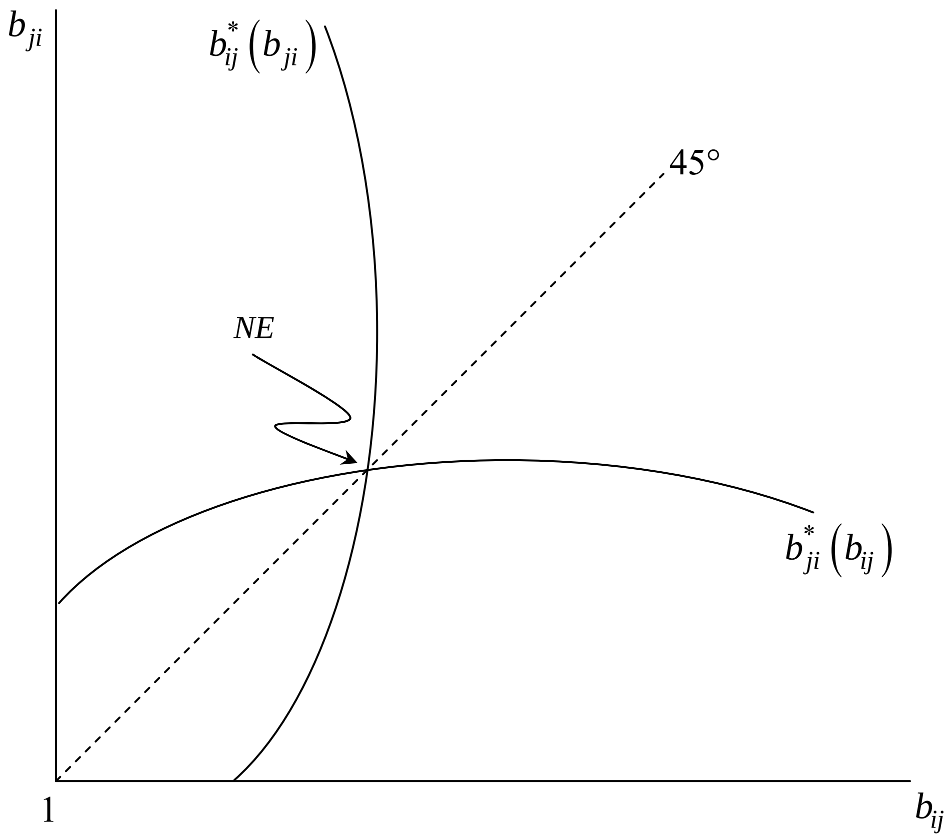

Figure 1: Nash equilibrium in tariff rates

4 Endowment and Investment Cost Asymmetries: A Simulation Analysis

To facilitate the exposition, we assume $K_i = \mu_i \bar{K}$, $K_j = \mu_j \bar{K}$ and $S_i = \mu_i \bar{S}$, $S_j = \mu_j \bar{S}$. Moreover, we allow for $g_i \neq g_j$ leading to country-specific costs of setting up foreign production plants.[11] Throughout the simulation exercises, we focus on interior solutions with both exporters and multinationals active in equilibrium.

To provide intuition for the main results, it is useful to introduce the concept of indirect utility. According to (1) and the CES-index *X*, indirect utility of the representative consumer in *i* is given by $V_i\left(P_i, E_i\right) = \alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha} E_i / P_i^{\alpha/(1-\varepsilon)}$, where price index P_i and income E_i are defined below (2).[12] Noting $\partial V_i\left(\cdot\right)/\partial P_i > 0$, $\partial V_i\left(\cdot\right)/\partial E_i > 0$ and $\partial P_i / \partial b_{ji} < 0$, it follows that $\partial E_i / \partial b_{ji}\big|_{b_{ji}^n, b_{ij}^n} > 0$ must hold if governments set welfare-maximizing (best-response) tariff rates in Nash equilibrium. Accordingly, we can distinguish between a *price* and an *income* motive of governments when interpreting subsequent simulation results. Thus, a strong negative price effect is associated with low tariff rates, while a strong positive income effect is associated with high tariff rates (for a given policy of the partner country).[13]

From the analysis in Section 3, we know that endowment differences in L do not affect best-response tariff rates, according to Lemma 1. As a consequence, Nash tariff rates are symmetric as long as countries only differ in their endowments with low-skilled labour (and production remains diversified, see Proposition 1). Things are different, if countries also differ in endowments of (human and physical) capital or with regard to the factor requirements for setting up multinational firms. Then, tariff rates in Nash equilibrium are no longer symmetric as can be seen from Figures 2 and 3.

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[11] Differences in the relative endowments of K and S are implicitly accounted for by differences in g_i and g_j.

[12] Note that, $P_i^{1/(1-\varepsilon)}$ is the true price index corresponding to the index of differentiated goods X_i (measured in relative terms) and E_i is *real* income in terms of the numéraire good. Hence, in the case of Cobb-Douglas preferences $\alpha E_i = P_i^{1/(1-\varepsilon)} X_i$.

[13] This interpretation is motivated by the finding in Egger, Egger and Greenaway (2005) that, given $\varepsilon \geq 2$ and the symmetry assumptions in Sections 2 and 3, equation (12) implies $\partial U_i\left(\cdot\right)/\partial b_{ji} > 0$ if $b_{ji} < b_{ji}^*$ and $\partial U_i\left(\cdot\right)/\partial b_{ji} < 0$ if $b_{ji} > b_{ji}^*$, so that the income effect dominates if $b_{ji} < b_{ji}^*$, while the price effect dominates if $b_{ji} > b_{ji}^*$.

Figure 2 depicts Nash tariff rates for different levels of the endowment parameter μ_i. Two scenarios are distinguished. The red curves represent Nash tariff rates as a function of μ_i for a given size of foreign endowment (i.e., for a given $\mu_j = 0.5$). Hence, b_{ji}^n, b_{ij}^n-changes along the red curves comprise two effects, namely an "overall (world) endowment" and an "endowment difference" effect. To distinguish the two effects, the black curves in Figure 2 correspond to b_{ji}^n, b_{ij}^n-changes for given overall world endowments with human and physical capital. (In this case, $\mu_j = 1 - \mu_i$ is considered.)

