

Trade Costs, International Competition, and Competitive Selection: The Role of Unionisation and Inter-country Asymmetries

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Abstract: Within a two-country model of international trade in which heterogeneous firms face firm-specific unions, we study the effects of different forms of trade liberalisation on market structure and competitive selection in the presence of inter-country asymmetries in size and labour market institutions. For given levels of trade openness, an increase in a country's relative unions' strength reduces the average productivity of its domestic producers but increases that of its exporters. Whilst an *unfavourable* union power differential, by increasing wages, weakens a country's firms' competitive position, the higher wages reinforce standard market access mechanisms to give rise to aggregate income effects. When the initial levels of trade openness are sufficiently low, this 'expansionary' aggregate effect can attract industry in the country with stronger unions and also result in an increase in the extensive margin of exports. For sufficiently large inter-country differences in the bargaining power of unions, trade liberalization can then result in a *pro-variety* effect, with an increase in the total availability of varieties to consumers in both countries, regardless of there being inter-country differences in size.

Keywords: Competitive selection, international trade, unionisation, pro-variety effect, aggregate demand effect.

JEL classification: F12, F16, R13, J51

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1. INTRODUCTION

This paper analyses the effects of trade liberalisation on the process of competitive selection between heterogeneous firms and on market structures in a two country world in which economies are asymmetric in size and in labour market institutions.

An increasing availability of good quality firm-level data has underpinned in recent years the emergence of a considerable body of empirical evidence that points to the existence of significant intra-industry and inter-firm heterogeneity in behaviour and performance. Key stylised facts emerging from this literature are that more productive firms are larger, hold larger market shares and are more likely to become exporters than firms that operate only in domestic markets.¹ This empirical evidence has led to theoretical developments that provide microfoundations for the existence of inter-firm differences in productivity and performance.²

A key contribution of this body of literature is to have highlighted the importance of different types of trade costs in determining the performance and the export status of firms as well as the nature of the competitive selection process within industries. These trade costs are typically modelled as variable trade costs (reflecting distance-related and policy trade barriers) and fixed export costs (reflecting beachhead costs associated with adapting operations to a foreign administrative, legal, and regulatory environment). Consistent with the standard predictions of models *à la* Melitz (2003), empirical evidence broadly suggests that trade liberalisation affects aggregate export performance mainly via changes in the extensive margin of exports – for instance, Lawless (2010) finds that whilst distance negatively affects both the intensive and extensive margins of exports, the coefficient for the latter is significantly larger.

In most instances in the theoretical literature, the effects of trade liberalisation on inter-firm competitive selection and market structure have been studied within settings characterised by inter-country symmetry. Notable exceptions are Baldwin and Forslid (2010), who introduce inter-country asymmetries in size in a model *à la* Melitz, and Del Gatto *et al.* (2007) who introduce inter-country asymmetries in size, trade costs and technology in a multi-country model *à la* Melitz and Ottaviano (2008). None of these papers, however, considers the existence of labour market imperfections.

However, central to current policy debates are concerns that labour market rigidities may hinder the international performance of firms and industries, with the conventional wisdom holding

¹ See for instance: Bernard and Jensen (1999, 2004a,b), Eaton *et al.* (2004) and – for a recent survey – Tybout, J. (2003).

² Montagna (2001) analyses the effects of trade liberalization on firms' selection in the presence of inter-country differences in firms' efficiency distributions. Melitz (2003) introduces a fixed export cost in an environment characterized by uncertainty about after-entry efficiency and shows how firms with different efficiencies self-select into different behaviours, with only more productive firms choosing to become exporters. Among many others, see also: Bernard *et al.* (2003), Yeaple (2004), Bernard *et al.* (2007), Melitz and Ottaviano (2008). For a recent review of the literature, see Helpman (2006).

that, in the interest of competitiveness, labour markets deregulation is a necessary response to globalization. As argued in Montagna and Nocco (2008), labour market imperfections may not have entirely obvious effects on the equilibrium efficiency distribution of firms. This is particularly relevant when countries are asymmetric not only in their labour market institutions, but also in other dimensions, such as market size. In this paper, as in Montagna and Nocco (2008), we focus on unionised labour markets but we consider in greater depth the effects of trade liberalisation and their interaction with inter-country asymmetries in unions' bargaining power and in market size in determining equilibrium outcomes.

Most papers that study the effects of labour market imperfections on competitive selection and trade do not focus on the role of unions. Egger and Kreickemeier (2009) use a fair-wage effort mechanism. Helpman and Itskhoki (2010) focus on the effects of hiring and firing rigidities on trade and unemployment, and Helpman *et al.* (2010) assume workers to be heterogeneous in some unobservable ability.³ Unionization is considered by Eckel and Egger (2009) who develop a right-to-manage model of wage determination, but within a different context from ours that focuses only on internationalised firms and on multinational production. Furthermore, with the exception of Helpman and Itskhoki (2010) and Helpman *et al.* (2010), who consider inter-country asymmetries in the degree of labour market frictions, all the above mentioned works differ from our model in that they assume fully symmetric countries.

In our model, firms in the monopolistically competitive sector face firm-specific unions with which they negotiate the wage according to a right-to-manage model. We allow for the bargaining power of unions to differ across economies. We show how the existence of unions affects the endogenous emergence of the industry efficiency cut-off points for domestic production and export. Specifically, we find that for given levels of variable and fixed trade costs, an increase in the bargaining power of a country's unions relative to that of foreign unions, makes it easier for firms to survive in the domestic market and makes it more difficult to export (i.e. it reduces the productivity cut-off facing domestic producers and increases that of exporters). This result is independent of the relative size of countries. The latter, instead, plays a significant role in determining the other market structure variables: we find that the effects of trade liberalisation on both the extensive and intensive margins of export ultimately rest on the interplay between market access, competition, and aggregate demand effects. The relative magnitudes of these effects are affected by the degree of inter-country asymmetries in union strength and in market size, as well as by the initial level of trade openness.

A key result of our paper is that whilst a relatively high bargaining power of domestic unions (by resulting in a wage cost disadvantage) weakens the competitive position of a country's firms vis-

³ Vannoorenberghe (2011) analyses the effects of trade liberalisation on the skill premium in a Melitz model in which there exist two types of labour.

à-vis that of its competitors, the resulting higher wages reinforce standard market access mechanisms (stemming from market segmentation) via aggregate income effects: essentially, despite their negative impact on firms' price competitiveness, higher union power and wages combine with market access forces to generate a 'keynesian' type expansionary effect on aggregate demand. We show that when the initial levels of trade openness are sufficiently low, there are circumstances in which this expansionary effect can act as a catalyst for industry as well as lead to an increase in the extensive margin of exports. Clearly, if the difference in bargaining power becomes too large, then the negative effects of higher wages on firms' competitiveness will dominate.

We also find that, when differences in the bargaining power of unions in the two countries is sufficiently large, trade liberalization can produce a *pro-variety* effect, giving rise to an increase in the total availability of varieties to consumers *in both countries* – even if the countries are identical in size.⁴

Typically, the average size of firms selling in the domestic market (defined over both exporter and non-exporters) is smaller the stronger a country's unions. However, the average size of exporters (i.e. the intensive margin) – which falls as trade becomes more open in both countries – is larger in the relatively more unionized country at all levels of openness. Differences in country size do not alter this result.

The rest of the paper is organised as follows. Section 2 describes the set up and derives the equilibrium of the model. Section 3 studies the effects of trade liberalisation on competitive selection and market structure, whilst Section 4 analyses the effects of unionisation and changes in trade openness on real wages. Section 5 concludes the paper.

2. THE MODEL

The world consists of two economies each producing a homogeneous good within a perfectly competitive sector and a horizontally differentiated good within a monopolistically competitive industry. Labour is the only primary input of production and the economies are endowed with an inelastically supplied quantity of workers. In the monopolistic sector, firm-specific unions bargain with firms over the wage. The homogeneous good is freely traded. Retaining this good as the numeraire then implies that the wage in this sector is equal to one in both countries. In the differentiated good sector, markets are segmented, in the sense that exporting firms incur a per-unit (iceberg) trade cost $\tau > 1$.

⁴ This result differs from the 'anti-variety' effect found, in the absence of unions, by Baldwin and Forslid (2010) whereby the number of varieties bought by a typical consumer falls monotonically as the freeness of trade increases.

We shall focus on inter-country differences in market size (as captured by the size of the labour endowment) and in labour market institutions (in the form of asymmetric bargaining powers of unions). Whenever appropriate, the foreign country's variables will be denoted by an asterisk.

