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# Horizontally-integrated MNE and plant heterogeneity

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## Abstract

In the paper we develop a monopolistically competitive general equilibrium model of horizontally-integrated multinational enterprise (MNE) with heterogeneous plants. We demonstrate that smaller productivity differences between domestic and foreign plants increase the level of multinational activity. We also show that the level of multinational activity is the most intensive between countries of the similar size. Finally, we show that the relative wage increases (decreases) with relative productivity of workers and the degree of product differentiation when the home country is smaller (bigger) compared to the foreign country.

**Keywords:** horizontal integration, MNE, plant heterogeneity

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## 1. Introduction

The late 1970s and early 1980s saw the first wave of major developments in the theory of international trade. A number of authors, including Krugman (1979; 1980; 1981), Dixit and Norman (1980), Lancaster (1980), Helpman (1981), Brander (1981), Ethier (1982), and Brander and Krugman (1983) started introducing elements of industrial organization into the study of international trade. These developments were the response to growing dissatisfaction with the neoclassical trade theory that was unable to explain the actual foreign trade and investment patterns. This led the emergence of the first strand in the so-called new trade theory (NTT).

The traditional trade theory was criticized because of relying on the set of very extreme assumptions such as constant returns to scale (CRS), perfect competition and product homogeneity. The first strand in the NTT relaxed these assumptions and added increasing returns to scale (IRS), imperfect competition and product differentiation to the traditional trade models based on the concept of comparative advantage. According to the NTT, trade and the gains from trade can arise independently of any pattern of comparative advantage as firms exploit economies of scale and pursue strategies of product differentiation.

These early developments in the NTT provided a set of models that proved extremely useful in studying the emergence of multinational enterprises (MNEs) and foreign direct investment (FDI). This resulted in the development of the new theory of multinational enterprise (NTMNE) in the mid 1980s and the 1990s. The NTMNE was a response to the neoclassical theory of factor movements. The early theoretical studies of FDI such as Mundell (1957), MacDougall (1960) or Kemp (1962) viewed the expansion of multinational firms as the transfer of financial or physical capital. However, as argued by Krugman (1995) with the development of the NTT literature it turned out that the expansion of MNEs described as FDI and tracked via balance-of-payments statistics was a conceptual misunderstanding.

Lipsey (2004, p. 334), in his survey paper noted that according to the new concept FDI is rather "a set of economic activities or operations carried out in a host country by firms controlled or partly controlled by firms in some other (home) country. These activities are, for example, production, employment, sales, the purchase and the use of intermediate goods and fixed capital, and the carrying out of research." Thus, in this new concept of FDI no movement of physical or financial capital is necessary, although it might take place.[1]

While many models in the literature were proposed to study internationalization of production two distinct reasons why a firm should go multinational were identified: efficiency seeking and market seeking. According to the first one firms internationalize production and become multinationals in order to get access to inputs at lower costs. Foreign direct investment undertaken with the aim of reducing production costs is often called vertical FDI as it involves fragmenting production processes and locating each stage in the country where the factors used intensively in that particular stage

[1] In terms of the theory it was Caves (1971) who, building on the neoclassical specific factor model, first argued that FDI is associated with the transfer of firm-specific capital rather than physical or financial capital, although the idea that multinational firms are vehicles for the transfer of firm-specific assets goes back at least to Hymer (1960). According to Markusen and Maskus (2003) the approach proposed by Caves (1971) can be regarded as a crucial step in differentiating FDI associated with the inflow of firm intangible assets from the portfolio flows of homogenous capital in the earlier neoclassical models. However, the approach proposed by Caves (1971) was still neoclassical in many respects and assuming perfect competition, constant returns to scale and product homogeneity was unable to adequately address the determinants of FDI. See recent extensions of this approach in Cieślik (2008; 2012).

are relatively cheap. According to the second one multinational firms are vehicles to overcome distance and lower costs of foreign markets access. Foreign direct investment undertaken to serve local markets is often called horizontal FDI and refers to producing abroad roughly the same goods and services as in the parent country.

Horizontal FDI constitutes the largest fraction of multinational activity in the contemporary world economy and occurs mostly between developed countries that are similar both in terms of their relative factor endowments and economic size. To explain this phenomenon several models of horizontally integrated MNE have been developed. Typically, these models employed the tools used previously in the NTT literature that allowed addressing explicitly the issues of increasing returns and market structure. Initially, these models were extremely simple assuming identical factor endowments across countries and/or were based on partial equilibrium frameworks.