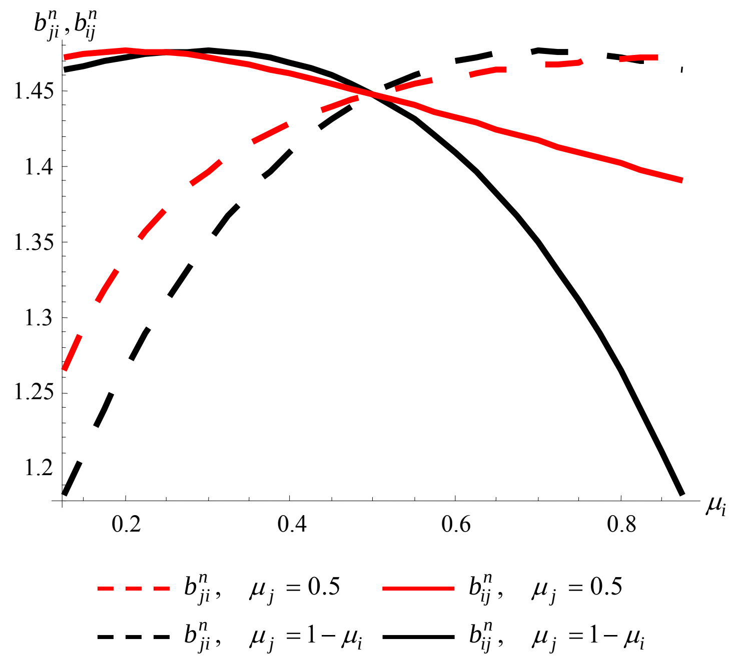

Figure 2. Nash tariff rates for different levels of μ_i [14]

By comparing the black with the respective red curves, we see there is a non-monotonic effect of "overall world endowment" with human and physical capital on Nash tariff rates. (This holds true in particular for the human and physical capital abundant country). Moreover, comparing the dashed and solid loci (associated with Nash tariff rates of countries *i* and *j*, respectively), we see the capital abundant country tends to set a higher tariff in Nash equilibrium. Interpreting Figure 2 against insights from the indirect utility analysis, we

[14] In Figure 2, the following parameter values are considered: *K*=700, *S*=500, *L*=1000, $t = 1.1$, $\alpha = 0.75$, $\varepsilon = 2$, $\lambda = 0.5$, $g_i = g_j = 3.5$ and $\mu_i \in [0.125, 0.875]$. In addition, red curves and black curves are drawn for $\mu_j = 0.5$ and $\mu_j = 1 - \mu_i$, respectively.

conclude that for low levels of μ_i the negative price effect is high (relative to the positive income effect), so tariffs are set at a low level in *i*. By contrast, if μ_i is large and, thus, country *i* is well endowed with human and physical capital, foreign products have a relatively small weight in its consumption basket, since the number of local producers is large relative to the number of importers. As a consequence, the negative impact of higher consumer prices of imported goods is relatively small and the income motive relatively strong, so country *i* sets high tariff rates for high levels of μ_i. However, the endowment effect is non-monotonic. For very high levels of μ_i (i.e., if dissimilarity in the endowments with human and physical capital is substantial) country *i* has an incentive to reduce the tariff rate with a further increase in μ_i. This result is difficult to interpret but may be explained by the fact that (in particular along the dashed black locus) foreign output in the industrial sector becomes negligible for sufficiently high values of μ_i.

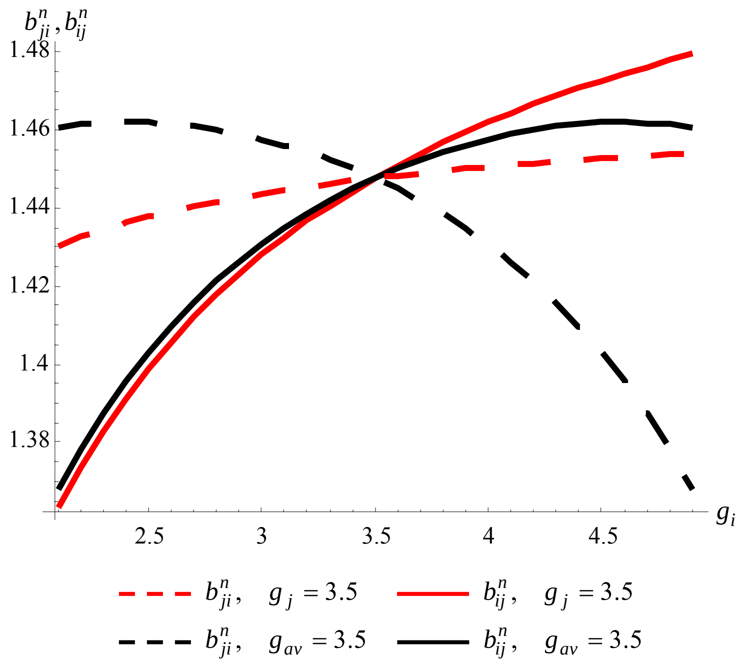

Figure 3. Nash tariff rates for different levels of g_i [15]

Figure 3 shows the impact of g_i-variation on Nash tariff rates. Again, two cases are distinguished. While the red loci depict g_i-changes for a given $g_j = 3.5$, the black curves are drawn under the assumption of a given average level of investment costs

[15] In Figure 3, the following parameter values are considered: *K*=700, *S*=500, *L*=1000, $t = 1.1$, $\alpha = 0.75$, $\varepsilon = 2$, $\lambda = 0.5$, $\mu = 0.5$, $g_i \in [2.1, 4.9]$. In addition, $g_j = 3.5$ holds along the red loci, while $g_{av} = 3.5$, with $g_{av} = 0.5 g_i + 0.5 g_j$, prevails along the black curves.

$g_{av} = 0.5g_i + 0.5g_j = 3.5$. Hence, g_i-variation along the red curves comprises two effects: a factor requirement difference and a factor requirement level effect. By contrast, the black loci represent a pure *g*-difference effect. To be more precise, the black curves indicate the impact of an increase in investment costs of a multinational located in country *i* with an affiliate in *j* relative to the investment costs of a country *j* firm with a plant in country *i*. Comparing red and black curves allows us to disentangle "level effects" (associated with changes in the average level of investment costs g_{av}) and pure "difference effects", associated with changes in the ratio g_i / g_j for given average investment costs.

Interestingly, from Figure 3 we can conclude that higher average investment costs tend to exhibit a monotonic effect and lead to higher Nash tariffs. To see this, note that to the left of $g_i = 3.5$ the red curves are associated with lower average investment costs, while to the right they are associated with higher average investment costs as compared to the respective black loci (drawn for a constant $g_{av} = 3.5$). This points to an important difference of μ_i- and g_i-effects. However, the shape of the black tariff functions indicates that a higher g_i / g_j for a given g_{av} and a lower $\mu_i / (1-\mu_i)$ have a similar impact on Nash tariffs. As a consequence, bigger differences endowments of human and physical capital (for a given overall world endowment) may be offset by higher pure investment cost differences, if multinationals in a capital-abundant country face a disadvantage in terms of investment costs for setting up an overseas plant. In this respect, the intuition for the g_i-effect is similar to that for the μ_i-effect.

In a further simulation experiment, we have investigated the impact of transport costs on the size of Nash tariff rates. The results are represented in Figure 4. The left panel reproduces the Nash tariff associated with pure relative endowment differences (similar to the black loci in Figure 2) for different levels of transport cost parameter *t*, while in the right panel Nash tariffs associated with pure relative investment cost differences (similar to the black curves in Figure 3) are depicted for different *t* levels. As can be seen, higher transport costs tend to mitigate the negative price effect relative to the positive income effect. Therefore, governments have an incentive to set higher Nash tariff rates.[16] The *t*-effect is symmetric for both economies since we do not account for country-specific differences in the size of transport costs.