2.1 Preferences

Consumers' preferences are assumed to be the same in both countries and to be defined over a composite index of a differentiated good, D , and a homogeneous competitive good, A . Thus, the utility function of the representative household in each country will be given by:

$$(1) \quad U(A, D) = \frac{(A)^{1-\mu} (D)^\mu}{(1-\mu)^{1-\mu} \mu^\mu},$$

with $0 < \mu < 1$. Using the homogeneous good as the numeraire of the model, and setting its price to unity, the budget constraint of the representative household is:

$$PD + A = I,$$

where I the household's income and P is the price (index) of the differentiated good. Constrained maximisation of (1) then yields:

$$A = (1 - \mu)I,$$

and

$$D = \mu \frac{I}{P}.$$

The quantity index D is a subutility function defined over a continuum of varieties of the horizontally differentiated good, given by:

$$D = \left[\int_0^M D(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}},$$

where $D(i)$ is consumption of a typical variety i , $\sigma > 1$ is the (constant) elasticity of substitution between varieties, and M is the endogenous set of varieties available for consumption in the country; specifically: $M = N_D + N_X^*$, where N_D is the mass of varieties produced within the country and N_X^* is the mass of imported varieties. Maximising D subject to the relevant constraint and imposing duality then implies that the demand for each variety i supplied to the domestic market and the price index P are respectively given by:

$$(2) \quad D(i) = \mu \frac{p(i)^{-\sigma}}{P^{1-\sigma}} I,$$

and

$$(3) \quad P^{1-\sigma} = \int_0^{N_D} p(i)^{1-\sigma} di + \int_0^{N_X^*} p^*(i)^{1-\sigma} di$$

2.2 Production

The production technology is the same in both countries. In the competitive sector, firms use a constant returns to scale technology, with one unit of the homogeneous good requiring one unit of labour. In the differentiated good sector, to start producing, each firm i bears a fixed entry cost f_I in terms of the homogeneous good that covers the cost of the innovation and R&D efforts required to develop a variety of the good. In addition, the firm incurs a fixed operating cost, always in terms of the homogeneous good, to cover plant and production lines outlays. This fixed cost differs depending on the firm's destination market; specifically, the beachhead fixed cost is given by f_D for domestic sales and f_X for exports. As for the entry cost f_I , f_D and f_X are also expressed in terms of the homogeneous good.⁵ We shall further assume that $f_X > f_D$. The fixed cost of innovation f_I is sunk after entry. To produce a quantity $q(i)$ of the good, a typical firm i has a variable input requirement of $l_m(i)$ units of labour, as described by the following production function:

$$(4) \quad q(i) = \frac{l_m(i)}{c(i)},$$

where $c(i)$ is the quantity of labour required to produce one unit of good i and is therefore an inverse measure of the productivity of the firm. Productivity is assumed to be heterogeneous across firms.

Prior to entry, all firms are identical. Since R&D is an uncertain activity, however, it is plausible to assume that it is only after making the irreversible investment f_I , that a firm learns how productive its technology, as measured by the parameter $1/c(i)$, is. Thus, we assume that the sunk investment cost delivers a new horizontally differentiated variety with a random unit labour requirement $c(i)$ drawn from some cumulative distribution, $G(c)$. As a result, R&D generates a distribution of entrants across marginal costs, with a firm i that produces in the economy facing the marginal cost of production $w_m(i)c(i)$, where $w_m(i)$ is the wage perceived by the workers it employs. We assume $G(c)$ to be the same in both countries.

⁵ Following Baldwin and Forslid (2004, 2010), we assume these fixed costs to correspond to the flow-equivalent of total fixed costs. Specifically, we ignore discounting by assuming that firms die according to a Poisson process with a hazard rate of δ . Hence, given that the expected life of a variety is $1/\delta$, the flow equivalent of the total life-time fixed innovation cost F_I is $f_I = \delta F_I$. The same reasoning applies for the other two fixed costs f_D and f_X in the model. Finally, as Baldwin and Forslid (2004) and Melitz (2003), we shall focus on steady states.

Denoting domestic sales and exports with $q_D(i)$ and $q_X(i)$ respectively, then the output of a purely domestic firm is $q(i) = q_D(i)$, and the output of a firm that supplies both the domestic and the foreign markets is $q(i) = q_D(i) + q_X(i)$.

Due to the transport cost involved in international trade, the delivered cost abroad of a unit produced with cost $w_m(i)c(i)$ is $\tau w_m(i)c(i)$. Thus, while in equilibrium production for the domestic market $q_D(i)$ necessarily coincides with sales $D(i)$ in that market, trade costs make the production for exports, $q_X(i)$, exceed the sales in the foreign country, $D_X(i)$, that is: $q_X(i) = \tau D_X(i)$. A firm's profits from domestic and foreign sales are then respectively given by:

$$\pi_D(i) = [p_D(i) - w_m(i)c(i)]q_D(i) - f_D, \text{ and } \pi_X(i) = [p_X(i) - \tau w_m(i)c(i)]\frac{q_X^j(i)}{\tau} - f_X,$$

conditional on the productivity distribution of the entrants that will decide to produce.⁶

Profit maximisation subject to the demand functions in (2) implies that the optimal price rules that firm i sets for its domestic and export markets are respectively given by:

$$(5) \quad p_D(i) = \frac{\sigma}{\sigma-1} w_m(i)c(i) \quad \text{and} \quad p_X(i) = \frac{\sigma}{\sigma-1} \tau w_m(i)c(i),$$

which implies that equilibrium prices in the export market are a multiple – by a constant factor of proportionality τ – of those in the domestic market.

Given (5), domestic sales and exports of the firm are then respectively given by:

$$(6) \quad D_D(i) = \mu \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{w_m(i)^{-\sigma} c(i)^{-\sigma}}{P^{1-\sigma}} I \quad \text{and} \quad D_X(i) = \mu \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{(\tau)^{-\sigma} w_m(i)^{-\sigma} c(i)^{-\sigma}}{P^{*1-\sigma}} I^*,$$

while maximized profits obtained by firm i from its domestic sales and exports are:

$$(7) \quad \pi_D(i) = \mu \left(\frac{1}{\sigma-1} \right)^{1-\sigma} \sigma^{-\sigma} \frac{w_m(i)^{1-\sigma} c(i)^{1-\sigma}}{P^{1-\sigma}} I - f_D, \text{ and } \pi_X(i) = \mu \left(\frac{1}{\sigma-1} \right)^{1-\sigma} \sigma^{-\sigma} \frac{(\tau)^{1-\sigma} w_m(i)^{1-\sigma} c(i)^{1-\sigma}}{P^{*1-\sigma}} I^* - f_X.$$

Using the production functions $q_D(i) = \frac{l_{mD}(i)}{c(i)}$ and $q_X(i) = \tau D_X(i) = \frac{l_{mX}(i)}{c(i)}$ together with

equation (6), the quantity of labour demanded by firm i for its domestic and export sales are respectively given by :

$$(8) \quad l_{mD}(i) = \mu \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{w_m(i)^{-\sigma} c(i)^{1-\sigma}}{P^{1-\sigma}} I \quad \text{and} \quad l_{mX}(i) = \mu \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{(\tau)^{1-\sigma} w_m(i)^{-\sigma} c(i)^{1-\sigma}}{P^{*1-\sigma}} I^*,$$

which can be used in (7) to rewrite the firm's maximized profits from domestic and foreign sales as:

⁶ As in Baldwin and Forslid (2010) “[s]ince the beachhead costs are sunk, firms consider the present value of operating profits and the beachhead costs. Given the constant firm-death rate δ and the zero discount rate, the present value of a given firm is just π/δ , where π is the operating profit the firm would earn if it actually produces.”

$$(9) \quad \pi_D(i) = \frac{w_m(i)l_{mD}(i)}{\sigma-1} - f_D \quad \text{and} \quad \pi_X(i) = \frac{w_m(i)l_{mX}(i)}{\sigma-1} - f_X.$$

2.3. Wages

In the homogenous perfectly competitive good sector, the labour market is perfectly competitive and all employers pay the same wage. Since the price of the good and the value of the marginal product of labour in this sector are both fixed at unity, the wage rate, w_c , is also equal to 1. In contrast, labour in the monopolistic sector is unionised. We adopt the right-to-manage model, with the wage being determined in a bargaining process between the firm specific union and the firm and the latter choosing (output, and hence) employment unilaterally.

The wage is determined via the maximisation of a bargaining product subject to the labour demand in (8). Specifically, the Nash bargaining solutions for a firm producing only for the domestic market and for one that produces for both the domestic and the foreign markets are obtained respectively by:

$$\max_{w_m(i)} \Pi_{iD} = v \ln \left\{ l_{mD}(i) [w_m(i) - 1] \right\} + (1-v) \ln \left[\frac{w_m(i)l_{mD}(i)}{\sigma-1} \right]$$

and:

$$\max_{w_m(i)} \Pi_{iX} = v \ln \left\{ [l_{mD}(i) + l_{mX}(i)] [w_m(i) - 1] \right\} + (1-v) \ln \left\{ \frac{w_m(i) [l_{mD}(i) + l_{mX}(i)]}{\sigma-1} \right\},$$

where $v \in [0,1]$ is the bargaining power of the union. Note that when $v=1$, the model collapses into the monopoly model in which employment is unilaterally determined by the employer, and the wage is unilaterally fixed by the union, taking into account the effect of changes in wages on employment and on prices. The firm's objective function is its profits above its reservation utility, which is $\pi_0 = -f_D$ for a domestic firm, and $\pi_0 = -(f_D + f_X)$ for a firm that also exports; the union's reservation utility is the total labour rent above the constant wage paid to non-unionised workers ($w_c = 1$). It can be easily verified that, for both domestic-only and exporting firms, the bargained wage will be:

$$(10) \quad w_m(i) = w_m = 1 + \frac{v}{\sigma-1}$$

which is independent of the firm-specific productivity level and hence is the same for all firms. Clearly, the union wage exceeds the reservation wage by a mark-up that is positively related to the bargaining power of unions.⁷

Using (10), the prices set by firms can now be written as:

$$(11) \quad p_D(i) = \frac{\sigma}{\sigma-1} \left(1 + \frac{\nu}{\sigma-1}\right) c(i) \quad \text{and} \quad p_X(i) = \frac{\sigma}{\sigma-1} \tau \left(1 + \frac{\nu}{\sigma-1}\right) c(i).$$

Hence, despite paying a common wage, for a given ν , firms with lower unit labour requirements will set lower prices and sell larger quantities than less efficient firms.

The labour market clearing condition $L = L_c - L_m$ and the definition of aggregate income $I = L_c + w_m L_m$ – where L is total labour supply, and L_c and L_m are the employment levels in the competitive and differentiated sector, respectively – complete the model.