Probably, the most frequently cited early example of this approach is the partial equilibrium model of oligopolistic competition developed by Markusen (1984) that assumes the existence of firm-level scale economies as the driving force for FDI. The multinational firm's headquarter produces a service of a firm-specific asset that can be simultaneously used in multiple plants in a non-rival manner. Therefore, two-plant firms have lower fixed costs than those of two single plants and this motivates multinational production.

The original Markusen (1984) model was later extended by Horstmann and Markusen (1987), Markusen and Venables (1998; 2000) and Markusen (2002) and allowed for endogenous market structure and different forms of competition between firms within the partial as well as general equilibrium frameworks. In these frameworks firms have different potential channels of entering a foreign market and each of these channels incurs different costs. A firm faces a choice between concentrating production in the home country and serving foreign markets exporting to achieve scale economies and producing abroad to benefit from proximity to consumers.

General-equilibrium extensions of the Markusen (1984) model allow relating the extent of multinational activity to country characteristics. They predict that given moderate to high trade costs, multinational firms will prevail in equilibrium when countries are similar in size and in relative factor endowments. If countries were of different sizes but similar in relative factor endowments horizontal multinationals would be at a disadvantage relative to national firms producing in the large country and serving the small country market through exporting as they would have to install costly capacity in the small market. If countries were of similar size but differed in terms of their relative factor endowments multinational firms would be at a disadvantage relative to national firms as they would have to incur a substantial part of their costs in a high-cost location, assuming that human capital was intensively used in both fixed and variable costs in the multinational sector.

Another early attempt to integrate MNEs into the NTT was made by Krugman (1983) who extended his previous models of international trade based on monopolistic competition. He considered a simple model with only one factor of production – labor and assumed that labor forces of two countries were equal. The perfect symmetry of the model setup resulted in wage equalization across countries which greatly simplified the analysis. In contrast to the Markusen (1984) model which assumed the same production technologies both in home and foreign countries, Krugman (1983) made an important contribution to the literature by allowing the productivities of labor to differ between domestic and foreign plants of the same MNE.

This early contribution was almost completely overlooked in the subsequent NTMNE literature but it seems especially important in the light of second wave of major developments in the trade theory literature initiated in the early 2000s by Melitz (2003) and Helpman, Melitz and Yeaple (2004) who focused on the role of firm heterogeneity and created a new strand in the NTT.[2] Their models, however, allowed for heterogeneity among firms in terms of their productivity but not among the plants belonging to the same firm. Therefore, it is useful to restate and extend the original model of MNE proposed by Krugman (1983) focusing on an important aspect of firm heterogeneity to a more general setting and reintegrate it into the mainstream literature on firm heterogeneity and FDI.

Hence, the main goal of this paper is to generalize Krugman (1983) model by relaxing the equal country size assumption and to derive a broader set of conclusions. In particular, we endogenize the relative wages and derive them as a function of three key model parameters: the relative labor force, productivity differences between domestic and foreign plants and the degree of product differentiation. Moreover, we demonstrate that multinational sales relative to domestic sales are maximized when countries are of equal size. This finding is in line with the previous studies by Markusen and his coauthors. However, in contrast to more complex monopolistic competition models proposed by Markusen and Venables (1998) and Markusen (2002, Chapter 8) this model can be solved analytically and there is no need to rely on numerical methods to study the properties of the equilibrium solution.

The structure of this paper is organized as follows. In Section 2 we discuss the main assumptions of the monopolistically competitive framework used by Krugman (1980; 1983) which is based on the earlier model developed by Dixit and Stiglitz (1977). In Section 3 we restate equilibrium properties in the closed economy that would constitute a useful benchmark for the interpretation of the results obtained for the open economy with multinational firms. In Section 4 we introduce the possibility of multinational production allowing for productivity differences between domestic and foreign plants. In Section 5 we determine the equilibrium relative wages and multinational sales. Finally, Section 6 summarized and concludes with directions for further study.