[16] The finding that higher transport costs shift the Nash tariff rates upwards has been confirmed for a large set of different transport cost levels in the empirically relevant interval $1 < t \leq 2$.

In a final set of simulation exercises (not drawn), we have investigated the slope of reaction functions in Nash equilibrium. Consistent with Proposition 1, we find in a large panel of different exercises that – irrespective of cross-country asymmetries – reaction functions are positively sloped in Nash equilibrium, i.e., $db_{ji}^{*}(\cdot)/db_{ij}\Big|_{b_{ji}^{n},b_{ij}^{n}} > 0$ and $db_{ij}^{*}(\cdot)/db_{ji}\Big|_{b_{ji}^{n},b_{ij}^{n}} > 0$, respectively. In addition, evaluating the slope of reaction functions for different *t*-values, we can conclude that higher transport costs make best response tariff rates less sensitive to marginal changes of foreign tariff rates. Finally, if countries differ with respect to endowments of human and physical capital, the capital abundant country reacts with a smaller tariff adjustment to trade policy changes in the foreign country than the country with scarce capital endowment does.

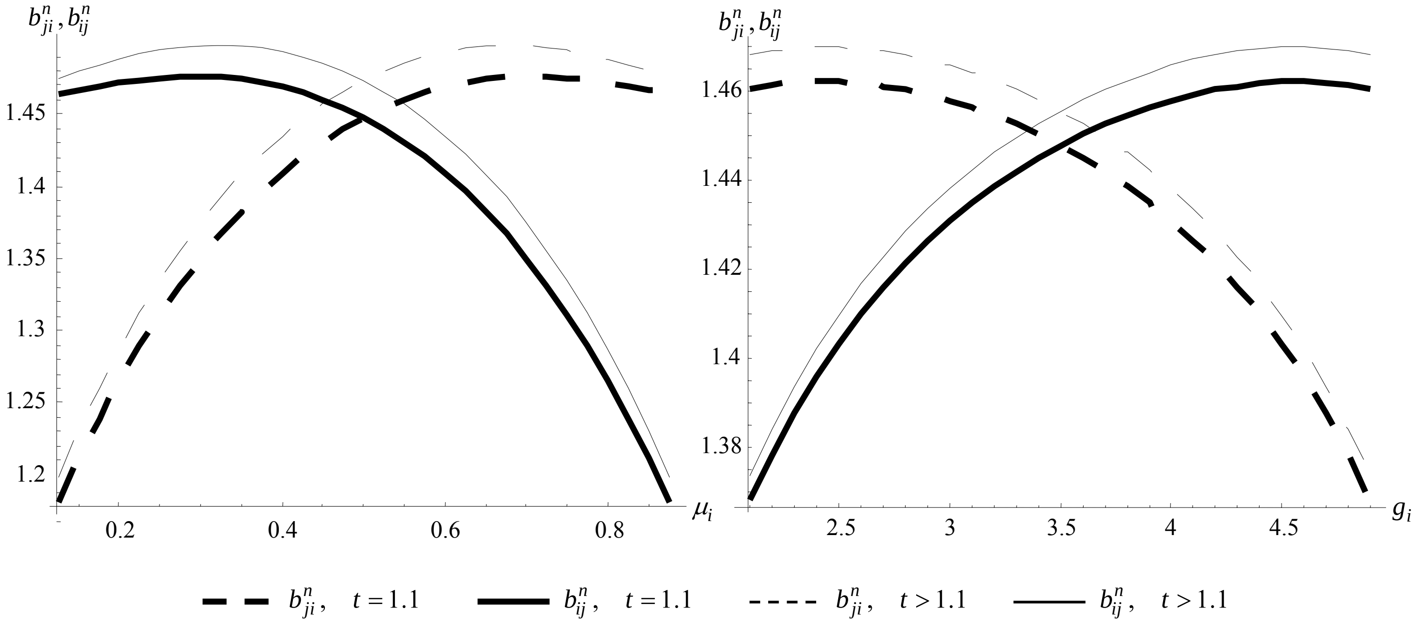

Figure 4. Nash tariff rates for different levels of *t*[17]

5 Empirical Analysis

Based on our theoretical framework, we set up an empirical model to estimate both the determinants of Nash tariffs and slope of the reaction function. For this analysis, we use tariff data from United Nation TRAINS database (Table A.1 in the Appendix provides details on the construction and sources of all variables). This contains tariff rates at the Harmonized

[17] In the left panel $t = 1.1$ is compared with $t = 1.5$, while in the right panel $t = 1.1$ is compared with $t = 1.2$.

System 6-digit level and trade volume figures at the same level of aggregation to construct weights. Data are annual. We intend to exploit information from all dimensions of the panel and use all country data for which observations in at least three years between 1993 and 1999 are available. Hence, there is a maximum of seven observations for each country's trade-weighted tariff rate.

According to our theoretical model, the position and slope of tariff reaction functions depend on endowment parameters, trade and investment costs. These variables are accounted for in the empirical analysis. A We follow the established literature on the determinants of trade volumes (e.g., Bergstrand 1985, 1989) to associate bilateral trade costs with bilateral distance measured in miles between economic centres (based on the great circle distance between capitals). Distance is time-invariant and, thus, controlled for by country-specific fixed effects. Beyond its direct impact, distance also matters for the importance of foreign countries' characteristics, such as endowments. In line with our theoretical results, we can conclude that higher distance reduces dependency on foreign economies and, therefore, raises Nash tariff rates (see Figure 4). Greater distance may therefore be interpreted as a step towards autarky.

For all countries, we can construct a bilateral distance matrix with zero diagonal entries and inverse bilateral distances in the other cells. We row-normalize the entries of this so that all elements in the same row sum to one (henceforth, we refer to this row-normalized matrix as $\mathbf{W}$). Since countries are repeatedly observed in the data, $\mathbf{W}$ is block-diagonal, consisting of blocks $\mathbf{W}_t, t = 1,...,7$. We pre-multiply the vectors of foreign countries' factor endowments and trade-weighted tariffs by $\mathbf{W}$ to obtain the spatially weighted variables. This procedure ensures that the importance of a foreign country's characteristics for a country's Nash tariffs declines in distance. Note that the latter effect of distance is not controlled for by fixed country effects.

Equilibrium tariffs should be determined by factor endowments. Accordingly, we include log low-skilled labour, $l_{it} = \ln(L_{it})$, log high-skilled labour, $s_{it} = \ln(S_{it})$, and log physical capital endowments, $k_{it} = \ln(K_{it})$, in the model. Additionally, we also include aggregate foreign endowments. Foreign endowments are spatially weighted and denoted as $Wl_{jt}, Ws_{jt}, Wk_{jt}$. In addition, tariffs of a particular country should positively depend on (spatially weighted) tariffs abroad Wb_{jt}, according to our theoretical model, which predicts that best-response tariff rates are strategic complements in Nash equilibrium. Hence, we hypothesize that the parameter of Wb_{jt} is significantly positive. For almost all variables, the sample size is 44 economies and 263 observations. Although our theoretical model yields hypotheses regarding the role of investment costs for equilibrium tariffs, we have not discussed them yet in the empirical model. The reason is that investment costs are not observed as such but have to be proxied. One possibility is to use rating-based data as published by Business Environment Risk Intelligence (BERI). However, data are only available for a smaller number of economies. Therefore, we consider investment costs and the associated hypotheses in the sensitivity analysis below but not in our main specification (see (13)).