2.4. The long-run equilibrium

Free entry and exit of firms into the monopolistically competitive industry implies that expected profits are driven to zero in equilibrium. A potential entrant faces uncertainty about its productivity. This uncertainty is resolved after paying the fixed entry cost f_I , at which point the firm's productivity is revealed. A firm will be able to operate in the domestic market only if its productivity can generate a level of variable profit that suffices to cover the fixed production cost f_D . Similarly, in order to be able to export, a firm's productivity draw needs to be sufficiently high so as to generate a variable profit that can cover the additional fixed export cost f_X and the variable iceberg trade cost. A competitive selection process follows entry: only firms with productivity above a certain threshold will be able to operate in the domestic market. The possibility of international trade – and the fact that trade is costly – gives rise to an additional selection process between exporting and non-exporting firms, with only relatively more productive firms being able to export. The process of competitive selection results in a partitioning of firms which is determined by the endogenous emergence of two cut-offs for c – that correspond to the upper limit of the range of c over which firms produce only for the local market, and to the upper limit of the range of c over which firms also export; we denote these two cut-offs by c_D and c_X , respectively. Hence, for a given number of entrants, N_E , a mass $N_D = G(c_D)N_E$ of firms will sell only in the domestic market

⁷ The fact that mark-ups (of both firms and unions) are constant in this model depends on the CES framework. Firm-specific mark-ups and wages are obtained in Montagna and Nocco (2008) within a similar framework that relies however on a quasi-linear utility function. The advantage of the current specification is that it allows for income effects to emerge.

and a mass $N_X = G(c_X)N_E$ of firms will also export. The two cut-off levels are defined respectively by:

$$(12) \quad \begin{aligned} c_D &= \sup \{c : \pi_D(c_D) = 0\} \\ c_X &= \sup \{c : \pi_X(c_X) = 0\} \end{aligned}$$

which describe the (zero-profit) indifference conditions of marginal firms. As a result, firms that are just able to cover their fixed costs for domestic and export sales are, respectively, characterized by:

$$(13) \quad \begin{aligned} \pi_D(c_D) = 0 &\Leftrightarrow p_D = \frac{\sigma}{\sigma-1} \left(1 + \frac{v}{\sigma-1}\right) c_D \\ \pi_X(c_X) = 0 &\Leftrightarrow p_X = \frac{\sigma}{\sigma-1} \tau \left(1 + \frac{v}{\sigma-1}\right) c_X \end{aligned}$$

It is easy to show that the productivity cut-offs for firms based in the home country satisfy the relationship:

$$c_X = \Lambda c_D,$$

where $\Lambda \equiv \left(\frac{I}{I^*}\right)^{\frac{1}{1-\sigma}} \left(\frac{P^*}{P}\right) \tau^{-1} \left(\frac{f_X}{f_D}\right)^{\frac{1}{1-\sigma}}$.⁸ Clearly, the minimum efficiency required to export depends

ultimately on the relative size of the two markets and on the fixed and variable trade costs. In the

special case of symmetric countries (i.e. where $I = I^*$ and $P = P^*$): $\Lambda \equiv \tau^{-1} \left(\frac{f_X}{f_D}\right)^{\frac{1}{1-\sigma}}$, which is less

than unity. When countries are asymmetric, other things equal, Λ will be larger (i.e. c_X will be larger relative to c_D) the larger is the relative size of the country's trading partner. A large foreign market can offset the effects of trade costs on the minimum efficiency required to export: by being able to 'sustain' the exporting activity of relatively less efficient producers, a large foreign market will thus work towards an increase in the extensive margin of export of the domestic industry. These results are consistent with stylised facts that suggest that larger numbers of small exporters can succeed in operating in foreign markets that are 'easier to access'⁹ – either because they involve lower trade costs or because they are larger.

⁸ To see this, note that firm i 's revenue from exports can be written as $r_X(i) = \frac{I^* P^{*\sigma-1}}{I P^{\sigma-1}} \tau^{1-\sigma} r_D(i)$ and that the relationship

between the revenue of firms i and j ($i \neq j$) operating in the same market implies: $\frac{r_D(j)}{r_D(i)} = \frac{r_X(j)}{r_X(i)} = \left(\frac{c(j)}{c(i)}\right)^{1-\sigma}$. Making

use of these the zero profit conditions from domestic and foreign sales then leads to the relationship discussed above.

⁹ See for instance, Mayer and Ottaviano (2007).

Using equations (7), (10) and (13), income for the two countries can respectively be written as:

$$(14) \quad I = f_D \sigma^\sigma \frac{P^{1-\sigma}}{\mu \left(\frac{1}{\sigma-1} \right)^{1-\sigma} \left(1 + \frac{v}{\sigma-1} \right)^{1-\sigma} (c_D)^{1-\sigma}}, \text{ and } I^* = f_X \sigma^\sigma \frac{P^{1-\sigma}}{\mu \left(\frac{1}{\sigma-1} \right)^{1-\sigma} (\tau)^{1-\sigma} \left(1 + \frac{v}{\sigma-1} \right)^{1-\sigma} (c_X)^{1-\sigma}},$$

which can be used to rewrite the profits from domestic sales and exports as:

$$(15) \quad \pi_D(i) = f_D \left[\left(\frac{c_D}{c(i)} \right)^{\sigma-1} - 1 \right] \quad \text{and} \quad \pi_X(i) = f_X \left[\left(\frac{c_X}{c(i)} \right)^{\sigma-1} - 1 \right].$$

2.4.1. Derivation of the cut-offs

In order to analyse the effects of trade liberalisation and unionisation on the competitive selection process within industries, we shall now proceed to derive the equilibrium cut-off points. In a two country setting, the equilibrium cut-off points of one country will depend on its trading partner's parameters. Hence, the two countries' efficiency cut-off points need to be determined jointly.

We choose, as is standard in the literature given its consistency with stylised facts about the productivity distribution of firms within industries,¹⁰ to work with a Pareto distribution as the specific parameterisation of $G(c)$. This distribution has a higher unit labour requirement bound c_M and shape parameter $\kappa \geq 1$:

$$G(c) = \left(\frac{c}{c_M} \right)^\kappa, \quad c \in [0, c_M].$$

Using this parameterization, the free entry zero expected profit condition:

$$\int_0^{c_D} \pi_D(c) dG(c) + \int_0^{c_X} \pi_X(c) dG(c) = f_I$$

can be rewritten as:

$$(16) \quad f_D (c_D)^\kappa + f_X (c_X)^\kappa = f_I (c_M)^\kappa \frac{\kappa - \sigma + 1}{\sigma - 1},$$

where $\kappa > \sigma - 1$ is a necessary condition for the integral in the free entry condition to converge. Then, making use of the income expression in (14), a relationship can be derived between c_D and c_X^* that effectively determines the efficiency composition of the (domestic and foreign) population

¹⁰ See for instance Del Gatto *et al.* (2007).

of firms that compete for the domestic market and hence reflects the competitive pressure that domestic firms face from foreign exporters:

$$(17) \quad c_X^* = c_D (\tau)^{-1} \left(\frac{1 + \frac{\nu}{\sigma-1}}{1 + \frac{\nu^*}{\sigma-1}} \right) \left(\frac{f_X}{f_D} \right)^{\frac{1}{1-\sigma}}.$$

It is clear from (17), that asymmetries in labour market institutions play an important role in determining the relationship between c_D and c_X^* . This relationship can now be used in the free entry zero expected profit condition (16) for both countries in the following system of equations:

$$\begin{cases} f_D (c_D)^\kappa + f_X (c_X)^\kappa = f_I (c_M)^\kappa \frac{\kappa - \sigma + 1}{\sigma - 1} \\ f_D (c_D^*)^\kappa + f_X (c_X^*)^\kappa = f_I (c_M)^\kappa \frac{\kappa - \sigma + 1}{\sigma - 1} \end{cases},$$

that can be solved to derive c_D and c_D^* as follows:

$$(18) \quad c_D = c_M \left\{ \frac{f_I}{f_D} [1 - \phi \tilde{\nu} \rho] \left(\frac{\frac{\kappa}{\sigma-1} - 1}{[1 - \phi^2 \rho^2]} \right)^{\frac{1}{\kappa}} \right\}, \quad \text{and} \quad c_D^* = c_M \left\{ \frac{f_I}{f_D} [1 - \phi \frac{\rho}{\tilde{\nu}}] \left(\frac{\frac{\kappa}{\sigma-1} - 1}{[1 - \phi^2 \rho^2]} \right)^{\frac{1}{\kappa}} \right\},$$

where: $\rho \equiv \tau^{-\kappa} < 1$ represents an inverse measure of trade costs (i.e. it captures the ‘freeness’ of

trade); $\phi \equiv \left(\frac{f_D}{f_X} \right)^{\frac{\kappa}{\sigma-1}} < 1$ is an inverse measure of the size of the export fixed cost relative to the

domestic one; and $\tilde{\nu} \equiv \left(\frac{1 + \frac{\nu^*}{\sigma-1}}{1 + \frac{\nu}{\sigma-1}} \right)^\kappa$ is an inverse measure of the power of domestic unions relative

to foreign ones – with $\tilde{\nu} < 1$ when $\nu > \nu^*$. The condition $\phi \rho < \tilde{\nu} < \frac{1}{\phi \rho}$ ensures that $c_D > 0$ (by the

second inequality) and $c_D^* > 0$ (by the first inequality).¹¹ It is clear from (18) that for a given level of economic integration between the two countries, as determined by ρ and f_X , an increase in the relative domestic bargaining power of unions (i.e. a fall in $\tilde{\nu}$) results in an increase in the cut-off for domestic producers, c_D : thus, if domestic unions become more powerful (or if foreign unions become less so) it becomes easier for domestic firms to survive in equilibrium.