## 2. Main assumptions

In this section we discuss the main assumptions underlying the model of monopolistic competition originally developed by Krugman (1980) and later extended in Krugman (1983) to incorporate the MNEs. Following his previous studies we consider a world that consists of two countries named Home and Foreign that may differ in their size. Each country has only a single homogenous factor of production called labor. Labor supply in each country is fixed and does not respond to changes in wage rates. Within each country labor can produce any of a potentially large number of goods. However, in equilibrium the number of goods actually produced in Home and Foreign countries,

[2] In particular, Melitz (2003) relaxed the key assumption of the firm symmetry in the Krugman (1980) model and introduced firm heterogeneity in terms of labor productivity. In his model productivity differences among firms are exogenously given and each firm has to pay fixed costs of entry into domestic and foreign markets. The model predicts that the most productive firms with lowest marginal costs can cover the fixed cost of entry and become exporters. This model was later extended by Helpman, Melitz and Yeaple (2004) to allow for horizontal FDI.

denoted respectively by $N$ and $N^*$, will be smaller than the potential number. This is because of the existence of fixed costs in production. The technology of production is assumed to be the same in both countries.

To produce a good requires a fixed startup cost and a constant marginal cost afterwards. For simplicity, the same cost function for all goods produced within each country is assumed. Thus, the labor requirements for production of particular goods $i$ and $j$ in Home and Foreign countries are respectively:

$$l_i = \alpha + \beta x_i \tag{1}$$

$$l_j^* = \alpha + \beta x_j^* \tag{2}$$

where $l_i$ and $l_j^*$ are respectively the amounts of labor used in producing the $i$-th good in Home country and $j$-th good in Foreign country; $x_i$ and $x_j^*$ are the outputs of the $i$-th in Home country and the $j$-th good in Foreign country, respectively; $\alpha > 0$ is the fixed cost (expressed in terms of labor) and $\beta > 0$ is the constant marginal cost that is independent of the volume of output.

In Home and Foreign countries full employment is assumed, so that the total labor forces in their economies must be exhausted by employment in production of particular goods:

$$L = \sum_{i=1}^{N} l_i = \sum_{i=1}^{N} (\alpha + \beta x_i) \tag{3}$$

$$L^* = \sum_{j=N+1}^{N+N^*} l_j^* = \sum_{j=N+1}^{N+N^*} (\alpha + \beta x_j^*) \tag{4}$$

where $N$ and $N^*$ are the numbers of goods produced in Home and Foreign countries, respectively; and $L$ and $L^*$ are the sizes of the labor forces in Home and Foreign countries respectively.

Finally, all residents in both countries are assumed to have the exactly the same utility function into which all goods enter symmetrically:

$$U(c) = \sum_{i=1}^{N} c_i^{\Theta} \tag{5}$$

$$U^*(c^*) = \sum_{j=N+1}^{N+N^*} c_j^{*\Theta} \tag{6}$$

where $c_i$ is the consumption of the $i$-th good and $\Theta \in (0,1)$ is a fixed parameter that measures the elasticity of substitution between particular goods which is the same in both countries.

Each good yields diminishing marginal utility so that consumers would always prefer to have one unit of each good instead of two units of either.

Consumers are at the same time workers.[3] The economy-wide budget constraints for Home and Foreign countries can be written, respectively, as:

$$\sum_{i=1}^{N} p_i x_i = \sum_{i=1}^{N} p_i c_i L = wL \tag{7}$$

$$\sum_{j=N+1}^{N+N^*} p_j^* x_j^* = \sum_{j=N+1}^{N+N^*} p_j^* c_j^* L^* = w^* L^* \tag{8}$$

## 3. Benchmark: equilibrium in the closed economy

In this section we restate the main properties of the market equilibrium in the closed economy for Home and Foreign countries with national firms only. This yields the optimal pricing conditions ($p_i$, $p_j^*$), the equilibrium outputs of each firm ($x_i$, $x_j^*$) and the equilibrium number of goods produced under autarky in each country being at the same time the equilibrium number of firms ($N$, $N^*$). These results will constitute a useful benchmark for the interpretation of the results obtained from the model of horizontally-integrated MNEs developed in the subsequent sections of the paper. The analysis proceeds as follows. First, we analyze consumer behavior in both countries to derive demand functions. Then we derive the profit maximizing behavior of firms treating the number of firms as given. Finally, we use the free entry assumptions to derive the equilibrium number of firms.