In addition to these, we include fixed country effects (capturing, e.g., a countries distance from all economies labelled ψ_i with country index $i = 1,...,44$; see Table A.2 in the Appendix for a list of countries) and a time trend (λ_t, picking up time-variant determinants that affect all economies' tariffs in the same way). Formally, we estimate the following model:

$$b_{it} = \beta_1 Wb_{jt} + \beta_2 s_{it} + \beta_3 k_{it} + \beta_4 l_{it} + \beta_5 Ws_{jt} + \beta_6 Wk_{jt} + \beta_7 Wl_{jt} + \beta_8 \lambda_t + \psi_i + \nu_{it}, \qquad (13)$$

with ν_{it} denoting the error term. For the latter, we allow for spatially correlated errors of the form $\mathbf{v} = \phi \mathbf{W} \mathbf{v} + \boldsymbol{\chi}$, $\chi_{it} \sim IID(0, \sigma_\chi^2)$. Hence, there are three modes of cross-sectional dependence in the data: cross-sectional dependence in the exogenous variables without any consequence for the estimation approach ($Wl_{it}, Ws_{it}, Wk_{it}$); a spatial lag in the dependent variable (Wb_{it}) associated with the Nash reaction function which establishes an endogeneity problem; and spatially autocorrelated stochastic shocks (ν_{it}) that require estimators for spatially dependent data such as the generalized method of moments (GMM) approach used below. Note that tariff rates exhibit values between zero and one. This should be accounted for in the empirical model to make sure that the model prediction lies in the corresponding interval. Accordingly, we logistically transform tariffs to obtain unbiased parameter estimates. In the empirical analysis, therefore, b_{it}, b_{jt} always refer to transformed tariff values. Table 1 summarizes the descriptive statistics of all variables used.

- Table 1 -

We estimate four versions of (13) using the GMM approach of Kelejian and Prucha (1999).[18] This GMM estimator relies on a two-stage procedure, where all parameters $\beta_k, k = 1,...,8$ and μ_i and, hence, an estimate of the residuals are obtained in a first stage, and the parameter ϕ and the variance σ_χ^2 are estimated by solving a system of three non-linear equations. A feasible GLS estimator of the model parameters is obtained from OLS on the Cochrane-Orcutt-transformed model based on the estimate $\hat{\phi}$. Table 2 summarizes our findings.

- Table 2 -

Fixed country effects enter significantly in all estimated models. Models 1 and 2 in Table 2 do not include the weighted foreign tariff rates, and Models 1 and 3 exclude all weighted foreign exogenous variables. $\beta_1 = 0$ is significantly rejected according to the t-values for Models 3 and 4, and $\beta_5 = \beta_6 = \beta_7 = 0$ is significantly rejected according to an F-test for Model 4. Finally, $\phi = 0$ is significantly rejected according to the Moran I test for Model 4. Hence, there is strong support for all three modes of spatial dependence, rendering Model 4 preferable among the estimated ones. Model 4 also performs very well in terms of its explanatory power (with an R^2 of about 0.93).

As predicted, the significantly positive coefficient of (spatially weighted) foreign tariffs indicates strategic complementarity of tariff rates in Nash equilibrium ($\beta_1 > 0$). The positive coefficient of s_{it} ($\beta_2 > 0$) and negative coefficient of Ws_{jt} ($\beta_5 > 0$) support our theoretical insights that countries with abundant human capital set higher tariff rates (see Figure 2). The negative coefficient of domestic capital endowment k_{it} ($\beta_3 < 0$) and positive coefficient of foreign capital endowment Wk_{jt} ($\beta_6 > 0$) warrant further discussion. The impact of differences in physical capital endowments as depicted by Figure 2 should be interpreted together with the investment cost parameter g. Put differently, Figure 2 displays Nash tariff rates for different endowments but identical values of g. However, g-differences may counteract the effect of capital endowment differences, making the negative coefficient of k_{it}

[18] Unlike maximum likelihood estimation, this estimator does not require normally distributed errors.

and positive coefficient of Wk_{jt} plausible from a theoretical point of view.[19] Moreover, as stressed in discussion of Figure 2, capital endowment differences have a non-monotonic impact on tariff rates. Hence, the positive coefficient of k_{it} is also consistent with Figure 2, if differences in endowments of physical capital are substantial.[20] Finally, the significant coefficients of low-skilled labour endowments ($\beta_4 > 0$ and $\beta_7 < 0$) are more difficult to interpret. In our theoretical analysis, we have derived the hypothesis for the impact of low-skilled labour endowments on Nash tariffs under three simplifying assumptions to keep the model tractable: (i) complete symmetry in every other respect (i.e., high-skilled labour and physical capital endowments, investment costs), (ii) low-skilled labour is not used to create plant-specific or firm-specific assets, whilst both human and physical capital are not employed in production, and (iii) production is diversified. In this case, low-skilled labour rewards are identical across economies and low-skilled labour endowments irrelevant for tariff setting. However, production cost asymmetries may be empirically important, rendering low-skilled labour endowments relevant for equilibrium tariffs. In our dataset, we find low-skilled labour endowments affect equilibrium tariffs in similar ways to high-skilled labour endowments (potentially due to complementarities of low- and high-skilled labour in industrial production).

6 Sensitivity Analysis and Extensions

Table 3 summarizes the findings of a sensitivity analysis. Seven modifications of our benchmark model are considered. First, we reduce the importance of distant countries in spatial weighting. Instead of using inverse distances, we rely on squared inverse distances. It turns out that this modification has no impact on parameter signs, indicating robustness .

- Table 3 -

Second, we include proxies of investment costs as published by Business Environment Risk Intelligence (BERI), Historical Ratings Research Package). Since data are not available for all countries, the analysis can only be carried out for a sub-sample of 29 economies and 191

[19] It is plausible that a firm with headquarters in a capital abundant country faces high set-up costs in a less-developed capital poor economy.

[20] This may be of particular relevance if both developed and developing countries are accounted for, such as in our data set.

observations. However, even in this smaller sample, there is strong evidence for strategic complementarity of tariff rates in Nash equilibrium. Also the point estimates of the other variables exhibit the same sign as in the original specifications. An increase in average investment costs seems to be positively associated with equilibrium tariffs, as we have hypothesized. Finally, an increase in (spatially weighted) foreign investment costs for domestic multinationals (Wg_{it}) relative to foreign multinationals (g_{jt}) is expected to reduce domestic tariff rates. These parameter coefficients support our theoretical results in Figure 3.