¹¹ Given (17), these conditions will also ensure the positivity of c_X^* and of c_X .

Given the relationship in (17), we can also derive the two countries' exporters cut-off points. Reporting, for ease of exposition, only that for the home country, we have:

$$(19) \quad c_X = c_M \left\{ \rho \frac{f_I}{f_D} [\tilde{v} - \phi\rho] \frac{\left(\frac{\kappa}{\sigma-1} - 1 \right)}{[1 - \phi^2 \rho^2]} \right\}^{\frac{1}{\kappa}} \phi^{\frac{1}{\kappa+1-\sigma}},$$

which shows that an increase in the bargaining power of domestic unions, ν , (or a decrease in the foreign bargaining power of unions, ν^*), by decreasing the cut-off of domestic exporters c_X , toughens the selection process into exporting status – i.e. it makes it more difficult for firms to be able to survive in the export market.¹² These results can be summarised in the following proposition:

Proposition 1: For given levels of variable and fixed trade costs, an increase in the bargaining power of domestic unions relative to that of foreign unions (i.e. a fall in \tilde{v}) increases the cut-off of domestic producers, c_D , and reduces the cut-off of domestic exporters, c_X .

By increasing the wage in the monopolistic sector, a rise in ν translates into higher marginal costs and thus, other things equal, makes firms less competitive relatively to foreign producers in both the domestic and foreign markets. The existence of a per unit trade cost compounds this adverse wage effect on firms' ability to export by making it more difficult to cover the fixed export costs. As will become clearer later, however, the higher wages have an expansionary effect on the size of the domestic market – with a higher aggregate income leading to an expansion in the aggregate demand for the differentiated good. This market size effect dominates the cost effect of higher wages on firms' profits and leads to a reduction in the minimum level of efficiency required to survive in the market.¹³

Finally, to complete the solution of the model, as shown in the Appendix, we derive the expressions for N_E and N_E^* :

$$N_E = \frac{\mu(\kappa - \sigma + 1)c_M^\kappa(\sigma + \nu - 1)(1 - \tilde{v}\phi\rho)}{\kappa f_D(1 + \phi\rho)(c_D)^\kappa} \frac{\left\{ L^* \phi \rho \sigma (\sigma + \nu^* - 1)(1 - \tilde{v}\phi\rho) + L \left[\sigma (\sigma + \nu^* - 1)(\phi\rho - \tilde{v}) + \nu^* \mu \tilde{v} (1 - \phi^2 \rho^2) (\sigma - 1) \right] \right\}}{(1 - \phi\rho) g(\nu, \nu^*, \sigma, \mu, \phi, \rho, \kappa)}$$

and

¹² These results are in line with those in Montagna and Nocco (2008).

¹³ Similarly, an increase in the foreign bargaining power of unions, ν^* , by toughening the competitive selection process among foreign competitors, toughens the foreign competition that domestic firms face their domestic market (i.e. c_D falls), but softens the competition that domestic exporters face in the foreign market – thus increasing the cut-off of domestic exporters, c_X .

$$N_E^* = \frac{\mu(\kappa - \sigma + 1)c_M^\kappa (\sigma + v^* - 1)(\tilde{v} - \phi\rho) \left\{ L\phi\rho\sigma(\sigma + v - 1)(\tilde{v} - \phi\rho) + L^* \left[\sigma(\sigma + v - 1)(\tilde{v}\phi\rho - 1) + v\mu(1 - \phi^2\rho^2)(\sigma - 1) \right] \right\}}{\kappa f_D(1 + \phi\rho)(c_D^*)^\kappa (1 - \phi\rho) g(v, v^*, \sigma, \mu, \phi, \rho, \kappa)}.$$

Given that the function $g(v, v^*, \sigma, \mu, \phi, \rho, \kappa)$ in the denominator is common to both N_E and N_E^* , and

that we know from (18) that $(c_D^*)^\kappa = (c_D)^\kappa \left(\frac{1 - \phi\rho}{1 - \tilde{v}\phi\rho} \right)$, we derive the relative number of firms that enter

the domestic and the foreign markets as:

$$(20) \quad \frac{N_E}{N_E^*} = \frac{\left\{ L^* \phi\rho\sigma \left(\frac{1}{\tilde{v}} - \phi\rho \right) + L \left[\sigma \left(\frac{\phi\rho}{\tilde{v}} - 1 \right) + \frac{v^*}{(\sigma + v^* - 1)} \mu(1 - \phi^2\rho^2)(\sigma - 1) \right] \right\}}{\left\{ L\phi\rho\sigma(\tilde{v} - \phi\rho) + L^* \left[\sigma(\tilde{v}\phi\rho - 1) + \frac{v}{(\sigma + v - 1)} \mu(1 - \phi^2\rho^2)(\sigma - 1) \right] \right\}}.$$

3. THE EFFECTS OF TRADE LIBERALIZATION

In this Section, we discuss the effects produced by trade liberalization in the presence of asymmetries between countries. Specifically, we shall consider how a reduction in both variable and fixed costs of exporting affects the competitive selection process in the two countries when they differ in market size, as captured by differences in labour endowments, and in their labour market institutions, reflected by different bargaining power of unions.

3.1. A reduction in variable trade costs

3.1.1. Effects on cut-offs

When countries differ in size ($L \neq L^*$) and labour market institutions ($v \neq v^*$), a reduction of the variable cost of export (i.e. an increase in ρ) does not produce unambiguous effects on the domestic and foreign cut-offs, in contrast with what established by those contributions to the literature that focus on the case of symmetric countries. That is, while in the standard symmetric model *à la* Melitz (2003) with no unions, an increase in the freeness of trade ρ decreases c_D and increases c_X for both countries, with asymmetric countries this is not always true. These effects continue to hold only when the two countries have similar or equal levels of union bargaining power (even though they may differ in market size). Thus, a fall in variable trade costs is found to increase the domestic cut-off and reduce the export cut-off if the bargaining power of domestic unions is sufficiently large

relative to that of foreign unions (i.e. if $\tilde{\nu}$ is sufficiently small). Specifically, we find that $\frac{\partial c_D}{\partial \rho} > 0$

and $\frac{\partial c_X}{\partial \rho} < 0$ if:

$$(21) \quad \tilde{\nu} < \frac{2\phi\rho}{1+\phi^2\rho^2} \equiv \Omega < 1,$$

while the opposite holds true otherwise. Symmetrically, for the foreign country, it is easy to verify that $\frac{\partial c_D^*}{\partial \rho}$ is positive and $\frac{\partial c_X^*}{\partial \rho}$ is negative if:

$$(22) \quad \tilde{\nu} > \frac{1}{\Omega}$$

while the opposite holds true otherwise. Hence, following a process of integration that reduces variable trade costs, contrary to the symmetric case analysed in the literature, the domestic cut-off for the foreign country c_D^* increases and the foreign export cut-off c_X^* falls if ν is low relative to ν^* .

Clearly, these conditions are more likely to hold the larger is Ω . Given that Ω is increasing in both ρ and ϕ , then – for a given higher bargaining power of domestic unions relative to foreign unions – an increase in ρ is more likely to increase the domestic cut-offs c_D and c_D^* and reduce the export cut-off c_X and c_X^* when variable transport costs are low (i.e. ρ is large) and when the fixed cost of export is small (i.e. ϕ is large).¹⁴

These results are summarised in the following proposition:

Proposition 2: When variable and/or fixed trade costs are sufficiently low, for given differences between the two countries' labour market institutions, a trade liberalization resulting in a reduction in variable trade costs (i.e. an increase in ρ): **(i)** reduces the average productivity of domestic firms selling in the domestic market in the country with relatively stronger unions, while it increases it in that with relatively weaker unions, and **(ii)** increases the average productivity of exporting firms that operate in the country with relatively stronger unions, while it reduces it in that with relatively weaker unions.

The impact of a reduction in variable trade costs on the domestic cut-off, c_D , is determined by two main effects: an *import competition effect* and an *aggregate demand effect*. The former occurs

¹⁴ With imperfect integration (i.e. $f_X > f_D$ and $\rho < 1$), Ω is increasing in ρ from a minimum of 0 to a maximum of $\Omega(\phi = 1) = \frac{2\rho}{1+\rho^2} < 1$. With perfect integration, $\Omega = 1$.

because of an increase in the competitive pressure facing domestic firms, as the fall in trade costs makes it easier for foreign firms to penetrate the domestic market. As in the symmetric model, other things equal, the import competition effect works towards a reduction in c_D . The aggregate demand effect results from a reduction in the industry price index triggered by the fall in trade costs – that leads to an increase in the aggregate demand for the differentiated good; the resulting increase in firms’ revenue makes it easier for firms to cover their fixed production costs. This effects works towards an increase in c_D . Note that the import competition effect is weaker when trade integration is already high. At the same time, the aggregate demand effect is stronger, because of higher wages and hence income, when domestic unions have a high bargaining power. Thus, for sufficiently high values of ρ and ϕ and for sufficiently low values of \tilde{v} , the net effect of an increase in ρ on c_D is positive.

As in the standard symmetric model, an increase in ρ will work towards an increase of the export cut-off, c_X , via a *market access effect* which occurs because a reduction in variable trade costs makes it easier for domestic exporters to access foreign markets. An easier access to the foreign market, however, also exposes domestic exporters to a *competition effect* by indigenous firms in that market. This competition is tougher the higher is the relative bargaining power of domestic unions – which translates in higher wages, and hence in higher marginal costs and lower competitiveness, for exporting firms. This effect works towards a reduction in the export cut-off c_X . When trade integration is already high and the relative bargaining power of domestic unions is high, the net effect of an increase in ρ will then be to reduce c_X , as the market access effect is relatively weak and the cost effect of higher wages is relatively strong.