Consumers in both countries maximize their utility functions (5)–(6) subject to their budget constraints (7)–(8) which yields the demand functions for $i$-th and $j$-th goods in Home and Foreign countries, respectively:

$$c_i = p_i^{1/(\Theta-1)} \frac{wL}{\sum_{i=1}^{N} p_i^{\Theta/(\Theta-1)}} \tag{9}$$

$$c_j^* = p_j^{*\,1/(\Theta-1)} \frac{w^* L^*}{\sum_{j=N+1}^{N+N^*} p_j^{*\,\Theta/(\Theta-1)}} \tag{10}$$

It can be noted that for the large number of goods produced in each country the demand facing an individual firm in each country becomes isoelastic and equals $\varepsilon_i = \varepsilon_j^* = 1/(1-\Theta)$.

Firms in Home and Foreign countries maximize the profit functions with respect to their sales $x_i$ and $x_j^*$, respectively:

$$\Pi_i(x_i) = p_i(x_i)x_i - (\alpha + \beta x_i)w \tag{11}$$

[3] According to Krugman (1980, p. 951): "output of each good must equal the sum of individual consumptions. If we identify individuals with workers, output must equal consumption of a representative individual times the labor force."

$$\Pi_j^*(x_j^*) = p_j^*(x_j^*)x_j^* - (\alpha + \beta x_j^*)w^* \tag{12}$$

Given the constant elasticity of demand in each country Home and Foreign firms charge the profit maximizing monopoly prices:

$$p_i = p = \frac{1}{\Theta}\beta w \tag{13}$$

$$p_j^* = p^* = \frac{1}{\Theta}\beta w^* \tag{14}$$

The profit maximizing prices are derived by the standard mark-up pricing rules from equating marginal costs to marginal revenue. It can be noted that since $\alpha$, $\beta$ and $w$ are the same for all firms in Home country prices are the same for all goods, hence index $i$ can be dropped because of symmetry. Similarly, since $\alpha$, $\beta$ and $w^*$ are the same for all firms in Foreign country prices are the same for all goods, hence index $j$ can be dropped.

Next, given the optimal pricing strategies of firms in Home and Foreign countries we need to determine the volume of output for each good. For this we can use the free entry assumptions. Free entry will drive down profits to zero in both countries so that in equilibrium prices will equal average costs. Substituting (13)–(14) into (11)–(12), respectively, and equating to zero yields the long-run equilibrium outputs of representative goods in Home and Foreign countries:

$$x_i = x = \frac{\alpha\Theta}{(1-\Theta)\beta} = x^* = x_j^* \tag{15}$$

It can be noted that the break-even outputs per firm in both countries are exactly the same since parameters determining technologies and preferences $\alpha, \beta$ and $\Theta$ are the same for all firms in both countries. Finally, the number of goods actually produced in each country can be determined from the full employment conditions (3)–(4):

$$N = \frac{L}{\alpha + \beta x} = \frac{(1-\Theta)L}{\alpha} \tag{16}$$

$$N^* = \frac{L^*}{\alpha + \beta x^*} = \frac{(1-\Theta)L^*}{\alpha} \tag{17}$$

## 4. Multinational enterprises

To explain horizontally-integrated MNEs we modify the closed economy model described in the previous section. For simplicity, suppose that trade costs are prohibitively high but firms in both countries can engage in cross-border FDI by establishing production subsidiaries abroad to exploit

economies of scope.[4] Note, however, that this is FDI only in the sense of establishing effective managerial control over production units located in different countries and there is no transfer of capital as by assumption labor is the only factor of production in this model.

As argued by Krugman (1990, p. 277) in his survey paper on the NTMNE "the idea of economies of scope is key for understanding (…) multinational modern firms". According to Panzar and Willig (1977) economies of scope arise when a firm that undertakes two activities will have lower joint costs than two firms undertaking the activities separately. We assume that fixed costs do not occur in production but rather in head quarter activities such as research and development (R&D). According to Krugman (1983, p. 61) "the asset acquired by the fixed cost might be technology in the usual sense, or it might be less easily specified 'know-how' in management, marketing, etc." This means that these fixed costs are not tied to the location of production and once they have been incurred they do not have to be repeated even if production takes place in more than one location.