Third, we assess the role of outliers, which we define as observations outside the range of two standard deviations around the mean of Hadi's (1992, 1994) measure in multivariate samples. Altogether, nine observations are classified as influential based on this method. However, excluding these has little effect on our general conclusions. The finding of a positive slope of the Nash reaction function is robust in this regard, and the parameter signs of exogenous variables do not change.

Fourth and fifth, we consider a separate estimation of Model 4 on the sub-samples of developed and developing economies. In our model, we have focused on horizontal multinationals, although it is characterized by considerable factor cost differences. Hence, vertical multinationals might coexist.[21] We find in either case the slope of the tariff reaction function is positive. Moreover, the signs of all explanatory variables' parameters are not affected. Interestingly, the negative (positive) impact of k_{it} (Wk_{jt}) on domestic Nash tariffs is mitigated in developed countries characterized by more similar factor endowments than the pooled sample. This lends support to our discussion of non-monotonic endowment effects above.

Sixth, we estimate the model based unweighted rather than trade-weighted average tariffs to assess the importance of weighting. Our results are insensitive to this modification.

Seventh, we use tariffs on final goods rather than overall tariffs., given that we have focused on final goods in our theoretical model. For this sensitivity analysis, we follow the definition used in United Nation Broad Economic Categories to isolate final products from intermediate

[21] See Carr, Markusen and Maskus (2001), Markusen and Maskus (2002) and Egger and Pfaffermayr (2004) for a discussion.

ones. Then, we apply trade-weights at the deepest level of aggregation to construct our database. Again, it turns out that our results are robust to this modification.[22]

So far, we have estimated specifications that must be interpreted as reduced form equations, as tariffs are explained by the exogenous variables in the model, while the theoretical structure has not been considered explicitly and the role of foreign direct investment (FDI) has not been analysed.[23] To address the question of how multinational activities affect equilibrium tariffs, we use FDI as an explanatory variable but have to account for its endogeneity. In fact, we know that investment costs only affect equilibrium tariffs through FDI, at least from a theoretical point of view. This renders them prime candidates for instruments of FDI. However, it seems difficult to estimate the determinants of equilibrium tariff levels and slope of the reaction function simultaneously if endogenous FDI is included. This may be explained by the capacity of the instruments to identify both FDI and spatially weighted tariffs simultaneously. Therefore, we have to focus on the determinants of equilibrium tariffs,(rather than on the slope of the reaction function).

- Table 4 -

The results in Table 4 refer to the impact of foreign direct investment on tariff rates. Three different measures of FDI are applied: (i) the sum of inbound and outbound stocks of foreign investment, (ii) inbound stocks of foreign investment, and (iii) outbound stocks of foreign investment. For the latter, only a smaller sample of observations is available (due to their availability in *World Investment Report* tables).

We find that both the sum of inbound and outbound FDI as well as inbound FDI alone has a positive impact on the tariff rate; although the point estimate for outbound FDI is also positive it is insignificant. That greater importance of multinational activities tends to have a positive impact on equilibrium tariff rates seems to be plausible. Indeed, one may hypothesize that governments should care less about exporters if their share in international activities declines. Or to put it in terms of our discussion in Section 4, the income motive may become stronger

[22] In a further experiment that is not displayed in the table, we have included an interaction term between spatially weighted foreign tariff rates and domestic relative to weighted foreign human and physical capital endowments. Note that this variable is treated as endogenous as well. Although the coefficient cannot be estimated significantly due to high multi-colinearity, the negative point estimate is well in line with our theoretical results presented in the last paragraph of Section 4.

[23] Although, from the impact of investment costs, the parameter estimates allow for indirect conclusions about the impact of FDI on equilibrium tariffs, no direct conclusions can be drawn.

relative to the price motive, when the magnitude of FDI increases. However, the empirical findings contrast with insights from Hillman and Ursprung (1993), who argue that "(...) *increased multinational presence via either merger or direct foreign investment has a liberalizing effect on trade policy*"(p. 347).

To embed the empirical results in our theoretical analysis, we have added further simulation exercises, which allow us to investigate the relationship between the volume of (inbound and outbound) FDI and (Nash) tariff rates, and FDI-variation is generated by changes in investment cost parameter g_i. The simulation exercises, which are based on the same parameter values as those depicted in Figure 3, are available from the authors on request. They reveal that the positive relationship between higher outbound FDI and higher equilibrium tariff rates is consistent with our theoretical analysis. Also, for certain (low) levels of investment cost parameter g_i (and a given g_{av}) the numerical experiments indicate a positive relationship between the sum of inbound and outbound FDI and the Nash tariff rate of a particular economy. Only the positive impact of inbound FDI is difficult to interpret against the background of our simulation results.

7 Conclusions

This paper presents a general equilibrium, two-country model with co-existence of exporters and horizontal multinational firms to study non-cooperative best-response tariff setting in the presence of FDI. For symmetric countries, we show analytically that tariffs are strategic complements in Nash equilibrium. A rigorous discussion of how asymmetries in factor endowments and the investment costs of multinationals influence equilibrium tariff rates is provided by reference to numerical simulation exercises. Our theoretical findings indicate that factor endowments, and non-tariff impediments to trade and investment are important determinants of Nash tariff rates.

Based on our theoretical insights, we set up an empirical model that investigates the main determinants of tariff rates and slopes of reaction functions in the Nash equilibrium. We use a panel dataset of trade-weighted most-favoured-nation tariff rates for a total of 44 economies, covering both developed and developing countries. And we include fixed country effects and a time trend to attribute neither mostly time-invariant variables related to political characteristics nor the general reduction in tariffs coordinated under the auspices of the WTO to the explanatory variables identified in the theoretical analysis.

The empirical findings support what our general equilibrium model suggests. Although fixed country effects and the time trend together wipe out information and explain part of the variation in tariff rates, we can show that domestic and weighted foreign factor endowment variables are systematically related to tariff rates. Moreover, we can identify a positive impact of weighted foreign tariffs on domestic ones. This supports the theoretical prediction that tariffs are strategic complements in Nash equilibrium. Finally, the empirical results confirm the intuitively appealing idea that equilibrium tariff rates are higher if FDI and multinational activities are prevalent. Again, this can be rationalized by our theoretical model.

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Appendix

A. Theoretical Appendix

Proof of Lemma 1.