The same intuition applies to the effects of trade liberalisation on the trading partner’s cut-off. If trade is already sufficiently free and the country’s unions relative strength is high (conditions that for the foreign country are summarised by the inequality $\tilde{v} > \frac{1}{\Omega}$), then the effects of an increase in ρ leads to a relaxation of the competitive pressure on domestic firms (i.e. to an increase in the domestic cut-off, c_D^*) and to a tightening of competitive pressure on foreign exporters (i.e. to a reduction of the export cut-off c_X^*).

Table 1 summarizes our findings on the effects produced by an increase in the level of economic integration that results from a reduction in the level of the iceberg trade costs.

	$\tilde{v} < \Omega$	$\Omega < \tilde{v} < \frac{1}{\Omega}$	$\tilde{v} > \frac{1}{\Omega}$
If $\rho \uparrow$	$c_D \uparrow$ $c_X \downarrow$ $c_D^* \downarrow$ $c_X^* \uparrow$	$c_D \downarrow$ $c_X \uparrow$ $c_D^* \downarrow$ $c_X^* \uparrow$	$c_D \downarrow$ $c_X \uparrow$ $c_D^* \uparrow$ $c_X^* \downarrow$

Table 1. Effects of changes in ρ on the cut-offs (with $\Omega < 1$)

The central column of Table 1 shows that the traditional effects produced by trade liberalization in the case of symmetric countries still hold in the case of asymmetric countries when their relative difference in the bargaining power of unions is not very large (that is, when $\Omega < \tilde{v} < \frac{1}{\Omega}$). In this case, as in the specific case of symmetric labour market institutions (i.e. when $v = v^*$, which implies that $\tilde{v} = 1$), we obtain the results that apply in the standard case: when integration increases, the cut-offs for sales in the domestic market fall, while they increase for firms exporting to the foreign market – with standard competitive selection effects in action.

Differences in the labour market sizes of the two countries do not affect the way in which the cut-offs are influenced by the changes in the level of economic integration analyzed in this Section.

3.1.2. Effects on market structure

We now turn to examine the effects that an increase in ρ produces on the economies' market structures. Given that in the presence of inter-country asymmetries in market size and in labour market institutions, comparative statics on the equilibrium solutions is analytically unwieldy, we shall rely on numerical simulations. For ease of exposition, unless otherwise stated, in what follows we shall consider the case in which the home country is characterised by a higher relative bargaining power of unions (i.e. $\tilde{v} < 1$). To start with, unless otherwise stated, we shall also assume that the two countries are identical in size (i.e. $L = L^*$).

As for the industry cut-off points, the effects of trade liberalisation on market structure ultimately rest on the interplay between market access, competition, and aggregate demand effects. The relative magnitudes of these effects are affected by the degree of inter-country asymmetries in union strength and in market size, as well as by the initial level of trade openness.

Proposition 3: For given differences between the two countries' labour market institutions and for sufficiently high levels of integration (i.e. for large ρ and small f_x) in the country with stronger unions, a trade liberalization resulting in a reduction in variable trade costs (i.e. an

increase in ρ) tends to reduce: (i) the mass entrants, (ii) the mass of domestic firms producing for the domestic market, and (iii) the mass of exporters. In the country with weaker unions, an increase in ρ tends to increase: (i) the mass entrants, (ii) the mass of domestic firms producing for the domestic market, and (iii) the mass of exporters.

Other things equal, a relative higher bargaining power of domestic unions (by resulting in higher wages) weakens the competitive positions of the home country's firms vis-à-vis their foreign competitors. *Ceteris paribus*, in these circumstances, a reduction in variable trade costs will – by increasing the competitive pressure facing firms – work towards a reduction in the number of firms entering the domestic industry (N_E); this can be seen in Figure 1.¹⁵ Nevertheless, the sign of $\partial N_E / \partial \rho$ is not unambiguous. Specifically, in the country with the stronger unions, $\partial N_E / \partial \rho < 0$ is more likely to hold the higher the initial levels of trade openness (i.e. the larger is ρ), the lower the levels of fixed export costs, and the smaller the relative size advantage of the country (this can be seen in Figure 2). At large values of ρ , further trade liberalisation in the presence of a wage cost disadvantage due to stronger unions reduces N_E and may eventually result in firms only attempting entry in the country with the more liberal labour market (i.e. N_E can go to zero, as seen in Figure 1).¹⁶ However, this negative effect on entry of the lower competitiveness resulting from a high bargaining power of unions is mitigated, and can even be more than offset, by: (i) sufficiently low levels of trade openness (i.e. small values of ρ), (ii) a sufficiently large size of the domestic market relative to the foreign one, and (iii) sufficiently high level of export fixed cost. In these circumstances, entry *increases* with trade liberalization in the country which has the stronger unions when its size is larger; furthermore, the *level* of entry may also be higher than in its trading partner – that is, starting from a low level of integration, the larger and more unionised country will enjoy higher entry (i.e. $N_E > N_E^*$, as seen in Figure 3.a). When ρ is small, there is a high incidence of trade costs on consumer expenditure. In this case, the larger country will attract relatively more firms – as a result of a standard market access effect. This market access mechanism is reinforced, via an income effect, by the higher wages resulting from stronger unions; essentially, despite their negative impact on firms' price competitiveness, higher union power and wages combine with market access forces to generate a 'keynesian' type expansionary effect on aggregate demand that acts as a catalyst for industry. Clearly, if the difference in bargaining power becomes too large, then the negative effects of higher wages on firms' competitiveness will dominate. As a result, the

¹⁵ All Figures in this Section are drawn for the following values of the parameters: $\mu = 0.3$, $c_M = 3$, $\kappa = 2.5$, $\sigma = 2.4$, $f_f = 0.1$, $f_d = 0.1$, $L^* = 1000$ and $v^* = 0.3$. The values of the other parameters are given in the Figures.

¹⁶ In Baldwin and Forslid (2010) a similar 'delocation' effect results from differences in market size.

smaller is \tilde{v} the lower the level of economic integration at which this combined expansionary effect will occur, as illustrated by Figure 3.b. Other things equal, this expansionary effect will also be stronger the higher is the fixed cost of exports (as shown by the blue lines in Figures 3.a-b) – which effectively protects the domestic market.

Shifting the focus of analysis on to the number of *surviving* firms, we find that in the home country, where the bargaining power of unions is higher, the number of domestic firms selling in the domestic market (N_D) is monotonically decreasing in ρ (see Figure 4.a). Instead, in the less unionized foreign country, N_D^* first falls and then – as ρ increases – increases when the fixed export cost is low (see the black line in Figure 4.b). However, when the fixed export cost is high, N_D^* typically falls as ρ increases (see the blue line in Figure 4.b). This is robust to the degree of asymmetry in country size. Hence, contrary to the case analyzed by Baldwin and Forslid (2010) with no unions (where with identical market sizes trade liberalisation reduces the number of produced varieties in each country), in this paper a fall in trade costs can increase the number of produced varieties in the country that has a relative wage cost advantage due to weaker unions. However, for sufficiently low levels of trade openness, despite the fact that trade liberalisation reduces the number of firms producing in the domestic market in the country with stronger unions, this country will have a larger population of firms than its trading partner – i.e. the ratio N_D/N_D^* is greater than one at sufficiently low values of ρ (Figure 5.a). If trade is very open, instead, the less unionized country will have a larger population of firms – even when it has a smaller size. Hence, the effect of market size does not offset the competitive disadvantage of a higher wage when the competitive pressure from trade is strong. Thus, N_D/N_D^* can be non-monotonic in ρ : it is greater than one at low levels of ρ and falls to below one for sufficiently large values of ρ .¹⁷ The ‘turning point’ (i.e. the value of ρ at which N_D become smaller than N_D^*) will occur at lower values of ρ the higher is the relative strength of domestic unions (see dotted lines in Figure 5.a). The existence of differences in country size increases the level of ρ at which N_D/N_D^* falls below one (to see this, compare Figure 5.a with Figure 5.b where countries have the same size). This is consistent with the intuition that a larger country size offsets to some extent the adverse effects of a higher union power.

To summarize: the country with more powerful unions has a competitive disadvantage that works towards a smaller number of domestic firms surviving in the economy. However, if the country is sufficiently protected from international competition, other things equal, the number of firms in this economy will be higher than that in the less unionized country; we have explained this

¹⁷ If the fixed export cost is sufficiently large, then N_D/N_D^* is more likely to be monotonically increasing in ρ (Figure 5.a).

as a kind of expansionary market size effect (with higher wages translating into a higher aggregate demand for this good that facilitates survival). If the fixed cost of export is sufficiently low, N_D/N_D^* falls as trade liberalization increases (and ρ gets bigger). In this case, it will eventually fall below one. This will occur at lower levels of ρ , for increasing levels of asymmetries in the bargaining of unions. If countries are asymmetric in size, then N_D/N_D^* will become smaller than one at higher levels of ρ – as a larger market size protects domestic firms from international competition despite the higher bargaining power of unions (and the wage that firms pay).