At the same time it is assumed that there are also additional costs of producing abroad related to unfamiliarity with local language, customs, tax or legal system, etc. Typically, such costs are modeled as additional fixed costs of foreign market entry (Markusen 1984; Markusen, Venables 1998; Markusen 2002; Helpman, Melitz, Yeaple 2004). However, in contrast to that strand in the literature we follow an alternative approach proposed by Krugman (1983) and consider only those costs that raise average variable costs of production. In particular we assume that in production plants located abroad labor is only a fraction $k < 1$ times as productive as it is in production at home. Therefore, the total costs including the R&D and production costs for a representative Home country multinational firm producing for both domestic and foreign markets are:

$$C_i(x_i, x_i') = \alpha w + \beta x_i w + (\beta / k) x_i' w^* < C_i(x_i, 0) + C_i(0, x_i') \tag{18}$$

where $x_i'$ is the extra output produced in Foreign country, $C_i(x_i, 0) = (\alpha + \beta x_i)w$ is the cost of producing only for the Home country market while $C_i(0, x_i') = (\alpha + (\beta / k)x_i')w^*$ is the cost of producing only for the Foreign country market.

It can be noted that due to economies of scope resulting from the common R&D fixed cost the joint cost of producing for two markets together is lower than the costs of producing for each market separately. Thus, the multinational firm will have lower costs than the single country firms. Similarly, for the representative foreign country multinational firm we have:

$$C_j^*(x_j^*, x_j^{*\prime}) = \alpha w^* + \beta x_j^* w^* + (\beta / k) x_j^{*\prime} w < C_j^*(x_j^*, 0) + C_j^*(0, x_j^{*\prime}) \tag{19}$$

where $x_j^{*\prime}$ is the extra output produced in Home country, $C_j^*(x_j^*, 0) = (\alpha + \beta x_j^*)w^*$ is the cost of producing only for the Foreign country market while $C_j^*(0, x_j^{*\prime}) = (\alpha + (\beta / k)x_j^{*\prime})w$ is the cost of producing only for the Home country market.

[4] The assumption on prohibitively high trade costs is made here for analytical convenience and not because it is realistic. If the trade costs were not prohibitive both trade and FDI as alternative modes of internalization would have to be considered as, for example, in Markusen (2002) or Helpman, Melitz and Yeaple (2004).

The profit functions for home and foreign country multinational firms can be written, respectively, as:

$$\Pi_i(x_i, x_i') = p_i(x_i)x_i + p_i'(x_i')x_i' - (\alpha + \beta x_i)w - (\beta / k)x_i' w^* \tag{20}$$

$$\Pi_j^*(x_j^*, x_j^{*\prime}) = p_j^*(x_j^*)x_j^* + p_j^{*\prime}(x_j^{*\prime})x_j^{*\prime} - (\alpha + \beta x_j^*)w^* - (\beta / k)x_j^{*\prime} w \tag{21}$$

where $p_i'(x_i')$ is the price of the extra output produced by the Home country multinational firm in the production subsidiary located in Foreign country while $p_j^{*\prime}(x_j^{*\prime})$ is the price of the extra output produced by the Foreign country multinational firm in the production subsidiary located in Home country.

Profit maximization of the representative Home country multinational firm with respect to its domestic and foreign sales $x_i$ and $x_i'$ yields the optimal pricing strategies for Home and Foreign country markets, respectively:

$$p_i = p = \frac{1}{\Theta}\beta w \tag{22}$$

$$p_i' = p' = \frac{1}{k\Theta}\beta w^* \tag{23}$$

Similarly, profit maximization of the representative Foreign country multinational firm with respect to its domestic and foreign sales $x_j^*$ and $x_j^{*\prime}$ yields the optimal pricing strategies for Foreign and Home country markets, respectively:

$$p_j^* = p^* = \frac{1}{\Theta}\beta w^* \tag{24}$$

$$p_j^{*\prime} = p^{*\prime} = \frac{1}{k\Theta}\beta w \tag{25}$$

It can be noted that in the case of the open economy with multinational firms prices charged by multinational firms in their own markets are exactly the same as in the case of the closed economy without multinational firms. However, due to lower efficiency in production in subsidiaries located abroad prices charged by multinational firms in their overseas markets can be higher compared to prices charged in their own markets depending on the relative wages.