Consider $\varepsilon \geq 2$ and diversification in the production pattern of both economies. Substituting (7)-(9) into the definition of E_i and accounting for (3), gives

$$E_i = \lambda L + \frac{1}{\varepsilon - 1}\frac{1-\tau b_{ij}^{-\varepsilon}}{g-1} x_{jj}\left(n + gh\right) + \frac{1}{\varepsilon - 1}\left[x_{ii} - x_{jj}\frac{1 - g\tau b_{ij}^{-\varepsilon}}{g-1}\right]\left(n+h\right) + \left(b_{ji} - 1\right)\frac{\varepsilon}{\varepsilon - 1} n_j \tau b_{ji}^{-\varepsilon} x_{ii} \tag{14}$$

Thereby, $p_{ii} = p_{ji}/t = \varepsilon/\left(\varepsilon - 1\right)$ has been considered. Moreover, noting

$$\frac{p_{ii}^{-\varepsilon}}{P_i} = \frac{\varepsilon - 1}{\varepsilon\left(2h + \left(1 + \tau b_{ji}^{1-\varepsilon}\right)n_j\right)}. \tag{15}$$

it follows from (2) that

$$x_{ii} = \frac{\alpha}{\varepsilon}\frac{\left(\varepsilon - 1\right)\lambda \overline{L} + \left(h + \tau b_{ij}^{-\varepsilon} n\right)x_{jj}}{\left(2 - \alpha/\varepsilon\right)h + \left[\left(1 - \alpha/\varepsilon\right) + \tau b_{ji}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ji} + \alpha\right)\right]n}. \tag{16}$$

In total analogy, we can calculate

$$x_{jj} = \frac{\alpha}{\varepsilon}\frac{\left(\varepsilon - 1\right)\left(1-\lambda\right)\overline{L} + \left(h + \tau b_{ji}^{-\varepsilon} n\right)x_{ii}}{\left(2 - \alpha/\varepsilon\right)h + \left[\left(1 - \alpha/\varepsilon\right) + \tau b_{ij}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ij} + \alpha\right)\right]n}. \tag{17}$$

We can use (16) and (17) to define

$$\begin{aligned}
\Gamma_i\left(x_{ji}, x_{ij}\right) &:= \frac{\alpha}{\varepsilon}\frac{\left(\varepsilon - 1\right)\lambda \overline{L} + \left(h + \tau b_{ij}^{-\varepsilon} n\right)x_{jj}}{\left(2 - \alpha/\varepsilon\right)h + \left[\left(1 - \alpha/\varepsilon\right) + \tau b_{ji}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ji} + \alpha\right)\right]n} - x_{ii} \equiv 0 \\
\Gamma_j\left(x_{ji}, x_{ij}\right) &:= \frac{\alpha}{\varepsilon}\frac{\left(\varepsilon - 1\right)\left(1-\lambda\right)\overline{L} + \left(h + \tau b_{ji}^{-\varepsilon} n\right)x_{ii}}{\left(2 - \alpha/\varepsilon\right)h + \left[\left(1 - \alpha/\varepsilon\right) + \tau b_{ij}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ij} + \alpha\right)\right]n} - x_{ii} \equiv 0
\end{aligned} \tag{18}$$

which implicitly determine the equilibrium values of x_{ii} and x_{jj} as functions of the two tariff rates b_{ji} and b_{ij}. Totally differentiating system (18), with respect to b_{ji}, we obtain

$$\begin{aligned}\frac{\partial \Gamma_i}{\partial x_{ii}}\frac{\partial x_{ii}}{\partial b_{ji}}+\frac{\partial \Gamma_i}{\partial x_{jj}}\frac{\partial x_{jj}}{\partial b_{ji}}&=-\frac{\partial \Gamma_i}{\partial b_{ji}}\\ \frac{\partial \Gamma_j}{\partial x_{ii}}\frac{\partial x_{ii}}{\partial b_{ji}}+\frac{\partial \Gamma_j}{\partial x_{jj}}\frac{\partial x_{jj}}{\partial b_{ji}}&=-\frac{\partial \Gamma_j}{\partial b_{ji}}.\end{aligned} \tag{19}$$

Applying Cramer's rule to system (19), yields

$$\frac{\partial x_{ii}}{\partial b_{ji}}=\frac{\partial \Gamma_i/\partial b_{ji}+\partial \Gamma_j/\partial b_{ji}\times \partial \Gamma_i/\partial x_{jj}}{1-\partial \Gamma_i/\partial x_{jj}\times \partial \Gamma_j/\partial x_{ii}}. \tag{20}$$

Thereby, $\partial \Gamma_i/\partial x_{ii}=\partial \Gamma_j/\partial x_{jj}=-1$ has been considered. Moreover, using partial derivatives

$$\frac{\partial \Gamma_i}{\partial x_{jj}}=\frac{\alpha}{\varepsilon}\frac{h+\tau b_{ij}^{-\varepsilon}n}{\left(2-\alpha/\varepsilon\right)h+\left[\left(1-\alpha/\varepsilon\right)+\tau b_{ji}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ji}+\alpha\right)\right]n}, \tag{21}$$

$$\frac{\partial \Gamma_j}{\partial x_{ii}}=\frac{\alpha}{\varepsilon}\frac{h+\tau b_{ji}^{-\varepsilon}n}{\left(2-\alpha/\varepsilon\right)h+\left[\left(1-\alpha/\varepsilon\right)+\tau b_{ij}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ij}+\alpha\right)\right]n}, \tag{22}$$

$$\frac{\partial \Gamma_i}{\partial b_{ji}}=\frac{x_{ii}}{b_{ji}}\frac{\tau b_{ji}^{-\varepsilon}n\left[\left(\varepsilon-1\right)\left(1-\alpha\right)b_{ji}+\alpha\varepsilon\right]}{\left(2-\alpha/\varepsilon\right)h+\left[\left(1-\alpha/\varepsilon\right)+\tau b_{ji}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ji}+\alpha\right)\right]n}, \tag{23}$$

$$\frac{\partial \Gamma_j}{\partial b_{ji}}=-\frac{x_{ii}}{b_{ji}}\frac{\alpha\tau b_{ji}^{-\varepsilon}n}{\left(2-\alpha/\varepsilon\right)h+\left[\left(1-\alpha/\varepsilon\right)+\tau b_{ij}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ij}+\alpha\right)\right]n} \tag{24}$$

in (20), gives

$$\frac{\partial x_{ii}}{\partial b_{ji}}=\frac{x_{ii}}{b_{ji}}\frac{\tau b_{ji}^{1-\varepsilon}n\left[\left(\varepsilon-1\right)\left(1-\alpha\right)+\alpha\left(\varepsilon-r_i\left(b_{ij}\right)\right)b_{ji}^{-1}\right]}{\left[2-\left(\alpha/\varepsilon\right)\left(1+r_i\left(b_{ij}\right)\right)\right]h+\left\{\left(1-\alpha/\varepsilon\right)+\tau b_{ji}^{-\varepsilon}\left[\left(1-\alpha\right)b_{ji}+\alpha\left(1-r_i\left(b_{ij}\right)/\varepsilon\right)\right]\right\}n}, \tag{25}$$

with

$$r_i\left(b_{ij}\right)=\frac{\alpha}{\varepsilon}\frac{h+\tau b_{ij}^{-\varepsilon}n}{\left(2-\alpha/\varepsilon\right)h+\left[\left(1-\alpha/\varepsilon\right)+\tau b_{ij}^{-\varepsilon}\left(\left(1-\alpha\right)b_{ij}+\alpha\right)\right]n}. \tag{26}$$