The number of exporters, N_x , first grows and then falls in ρ for the country with the stronger unions; the larger the fixed export cost, the higher the level of ρ at which the ‘turning point’ occurs – for sufficiently high levels of f_x , the number of exporters is always growing in ρ (Figure 6.a). This is consistent with the fact that the export cut-off can first grow and then fall in ρ (i.e. increases in ρ make it easier to export at sufficiently low levels of trade liberalization). Note however, that the switch in sign of $\partial c_x/\partial\rho$ (in Figure 6.b) can occur at higher levels of $\partial N_x/\partial\rho$.¹⁸ Hence, even at levels of trade liberalization at which increases in ρ continue to reduce the minimum efficiency required to be able to export, the actual number of firms that will do so starts reducing – as if ρ is sufficiently low, the competitive pressure resulting from the increase in the number of foreign competitors dominates the minimum efficiency effect. On the other hand, we find that the number of exporters increases monotonically in ρ for the country with the lower bargaining power of unions – even when this country is smaller (Figure 7.a). Indeed, the absolute number of exporters in this country is larger than in the one with the stronger unions (Figure 7.b). This seems to be robust to different parameters combinations, and is due to the fact that a lower bargaining power translates – other things equal – into a higher competitiveness of firms.

The total number of varieties M bought by a consumer in the country with stronger unions usually decreases in ρ (as in the traditional case with no unions and equal labour supply). However, when the country has a very high relative bargaining power of unions – and hence a ceteris paribus large wage cost disadvantage – trade liberalisation will lead to a relatively large increase in the mass of imported varieties and hence to an overall expansion in the product variety available to consumers; this effect will be particularly strong at low levels of export costs. In these circumstances, trade liberalisation can lead to a *pro-variety* effect with an overall increase in M – even if the two countries are symmetric in size,¹⁹ as shown in Figure 8. When the level of trade

¹⁸ This holds for small differences in L (continuous line in Figure 6.a).

¹⁹ This result differs from that obtained by Baldwin and Forslid (2010) where, with no unions, symmetry between countries results in the number of varieties available to consumers falling monotonically as the freeness of trade increases.

openness is sufficiently large, this pro-variety effect typically also applies to the country with weaker unions, regardless of its relative size.²⁰

In summary, the pro-variety effect of trade liberalization – characterising Krugman's (1980) original contribution with homogeneous firms and also found in Melitz and Ottaviano (2008) with heterogeneous firms, but absent from Melitz's (2003) model – can emerge not only when monopolistic firms are interconnected by vertical linkages (Nocco, 2010), or in the larger country when countries are asymmetric in size (Baldwin and Forslid, 2010), but also in a small country when its unions are weaker than those in the trading partner.

Our simulations show that the price index is always decreasing in the level of trade openness (Figure 9), thus implying that the typical result of trade liberalisation leading to higher real wages holds in this framework. Moreover, regardless of the initial levels of trade costs, the price index tends to be smaller in the larger country, even if this is the one with stronger unions, because it is characterized by a larger number of varieties bought by consumers.

In terms of average firm size, given in expression (A.7) in the Appendix, the country with the lower bargaining power of unions has a higher average size of firms operating in the domestic market (i.e. the average is over both domestic and exporting firms) at all levels of integration and even when country size differences (in favour of the country with the stronger union) are very large. So whilst a larger country compensates the effects of a strong union in terms of the extensive margin, it does not do so in terms of the intensive margin. Additionally, if ρ increases, the average quantity produced falls at sufficiently high values of ρ in the more unionized country, provided that the difference in union bargaining power is sufficiently large. On the contrary, the average size of exporters is larger in the relatively more unionized country at all levels of openness. The intuition for this is that, in order to be able to export, in the more unionized country firms need to be more efficient in order to be able to offset the effects of a higher wage – which is consistent with the fact that the cut-off c_X falls in v . For both countries, the average size of an exporter falls in ρ and differences in country size do not alter this result.

3.2. A reduction in fixed trade costs

We now examine the effects on the cut-offs of a trade liberalization consisting in a fall in the fixed cost of exports; a reduction in f_X can be thought of, for instances, as resulting from an international harmonisation of product standards and regulations that might reduce the adaptation and other costs

²⁰ In the absence of unions, as shown by Baldwin and Forslid (2010), the pro-variety effect would only emerge for the larger nation when trade barriers are at intermediate levels, and never for the smaller country. In our case it can materialize also for the smaller country when its unions are weaker and the level of openness is sufficiently high because, in this case, this country will have a larger population of firms (i.e. $N_D/N_D^* < 1$) despite its smaller size.

associated with the introduction of foreign produced varieties into a market. The effects of this type of liberalisation are summarized in Table 2 below. The first row of Table 2 shows that the impact on domestic cut-offs are qualitatively the same as those generated by increases in ρ . More specifically, we find that the sign of $\frac{\partial c_D}{\partial f_X}$ is positive (i.e. a reduction in f_X reduces c_D) if:

$$(23) \quad \tilde{v} > \Omega$$

while the sign of $\frac{\partial c_D^*}{\partial f_X}$ is positive if:

$$(24) \quad \tilde{v} < \frac{1}{\Omega}$$

	$\tilde{v} < \Omega$	$\Omega < \tilde{v} < \frac{1}{\Omega}$	$\tilde{v} > \frac{1}{\Omega}$
	$c_D \uparrow$	$c_D \downarrow$	$c_D \downarrow$
	$c_D^* \downarrow$	$c_D^* \downarrow$	$c_D^* \uparrow$
If $f_X \downarrow$	$\tilde{v} < \Theta$	$\Theta < \tilde{v} < \frac{1}{\Theta}$	$\tilde{v} > \frac{1}{\Theta}$
	$c_X \downarrow$	$c_X \uparrow$	$c_X \uparrow$
	$c_X^* \uparrow$	$c_X^* \uparrow$	$c_X^* \downarrow$

Table 2. Effects of changes in f_X on the cut-offs (with $\Omega < 1$ and $\Theta < 1$)

As for the case of a reduction in variable trade cost, the impact of a reduction in fixed export cost on the domestic cut-off c_D is determined by two main effects: an import competition effect and an aggregate demand effect. The former occurs because foreign exporters find it easier to penetrate the domestic market – thus increasing the competitive pressure on domestic firms. This effect works towards a reduction in c_D . The aggregate demand effect results from a reduction in the industry price index triggered by the growth of the number of imported varieties, that leads to an increase in the aggregate demand for the differentiated good; the resulting increase in firms' revenue makes it easier for firms to cover their fixed production costs. This effects works towards an increase in c_D .

As before, the import competition effect is weaker when trade integration is already high. At the same time, the aggregate demand effect is stronger when domestic unions have a high bargaining power. Thus, for sufficiently high values of ρ and ϕ and for sufficiently low values of \tilde{v} , the net effect of an increase in f_x on c_D is positive.

However, the parameter ranges over which the effects of a reduction in f_x on the cut-offs facing exporting firms are qualitatively similar to those resulting from an increase in ρ differ.

Specifically, the sign of $\frac{\partial c_x}{\partial f_x}$ is positive when:

$$(25) \quad \tilde{v} < \Theta \equiv \rho\phi \frac{\left(2\frac{\kappa}{1-\sigma} + 1\right) + \rho^2\phi^2}{\frac{\kappa}{1-\sigma} + \left(\frac{\kappa}{1-\sigma} + 2\right)\rho^2\phi^2} \quad \text{with } \Theta < 1,$$

and that of $\frac{\partial c_x^*}{\partial f_x}$ is positive when

$$(26) \quad \tilde{v} < \frac{1}{\Theta}.$$

Both $\frac{\partial c_x}{\partial f_x}$ and $\frac{\partial c_x^*}{\partial f_x}$ are negative when the opposite inequalities hold.

The effects of reductions in f_x on market structure are broadly qualitatively similar to those of increases in ρ . Specifically, we find that the number of entrants, N_E , in the more unionized country does not monotonically fall with reductions in f_x : when variable trade costs are sufficiently large, N_E can increase if the inter-country difference in union power is not too large – i.e. if the country does not have too strong a competitive disadvantage due to higher wages – and the more unionized country is sufficiently larger than its trading partner (as illustrated in Figure 11). So, qualitatively, the effects of liberalization on N_E are the same regardless of the type of liberalization.

As discussed in the previous subsection, there is an interaction between the two forms of trade barriers: high levels of one can offset the effects of reductions in the other. For instance, for sufficiently low values of ρ , N_E/N_E^* is more likely to be above one for given values of f_x the larger is the domestic country (with stronger unions) relative to the foreign one (Figure 12). When the two countries are identical in size, N_E/N_E^* tends to be smaller than one – i.e. the less competitive country is more likely to have a smaller number of entrants – and N_E/N_E^* decreases when f_x decreases. As before, the intuition is that a larger market can offset the negative effects on entry of higher wages.

The relative number of domestic firms selling in the domestic market with respect to that surviving in the other country, N_D/N_D^* , is first increasing and then decreasing in f_X when the home country is characterised by a higher bargaining power of unions (this can be seen in Figure 13). This happens when inter-country difference in labour force and in bargaining power are large (consistent with the case of liberalization resulting from a reduction in ρ). When the countries are symmetric in their size, N_D/N_D^* is always increasing in f_X and becomes greater than one for sufficiently large values of f_X . This is more likely the lower value is ρ , i.e. when variable trade costs are low. Hence, when countries are symmetric in their size, the number of domestic firms becomes larger than that operating in the foreign markets the higher the degree of protection (via f_X and/or ρ) that the country has from foreign competition. Trade barriers offset the negative impact of stronger unions (and higher wages) on the number of firms surviving in the more unionized country.

Moreover, we find that N_X/N_X^* is increasing in f_X , but it is always below 1 even when ρ is low, consistent with the case of liberalization resulting from a reduction in ρ .