Free entry conditions for the representative Home and Foreign country multinational firms can be used to determine the volumes of output produced by each firm for each market. Substituting solutions for equilibrium prices (22)–(23) for the Home country multinational firm into its profit function (20) and setting it to zero yields:

$$x_i = x = \frac{\alpha\Theta}{(1-\Theta)\beta} - \frac{1}{k}\left(\frac{w^*}{w}\right)x_i' \tag{26}$$

Similarly, substituting solutions for equilibrium prices (24)–(25) for the Foreign country multinational firm into its profit function (21) and setting it to zero yields:

$$x_j^* = x^* = \frac{\alpha\Theta}{(1-\Theta)\beta} - \frac{1}{k}\left(\frac{w}{w^*}\right)x_j^{*\prime} \tag{27}$$

It can be noted that equations (26)–(27) determine sales of multinational firms in their own markets in Home and Foreign countries, respectively, given their sales in overseas markets. This leaves us with four unknowns and two equations only. However, we know from the consumer utility maximization problems for Home and Foreign countries (5)–(6) the relative demands for goods produced by Home and Foreign country multinationals for the Home country market as well as the relative demands for goods produced by Home and Foreign country multinationals for the Foreign country market. This gives us two additional equations.

The structure of consumer preferences described by the "love of variety" approach implies that consumers in both countries will consume all the available goods. Given the symmetric firm pricing strategies in both countries (22)–(25) the modified economy-wide budget constraints for Home and Foreign countries can be written, respectively, as:

$$wL = Npx + Np^{*\prime}x^{*\prime} \tag{28}$$

$$w^*L^* = Np'x' + N^*p^*x^* \tag{29}$$

However, since goods produced in overseas MNE affiliates are more expensive the amounts consumed will be smaller. The solutions to consumer utility maximization problems for both countries (5)–(6) with respect to the modified economy wide budget constraints (28)–(29) yield now relative demands for goods invented in Home and Foreign countries:

$$\frac{c_i}{c_j^{*\prime}} = \left(\frac{p_i}{p_j^{*\prime}}\right)^{1/\Theta-1} = k^{1/\Theta-1} \tag{30}$$

$$\frac{c_i'}{c_j^*} = \left(\frac{p_i'}{p_j^*}\right)^{1/\Theta-1} = k^{1/1-\Theta} \tag{31}$$

Therefore, substituting (30)–(31) into (26)–(27) yields solutions for equilibrium sales in each market as functions of relative wages $w/w^*$ and productivity differential $k$:

$$x = \frac{\alpha\Theta}{(1-\Theta)\beta}\left\{\frac{1-\left(\frac{w^*}{w}\right)k^{\Theta/1-\Theta}}{1-k^{2\Theta/1-\Theta}}\right\} \tag{32}$$

$$x^* = \frac{\alpha\Theta}{(1-\Theta)\beta}\left\{\frac{1-\left(\frac{w}{w^*}\right)k^{\Theta/1-\Theta}}{1-k^{2\Theta/1-\Theta}}\right\} \tag{33}$$

$$x' = \frac{\alpha\Theta k^{1/1-\Theta}}{(1-\Theta)\beta}\left\{\frac{1-\left(\frac{w}{w^*}\right)k^{\Theta/1-\Theta}}{1-k^{2\Theta/1-\Theta}}\right\} \tag{34}$$

$$x^{*\prime} = \frac{\alpha\Theta k^{1/1-\Theta}}{(1-\Theta)\beta}\left\{\frac{1-\left(\frac{w^*}{w}\right)k^{\Theta/1-\Theta}}{1-k^{2\Theta/1-\Theta}}\right\} \tag{35}$$

It can be noted that the higher Home country wage rate relative to the Foreign country wage rate increases output produced by the Home country multinational firm for the Home country market and reduced output produced for the Foreign country market. The reverse is true for the Foreign country multinational which reduces its output for the Home country market and increases output for the Foreign country market when the relative wage rate increases. In the extreme case of the model when wages across countries are equal and there is no productivity difference between domestic and Foreign production subsidiaries the volumes of output for each firm in each country are the same and equal to the half of the total volumes produced in the closed economy (15).