Substituting (25) into (12) and using (10), we obtain

$$\frac{\partial U_i}{\partial b_{ji}}=\frac{U_i\tau n}{b_{ji}^{\varepsilon}}\times\left[\zeta_i^1\left(b_{ji},b_{ij}\right)-\zeta_i^2\left(b_{ji}\right)\right], \tag{27}$$

where

$$\zeta_i^1\left(b_{ji},b_{ij}\right):=\frac{\left(\varepsilon-1\right)\left(1-\alpha\right)+\alpha\left(\varepsilon-r_i\left(b_{ij}\right)\right)b_{ji}^{-1}}{\left[2-\left(\alpha/\varepsilon\right)\left(1+r_i\left(b_{ij}\right)\right)\right]h+\left\{\left(1-\alpha/\varepsilon\right)+\tau b_{ji}^{-\varepsilon}\left[\left(1-\alpha\right)b_{ji}+\alpha\left(1-r_i\left(b_{ij}\right)/\varepsilon\right)\right]\right\}}\qquad(28)$$

and

$$\zeta_i^2\left(b_{ji}\right):=\frac{\left(\varepsilon-1+\alpha\right)}{2h+\left(1+\tau b_{ji}^{1-\varepsilon}\right)n}.\qquad(29)$$

It is worth noting that

$$\zeta_i\left(b_{ji},b_{ij}\right):=\zeta_i^1\left(b_{ji},b_{ij}\right)-\zeta_i^2\left(b_{ji}\right)\equiv 0\qquad(30)$$

implicitly determines country *i*'s reaction function $b_{ji}=b_{ji}^*\left(b_{ij}\right)$, which is continuous and (twice) differentiable.[24] Moreover, it follows from (27)-(30) that best-response tariff setting of the two economies is symmetric if countries only differ in their endowments with factor *L* (and production is diversified in both economies). This completes the proof of Lemma 1. ■

Proof of Proposition 1.

Consider $\varepsilon\geq 2$ and diversification in the production pattern of both economies. Moreover, note $\lim_{b_{ij}\to 1}b_{ji}^*\left(b_{ij}\right)>1$, $\lim_{b_{ij}\to\infty}b_{ji}^*\left(b_{ij}\right)<\infty$ and, equivalently, $\lim_{b_{ji}\to 1}b_{ij}^*\left(b_{ji}\right)>1$, $\lim_{b_{ji}\to\infty}b_{ij}^*\left(b_{ji}\right)<\infty$ follows from (26)-(30) (see Footnote 24). Since reaction functions $b_{ji}=b_{ji}^*\left(b_{ij}\right)$ and $b_{ij}=b_{ij}^*\left(b_{ji}\right)$ are continuous in their arguments, this proves existence of a Nash equilibrium. Together with the fact that best-response tariff setting of the two economies is symmetric if countries only differ in their endowments with factor *L*, we can conclude that the Nash equilibrium is symmetric, leading to identical tariff rates $b_{ij}^n=b_{ji}^n=b^n$.

Next, we show that reaction functions are positively (non-negatively) sloped in the (symmetric) Nash equilibrium. Therefore, let us calculate the partial derivatives of $\zeta_i\left(b_{ji},b_{ij}\right)$, according to (28)-(30), and let us evaluate the respective expressions at b_{ji},b_{ij}-

[24] That $\zeta_i\left(b_{ji},b_{ij}\right)=0$ determines a unique best response tariff rate $b_{ji}^*\in\left(1,\infty\right)$ for any tariff rate $b_{ij}\geq 1$ in the partner country is not a trivial result but is rigorously analysed in Egger, Egger and Greenaway (2005). To save on space, we refer the interested reader to this paper for technical details.

pairs which guarantee $\zeta_i\left(b_{ji},b_{ij}\right)=0$ (and, therefore, are part of country i's reaction function). Differentiating $\zeta_i(\cdot)$ with respect to b_{ji} (and noting $\zeta_i\left(b_{ji},b_{ij}\right)=0$) gives[25]

$$\frac{\partial\zeta_i\left(b_{ji},b_{ij}\right)}{\partial b_{ji}}=\Big\{\tau n\Big[(\varepsilon-1)(1-\alpha)\left(b_{ji}^{2-\varepsilon}-b_{ji}^{1-\varepsilon}\right)-(1-\alpha)\left(1-r_i\left(b_{ij}\right)\right)b_{ji}^{1-\varepsilon}\Big] -(2h+n)\left(\varepsilon-r_i\left(b_{ij}\right)\right)\Big\}\times\Theta_i\left(b_{ji},b_{ij}\right) \tag{31}$$

according to (28)-(30), where

$$\Theta_i\left(b_{ji},b_{ij}\right):=\frac{\alpha b_{ji}^{-2}\zeta_i^1\left(b_{ji},b_{ij}\right)}{\left[(\varepsilon-1)(1-\alpha)+\alpha\left(\varepsilon-r_i\left(b_{ij}\right)\right)b_{ji}^{-1}\right]\left[2h+\left(1+\tau b_{ji}^{1-\varepsilon}\right)n\right]}>0 \tag{32}$$

has been considered. From (31) it is obvious that $\varepsilon\geq 2$ and $r_i\left(b_{ij}\right)<1$ are sufficient for $\partial\zeta_i(\cdot)/\partial b_{ji}<0$. Moreover, differentiating $\zeta_i(\cdot)$ with respect to b_{ij} (again noting $\zeta_i\left(b_{ji},b_{ij}\right)=0$) leads to[26]

$$\begin{aligned}\frac{\partial\zeta_i\left(b_{ji},b_{ij}\right)}{\partial b_{ij}}&=\frac{\partial\zeta_i^1\left(b_{ji},b_{ij}\right)}{\partial r_i}\frac{dr_i\left(b_{ij}\right)}{db_{ij}}\\&=\frac{\alpha\left[\varepsilon-1+\alpha\right]b_{ij}^{-\varepsilon}b_{ji}^{2}\tau n}{\left[(\varepsilon-1)(1-\alpha)+b_{ji}^{-1}\alpha\left(\varepsilon-R_i(\cdot)\right)\right]}\times\frac{\Theta_i\left[r_i(\cdot)\right]^2\times\eta\left(b_{ji}\right)\times\eta\left(b_{ij}\right)}{(\alpha/\varepsilon)^2\left[h+\tau n b_{ij}^{-\varepsilon}\right]^2},\end{aligned} \tag{33}$$

with

$$\eta(b):=\left(1-\frac{\alpha}{\varepsilon}\right)b^{-1}(h+n)+h(1-\alpha)\left[b^{-1}-\left(1-\frac{1}{\varepsilon}\right)\right]+\tau n\frac{1-\alpha}{\varepsilon}b^{-\varepsilon}. \tag{34}$$

Applying the implicit function theorem to $\zeta_i\left(b_{ji},b_{ij}\right)\equiv 0$ and using (31) and (33) in

$$\frac{db_{ji}^*\left(b_{ij}\right)}{db_{ij}}=-\frac{\partial\zeta_i\left(b_{ji},b_{ij}\right)/\partial b_{ij}}{\partial\zeta_i\left(b_{ji},b_{ij}\right)/\partial b_{ji}}, \tag{35}$$

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[25] Noteworthy, $\varepsilon\geq 2$ is sufficient for $d\zeta_i(\cdot)/db_{ji}<0$.