Finally, the total number of firms M operating in the domestic market (including foreign exporters) first falls and then increases with reductions in f_X . The fixed export cost influences the number of exporters more directly than changes in ρ . At high levels of fixed costs, the effect of a fall in fixed cost is dominated by the reduction in domestic varieties. When fixed costs of export are already low, the effect of further reductions in f_X on the mass of varieties available to consumers is dominated by the large inflow of imports (that more than offsets the fall in domestic varieties). However, as we saw, this non-monotonicity of M can also occur with respect to increases in ρ for the country with the higher bargaining power of unions when fixed export costs are low. So, qualitatively, the effects of trade liberalization on M are the same regardless of the type of liberalization.

4. REAL WAGES

In this Section, we study the effects produced by changes of the bargaining power of unions (v) on real wages in the monopolistic sector, given by:

$$(27) \quad \frac{w_m}{P^\mu} = \frac{1 + \frac{v}{\sigma - 1}}{P^\mu}$$

Substituting the expression for the price index P from expression (A.1) derived in the Appendix into (27) we obtain:

$$(28) \quad \frac{w_m}{P^\mu} = \frac{\left(1 + \frac{v}{\sigma-1}\right)^{1-\mu} (c_D)^\mu \left(\frac{\kappa}{\sigma-1}\right) \left\{ N_E + \rho \left(\frac{1 + \frac{v}{\sigma-1}}{1 + \frac{v^*}{\sigma-1}} \right)^\kappa \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} N_E^* \right\}^{\frac{\mu}{\sigma-1}}}{\left(\frac{\kappa}{c_M^\kappa} \frac{1}{\kappa - \sigma + 1} \right)^{\frac{\mu}{1-\sigma}} \left(\frac{\sigma}{\sigma-1} \right)^\mu}$$

The three factors in the numerator of (28) are all affected by changes in v . More specifically, while an increase in v unambiguously increases the first two factors, its effect on the third is more difficult to assess given that it depends on the number of firms entering both markets (N_E and N_E^*).

Given the complexity of the algebra, in order to establish analytically the redistributive effects produced by changes of v on the welfare level of workers, we shall limit the analysis to the case of symmetric countries. In this case, the real wage of workers employed in the monopolistic sector given in expression (28) can be rewritten as:

$$(29) \quad \frac{w_m}{P^\mu} = \frac{\left(1 + \frac{v}{\sigma-1}\right)^{1-\mu} (c_D)^\mu \left(\frac{\kappa}{\sigma-1}\right) \left\{ 1 + \rho \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} \right\}^{\frac{\mu}{\sigma-1}} N_E^{\frac{\mu}{\sigma-1}}}{\left(\frac{\kappa}{c_M^\kappa} \frac{1}{\kappa - \sigma + 1} \right)^{\frac{\mu}{1-\sigma}} \left(\frac{\sigma}{\sigma-1} \right)^\mu},$$

which depends on the number of entrants and on the domestic cut-off. These are given respectively by:

$$(30) \quad N_E = \frac{\mu L}{\kappa f_I} \frac{(\sigma-1+v)}{\left[\sigma + v \left(\frac{\sigma}{\sigma-1} - \mu \right) \right]}$$

and, from (18):

$$c_D = c_M \left\{ \frac{f_I}{f_D} \frac{\left(\frac{\kappa}{\sigma-1} - 1 \right)}{\left[1 + \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} \rho \right]} \right\}^{\frac{1}{\kappa}},$$

which shows that there is no effect of the level of the bargaining power of unions, v , on the domestic cut-off level. It can be readily seen from expression (30) that: $\frac{\partial N_E}{\partial v} > 0$. It then follows that, in the case of symmetric countries, an increase in v unambiguously increases the real wage of workers employed in the monopolistic sector.

It is also easy to verify that, with symmetric countries, an increase in v unambiguously lowers the real wage of workers employed in the competitive sector, which by making use of (10), (29) and (30), can be rewritten as:

$$(31) \quad \frac{w_c}{P^\mu} = \frac{1}{P^\mu} = \frac{w_m}{P^\mu \left(1 + \frac{v}{\sigma-1}\right)} = \frac{\left\{ \left(\frac{1}{f_D}\right)^{\frac{\kappa}{\sigma-1}-1} \left[1 + \left(\frac{f_D}{f_X}\right)^{\frac{\kappa}{\sigma-1}-1} \rho \right] \right\}^{\frac{\mu}{\kappa}} \left[\mu L \frac{\left(1 + \frac{v}{\sigma-1}\right)}{\sigma + v \frac{\sigma(1-\mu) + \mu}{\sigma-1}} \right]^{\frac{\mu}{\sigma-1}}}{\left[\frac{\sigma}{\sigma-1} \left(1 + \frac{v}{\sigma-1}\right) \right]^\mu}.$$

Finally, from expressions (31), it is straightforward to see that, under symmetry, an increase in the degree of economic integration (regardless of whether it is produced by a reduction in the level of variable or fixed trade costs) unambiguously increases the real wages of workers employed in both sectors.

5. CONCLUSIONS

In this paper we have developed an international trade model in which firms in the imperfectly competitive sector are heterogeneous and face unionised labour markets. We highlight the interaction of openness to trade, unions' bargaining power, and country asymmetries in affecting the process of competitive selection within industries.

For given levels of international openness, an increase in a country's unions' strength reduces the productivity cut-off facing domestic producers (thus lowering their average productivity) and increases that of exporters (thus raising their average productivity) – regardless of the relative size of countries. Trade liberalisation is shown to affect both extensive and intensive margins of export via the emergence of market access, competition, and aggregate demand effects whose magnitude depends on the initial level of openness to trade as well as on the degree of inter-country asymmetries in labour market institutions and size. *Ceteris paribus*, a relatively high bargaining power of unions in a country will translate in higher wages and thus weaken its firms' competitive position vis-à-vis that of their competitors. However, the higher wages will lead, other things equal,

to a higher aggregate demand and thus reinforce standard market access mechanisms (stemming from the existence of trade barriers) by giving rise to aggregate income effects. When the initial levels of trade openness are sufficiently low, this ‘expansionary’ aggregate effect can attract industry in the country with stronger unions and also result in an increase in the extensive margin of exports. For sufficiently large inter-country differences in the bargaining power of unions, trade liberalization can result in a *pro-variety* effect, with an increase in the total availability of varieties to consumers, in both countries – regardless of there being inter-country differences in size.

With respect to the (average) intensive margin of export we find it falls as a result of trade liberalisation, but that is larger in the relatively more unionized country at all levels of openness.

APPENDIX

Making use of (11) and the Pareto distribution in the aggregate price index of the differentiated good in the home country in (3), we obtain:

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \left[\left(1 + \frac{v}{\sigma-1} \right)^{1-\sigma} N_D \int_0^{c_D} c^{1-\sigma} \kappa \frac{c^{\kappa-1}}{(c_D)^\kappa} dc + \tau^{1-\sigma} \left(1 + \frac{v^*}{\sigma-1} \right)^{1-\sigma} N_X^* \int_0^{c_X^*} c^{1-\sigma} \kappa \frac{c^{\kappa-1}}{(c_X^*)^\kappa} dc \right]$$

which, using (17) can be rewritten as:

$$P^{1-\sigma} = \kappa \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \frac{1}{\kappa-\sigma+1} (c_D)^{1-\sigma} \left(1 + \frac{v}{\sigma-1} \right)^{1-\sigma} \left[N_D + N_X^* \left(\frac{f_X}{f_D} \right) \right].$$

Further substitution of $N_D = G(c_D)N_E = \frac{(c_D)^\kappa}{c_M^\kappa} N_E$ and $N_X^* = G(c_X^*)N_E^* = \frac{(c_X^*)^\kappa}{c_M^\kappa} N_E^*$ into this expression, yields:

$$(A.1) \quad P^{1-\sigma} = \frac{\kappa}{c_M^\kappa} \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \frac{1}{\kappa-\sigma+1} (c_D)^{\kappa+1-\sigma} \left(1 + \frac{v}{\sigma-1} \right)^{1-\sigma} \left\{ N_E + \tau^{-\kappa} \frac{1}{\tilde{v}} \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} N_E^* \right\}.$$

The total income of the home country is: $I = L_c + w_m L_m$. Given that $L_c = L - L_m$, this can be rewritten as: $I = L + (w_m - 1)L_m$. Making use of this and (A.1), the home country's income in (14) can then be rewritten as:

$$(A.2) \quad \mu \left[L + (w_m - 1)L_m \right] = f_D \sigma \frac{\kappa}{c_M^\kappa} \frac{1}{\kappa-\sigma+1} (c_D)^\kappa \left\{ N_E + \tau^{-\kappa} \frac{1}{\tilde{v}} \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} N_E^* \right\}$$

Then, we can make use of (9) together with (15) and the wage in (10) to find that the amount of labour employed by firm i to produce for the local and the foreign market is respectively given by:

$$(A.3) \quad l_{mD}(i) = \frac{\sigma-1}{1+\frac{v}{\sigma-1}} f_D \left(\frac{c_D}{c(i)} \right)^{\sigma-1} \quad \text{and} \quad l_{mX}(i) = \frac{\sigma-1}{1+\frac{v}{\sigma-1}} f_X \left(\frac{c_X}{c(i)} \right)^{\sigma-1}$$

The expressions in (A.3) can then be used to compute the average labour quantities employed by firms to produce respectively for the domestic and the foreign markets:

$$(A.4) \quad \bar{l}_{mD} = \frac{\sigma-1}{\left(1+\frac{v}{\sigma-1}\right)} \frac{f_D \kappa}{\kappa-\sigma+1} \quad \text{and} \quad \bar{l}_{mX} = \frac{\sigma-1}{\left(1+\frac{v}{\sigma-1}\right)} \frac{f_X \kappa}{\kappa-\sigma+1}$$