The numbers of multinational firms in each country expressed as a function of the volumes of output for each market can be determined using the full employment conditions. Equating labor supply to labor demand in each country yields:

$$L = N(\alpha + \beta x) + N^*(\beta / k)x^{*\prime} \tag{36}$$

$$L^* = N^*(\alpha + \beta x^*) - N(\beta / k)x' \tag{37}$$

Solving for $N$ and $N^*$ we obtain:

$$N = \frac{L(\alpha + \beta x^*) - \beta k^{\Theta/1-\Theta} x L^*}{(\alpha + \beta x)(\alpha + \beta x^*) - \beta^2 k^{2\Theta/1-\Theta} x x^*} \tag{38}$$

$$N^* = \frac{L^*(\alpha + \beta x) - \beta k^{\Theta/1-\Theta} x^* L}{(\alpha + \beta x)(\alpha + \beta x^*) - \beta^2 k^{2\Theta/1-\Theta} x x^*} \tag{39}$$

## 5. Equilibrium relative wages and multinational sales

The last thing that we need to determine to be able to solve the open economy model with MNEs is the relative wage. This can be done using the economy-wide budget constraints for both countries (28)−(29). Dividing (28) by (29) and substituting solutions for prices (22)−(25), quantities (32)−(35) and the number of domestic and foreign multinational firms (38)−(39), we obtain the following quadratic equation:

$$\omega^2 k^{\Theta/1-\Theta}\frac{(1+\ell k^{\Theta/1-\Theta})\ell}{\ell+k^{\Theta/1-\Theta}}+\omega\frac{(1-\ell^2)k^{\Theta/1-\Theta}}{\ell+k^{\Theta/1-\Theta}}-k^{\Theta/1-\Theta}=0 \tag{40}$$

where $\omega = w/w^*$ is the relative wage and $\ell = L/L^*$ is the relative country size.

This quadratic equation has two roots: one positive and one negative. The positive root is the only meaningful solution as the relative wage cannot be negative. Therefore, the equilibrium relative wage is given by the following relationship:

$$\omega = \frac{\ell + k^{\Theta/1-\Theta}}{1+\ell k^{\Theta/1-\Theta}} \tag{41}$$

It turns out that the relative wage ($\omega$) depends on three exogenously given parameters of the model: the relative country size ($\ell$), the degree of product differentiation ($\Theta$) and the relative productivity of workers in plants located abroad and at home ($k$). The relative wage is an increasing function in the relative country size. Moreover, the relative wage increase (decreases) with relative productivity of workers and the degree of product differentiation when the Home country is smaller (bigger) compared to the Foreign country. Finally, it can be noted that wages in both countries are equalized when either: i) countries are of equal size $L = L^*$ (i.e. $\ell = 1$), ii) products are very differentiated and no substitution between different varieties is possible (i.e. $\Theta = 0$) and/or iii) workers in plants located at home and abroad are equally efficient (i.e. $k = 1$).

Substitution of the equilibrium relative wage (41) into (32)−(35) allows us to obtain equilibrium output volumes for domestic and local sales for the Home country and Foreign country firms. Then, substituting the equilibrium output volumes into (38)−(39) the total number of multinational firms originating from each country can be obtained. Finally, we can also determine the degree of multinational activity defined by the ratio of multinational to domestic sales (RMDS) for both Home and Foreign country firms.

The sales of the Home country firms in Foreign and Home markets can be respectively defined as:

$$p'x'N = \frac{\beta}{\Theta} w^* x^* k^{\Theta/1-\Theta} N \tag{42}$$

$$pxN = \frac{\beta}{\Theta} wxN \tag{43}$$

Similarly, the sales of the Foreign country firms in Home and Foreign markets can be defined as:

$$p^{*\prime} x^{*\prime} N^{*} = \frac{\beta}{\Theta} wxk^{\Theta/1-\Theta} N^{*} \tag{44}$$

$$p^{*} x^{*} N^{*} = \frac{\beta}{\Theta} w^{*} x^{*} N^{*} \tag{45}$$

It can be noted that multinational sales are the sum of (42) and (44), while domestic sales are the sum of (43) and (45). Hence, the ratio of multinational to domestic sales can be written as:

$$RMDS = \left[ \frac{w^{*} x^{*} N + wxN^{*}}{wxN + w^{*} x^{*} N^{*}} \right] k^{\Theta/1-\Theta} \tag{46}$$

Dividing the numerator and denominator of (46) by $w^{*} x^{*} N^{*}$ allows us to express the RMDS as the function of the relative country size:

$$RMDS = \left[ \frac{n(\ell) + \ell}{\ell n(\ell) + 1} \right] k^{\Theta/1-\Theta} \tag{47}$$

where $n(\ell) = N/N^{*}$ is the relative number of firms which is an increasing function of the relative country size $\ell$.