[26] For the derivation, $\frac{\partial\zeta_i(\cdot)}{\partial r_i}=-\frac{(\varepsilon-1+\alpha)\eta\left(b_{ji}\right)\Theta_i b_{ji}^2}{(\varepsilon-1)(1-\alpha)+\alpha\left(\varepsilon-r_i\left(b_{ij}\right)\right)b_{ji}^{-1}}$ and $\frac{dr_i\left(b_{ij}\right)}{db_{ij}}=-\frac{\alpha r_i^2\left(b_{ij}\right)\tau n b_{ij}^{-\varepsilon}\eta\left(b_{ij}\right)}{(\alpha/\varepsilon)^2\left(h+\tau b_{ij}^{-\varepsilon}n\right)^2}$ have been considered, according to (26) and (28)-(30).

gives the slope of reaction function $b_{ji}^{*}\left(b_{ij}\right)$. Since $\partial\zeta_i\left(\cdot\right)/\partial b_{ji}<0$ if $\varepsilon\geq 2$, it follows from (35) that

$$\partial b_{ji}^{*}\left(b_{ij}\right)/\partial b_{ij} >,=,< 0 \;\text{ if }\; \partial\zeta_i\left(b_{ji},b_{ij}\right)/\partial b_{ji} >,=,< 0. \tag{36}$$

Noting $b_{ji}^{n}=b_{ij}^{n}=b^{n}$ in Nash equilibrium, it is a direct consequence of (32) and (33) that $\partial\zeta_i\left(b_{ji},b_{ij}\right)/\partial b_{ji}\geq 0$, since $\eta^2\left(b\right)\geq 0$. This implies $\partial b_{ji}^{*}\left(b_{ij}\right)/\partial b_{ij}\geq 0$, according to (36). Since an analogous result can be derived for the reaction function $b_{ij}^{*}\left(b_{ji}\right)$, this proves that both reaction functions are positively (non-negatively) sloped in Nash equilibrium.

Finally, we have to show that the (symmetric) Nash equilibrium is unique. For this, we show that reaction functions have a slope of less than one at tariff rates $b_{ji}^{n}=b_{ij}^{n}=b^{n}$, which guarantees a unique point of intersection of the two reaction functions in the $b_{ji}-b_{ij}$ space (see Figure 1). It is worth noting that $\partial b_{ji}^{*}\left(b_{ij}\right)/\partial b_{ij}<1$ holds if

$$-\frac{\partial}{\partial b_{ji}}\zeta_i\left(\cdot\right)>\frac{\partial}{\partial b_{ij}}\zeta_i\left(\cdot\right), \tag{37}$$

according to (35). Rearranging terms, it follows from (31) and (33) that inequality (37) is fulfilled in the symmetric Nash equilibrium if

$$\begin{aligned}\left(\varepsilon-r_i\left(b\right)\right)\left(2h+n\right)>\tau n\Big\{&\left(\varepsilon-1\right)\left(1-\alpha\right)\left(b^{2-\varepsilon}-b^{1-\varepsilon}\right)-\left(1-\alpha\right)\left(1-r_i\left(b\right)\right)b^{1-\varepsilon}\\&+b^{2-\varepsilon}\left[\eta^2\left(b\right)/\chi^2\left(b\right)\right]\alpha\left(\varepsilon-1+\alpha\right)/\left[\left(\varepsilon-1\right)\left(1-\alpha\right)+b^{-1}\alpha\left(\varepsilon-r_i\left(b\right)\right)\right]\Big\}.\end{aligned} \tag{38}$$

Thereby, $\chi\left(b\right):=\left(\alpha/\varepsilon\right)\left(h+\tau b^{-\varepsilon}n\right)/r_i\left(b\right)$, with $b^2\eta^2\left(b\right)/\chi^2\left(b\right)<1$, according to (26) and (34), has been used.

Consider $\tau n<2h+n$, $b^{1-\varepsilon}\leq 1$, $b^{2-\varepsilon}\leq 1$ (due to $\varepsilon\geq 2$), and note that

$$\frac{b^{1-\varepsilon}\varepsilon}{\varepsilon-r_i\left(b\right)}>\frac{b^2\eta^2\left(b\right)}{\chi^2\left(b\right)}\;\frac{\alpha\left(\varepsilon-1+\alpha\right)b^{-\varepsilon}}{\left(\varepsilon-1\right)\left(1-\alpha\right)+b^{-1}\alpha\left(\varepsilon-r_i\left(b\right)\right)}, \tag{39}$$

if $b^2\eta^2\left(b\right)/\chi^2\left(b\right)<1$. Then, it is obvious from (38) that

$$\varepsilon-r_i\left(b\right)>\left(\varepsilon-1\right)\left(1-\alpha\right)+\varepsilon/\left(\varepsilon-r_i\left(b\right)\right) \tag{40}$$

is sufficient for (37) (and, therefore, $\partial b_{ji}^{*}\left(b_{ij}\right)/\partial b_{ij}<1$) to hold in the (symmetric) Nash equilibrium. Rearranging terms, inequality (40) can be transformed into

$$\alpha(\varepsilon-1)(\varepsilon-r_i(b))+(1-r_i(b))(\varepsilon-r_i(b))-\varepsilon>0 \tag{41}$$

and, thus,

$$\alpha(\varepsilon-1)(\varepsilon-r_i(b))-r_i(b)(\varepsilon+1-r_i(b))>0\,. \tag{42}$$

Finally, noting $r_i(b)<\alpha/\varepsilon$, according to (26), it becomes obvious that $r_i(b)(\varepsilon-1+r_i(b))<$ $\alpha(2-r_i(b))$. Substituting into (42), we can show that

$$\alpha(\varepsilon-1)(\varepsilon-r_i(\cdot))-\alpha(2-r_i(\cdot)) \tag{43}$$

is sufficient for (37) to hold in the symmetric Nash equilibrium. Since (43) is always fulfilled if $\varepsilon\geq 2$, we can conclude that $\partial b_{ji}^{*}(b_{ij})/\partial b_{ij}<1$ must hold at equilibrium tariff rates $b_{ji}^{n}=b_{ij}^{n}=b^{n}$. For analogous reasoning, we find $\partial b_{ij}^{*}(b_{ji})/\partial b_{ji}>1$ at tariff rates $b_{ji}^{n}=b_{ij}^{n}=b^{n}$, which guarantees uniqueness of the Nash equilibrium and completes the proof of Proposition 1. ■

B. Data Appendix

Variable descriptions and data sources are listed in Table A.1.

- Table A.1 -

Table A.2 provides information on the composition of the country sample.

- Table A.2 -