Taking the derivative of (47) with respect to the relative country size it is possible to demonstrate that the ratio of multinational to domestic sales is maximized when countries are of equal size. Then, the RMDS simplifies to:

$$RMDS^{\max} = k^{\Theta/1-\Theta} \tag{48}$$

It can be noted that when countries are of equal size RMDS depends only on two parameters: the degree of product differentiation ($\Theta$) and the relative productivity of workers in plants located abroad and at home ($k$). The higher degree of product differentiation (i.e. the lower value of $\Theta$) the higher the ratio of multinational to domestic sales. Similarly, the lower the productivity difference between domestic and foreign plants (i.e. the higher the value of $k$) the higher the ratio of multinational to domestic sales. When workers in plants located at home and abroad are equally productive (i.e. $k = 1$), or/and goods are very differentiated (i.e. $\Theta = 0$) the ratio of multinational sales to domestic sales equals 1. This means that the volume of multinationals sales is equal to the volume of domestic sales.

## 6. Conclusions

Following the new strand in the trade literature that focuses on firm heterogeneity, in the paper we developed a monopolistically competitive general equilibrium model of horizontal foreign direct

investment that is a generalization and extension of the early work of Krugman (1983). However, in contrast to this strand new that assumes productivity differences between firms within each country, we allowed for productivity differences between production plants located at home and abroad belonging to the same multinational enterprise.

We endogenized the relative wages and expressed them as the function of the relative country size, the degree of product differentiation and the productivity difference between the domestic and Foreign plants of multinational firms. We showed that the relative wage is an increasing function in the relative country size. Moreover, the relative wage increases (decreases) with relative productivity of workers and the degree of product differentiation when the Home country is smaller (bigger) compared to the Foreign country.

Furthermore, we demonstrated that the multinational activity is the most intensive between countries of the similar size. This finding is in line with predictions of the studies by Markusen and his coauthors and empirical evidence on FDI patterns quoted in their studies. We also showed that smaller productivity differences between domestic and foreign plants increase the level of multinational activity.

The proposed theoretical framework should be complemented with future empirical studies aimed at verifying the predictions of the model based on the firm and plant level data. An especially promising research area would be to test whether indeed there are significant productivity differences between plants that belong to the same MNE that are located in different countries. Moreover, it would also be interesting to test study the behavior of productivity differences between domestic and foreign plants over time to see whether these differences are permanent or declining over time with technology standardization across all plants in the long run.

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## Technical appendix. Derivation of the demand functions

To derive the demand function facing an individual firm in Home country we need to solve a decision problem of a representative consumer:

$$\max_{c_i} U(c) = \sum_{i=1}^{N} c_i^{\Theta}$$

$$s.t. \sum_{i=1}^{N} c_i p_i = wL$$

To solve this problem we set up a standard Lagrangian:

$$\ell = \sum_{i=1}^{N} c_i^{\Theta} + \lambda \left[ wL - \sum_{i=1}^{N} c_i p_i \right]$$

where $\lambda$ denotes the shadow price (marginal utility of income).

This yields the first order condition (FOC) that can be written as:

$$\Theta c_i^{\Theta-1} = \lambda p_i$$

$$p_i = \Theta \lambda^{-1} c_i^{\Theta-1}$$

$$c_i = (\lambda p_i)^{1/\Theta-1} \Theta^{1/1-\Theta}$$

Then, we substitute the FOC into the budget constraint to obtain:

$$\sum_{i=1}^{N} c_i p_i = \sum_{i=1}^{N} (\lambda p_i)^{1/\Theta-1} \Theta^{1/1-\Theta} p_i = wL$$

$$\lambda^{1/\Theta-1} \Theta^{1/1-\Theta} \sum_{i=1}^{N} (p_i)^{\Theta/\Theta-1} = wL$$

$$\lambda^{1/\Theta-1} \Theta^{1/1-\Theta} = \frac{wL}{\sum_{i=1}^{N} p^{\Theta/\Theta-1}}$$

Finally, we substitute this back into the FOC to eliminate $\lambda$ and obtain the demand function (9):

$$c_i = p_i^{1/\Theta-1} \frac{wL}{\sum_{1}^{N} p_i^{\Theta/\Theta-1}}$$

In a similar manner we can also derive the demand function facing an individual firm in Foreign country (10).