Hence, given that $N_X = \frac{(c_X)^\kappa}{c_M^\kappa} N_E = \frac{\left[c_D^* (\tau)^{-1} \left(\frac{f_X}{f_D} \right)^{\frac{1}{1-\sigma}} \right]^\kappa}{c_M^\kappa} N_E$, and making use of (A.4) we

can rewrite the level of labour employment in the manufacturing sector, L_m^j , as follows:

$$L_m = \bar{l}_{mD} N_D + \bar{l}_{mX} N_X = \left\{ f_D (c_D)^\kappa + f_X \left[c_D^* \tau^{-1} \left(\frac{f_X}{f_D} \right)^{\frac{1}{1-\sigma}} \right]^\kappa \right\} \tilde{v} \left\{ \frac{(\sigma-1) \left(\frac{\kappa}{\kappa-\sigma+1} \right) N_E}{c_M^\kappa \left(1 + \frac{v}{\sigma-1} \right)} \right.$$

Finally, substituting L_m from the previous expression into (A.2), we obtain that, for the home country:

(A.5)

$$\mu \left\{ L + \frac{v \left(\frac{\kappa}{\kappa-\sigma+1} \right) \left[f_D (c_D)^\kappa + f_X (c_D^*)^\kappa \tau^{-\kappa} \tilde{v} \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}} \right] N_E}{c_M^\kappa \left(1 + \frac{v}{\sigma-1} \right)} \right\} = f_D \sigma \frac{\kappa (c_D)^\kappa}{c_M^\kappa} \left[\frac{N_E + \tau^{-\kappa} \frac{1}{\tilde{v}} \left(\frac{f_X}{f_D} \right)^{\frac{\kappa}{1-\sigma}+1} N_E^*}{k - \sigma + 1} \right]$$

This expression together with the analogous expression for the foreign country forms a system of two equations in two unknowns, N_E and N_E^* .²¹

Finally, we can use (A.3) and (4) to write:

$$(A.6) \quad q_D(i) = \frac{l_{mD}(i)}{c(i)} = \frac{\sigma-1}{1+\frac{v}{\sigma-1}} f_D (c_D)^{\sigma-1} \frac{1}{(c(i))^\sigma} \quad \text{and} \quad q_X(i) = \frac{l_{mX}(i)}{c(i)} = \frac{\sigma-1}{1+\frac{v}{\sigma-1}} f_X (c_X)^{\sigma-1} \frac{1}{(c(i))^\sigma},$$

and find that the average output per-firm for the domestic market, \bar{q}_D , and for the foreign market, \bar{q}_X , are respectively given by:

²¹ To solve this system, we rewrite c_D^* as a function of c_D , so that the solutions are expressed only in terms of c_D .

$$(A.7) \quad \bar{q}_D = \frac{\sigma-1}{\left(1+\frac{v}{\sigma-1}\right)} \frac{f_D \kappa}{(\kappa-\sigma)c_D} \quad \text{and} \quad \bar{q}_X = \frac{\sigma-1}{\left(1+\frac{v}{\sigma-1}\right)} \frac{f_X \kappa}{(\kappa-\sigma)c_X}.$$

Note that both average quantities are negatively related to the respective cut-offs and require, to be positive, that $\kappa > \sigma$.

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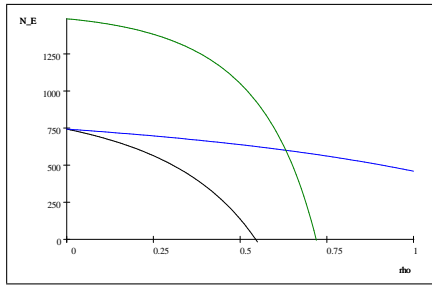


Figure 1. N_E
 $v = 0.7$
 Black line: $f_X = 0.2$ and $L = 1000$
 Blue line: $f_X = 0.8$ and $L = 1000$
 Green line: $f_X = 0.2$ and $L = 2000$

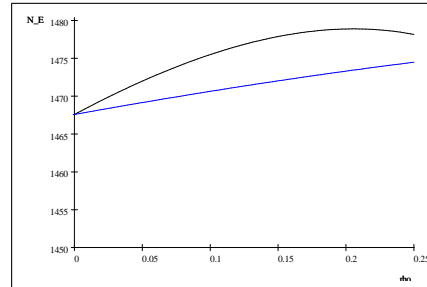


Figure 2. N_E
 $L = 2000, v = 0.5$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

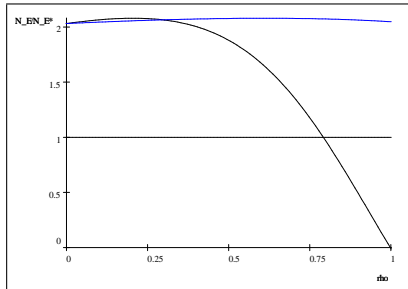


Figure 3.a. N_E / N_E^*
 $L = 2000, v = 0.5$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

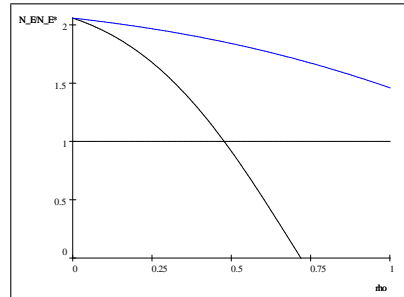


Figure 3.b. N_E / N_E^*
 $L = 2000, v = 0.7$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

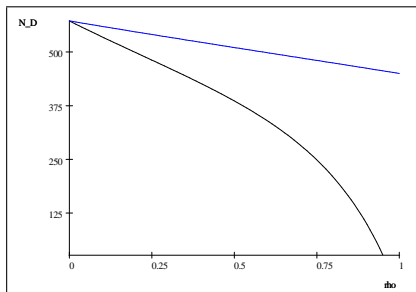


Figure 4.a. N_D
 $L = 1000, v = 0.4$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

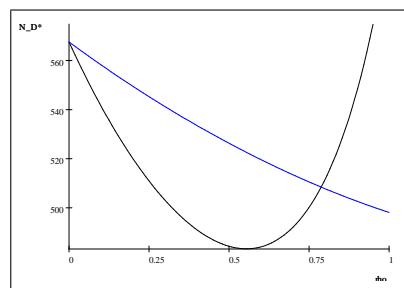


Figure 4.b. N_D^*
 $L = 1000, v = 0.4$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

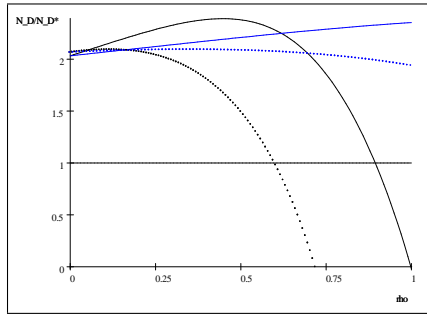


Figure 5.a. N_D/N_D^*
 $L = 2000$
 — $v = 0.5$ vs ... $v = 0.7$
 Black lines: $f_X = 0.2$
 Blue lines: $f_X = 0.8$

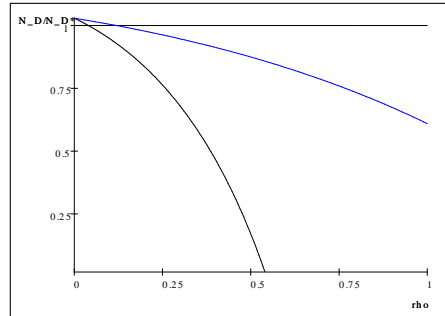


Figure 5.b. N_D/N_D^*
 $L = 1000$
 $v = 0.7$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

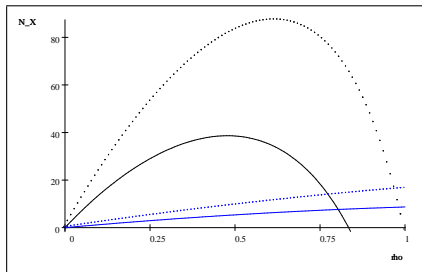


Figure 6.a. N_X
 $v = 0.5$
 — $L = 1200$ vs ... $L = 2000$
 Black lines: $f_X = 0.2$
 Blue lines: $f_X = 0.8$

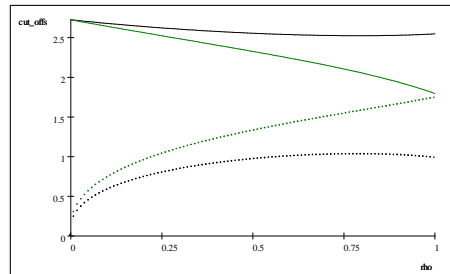


Figure 6.b. c_D, c_D^*, c_X, c_X^*
 $v = 0.5$

Black lines: domestic c_D (—) and c_X (...)
 Green lines: foreign c_D^* (—) and c_X^* (...)

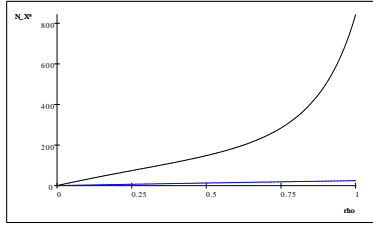


Figure 7.a. N_X^*
 $L = 2000, v = 0.5$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

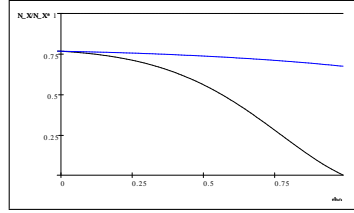


Figure 7.b. N_X/N_X^*
 $L = 2000, v = 0.5$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

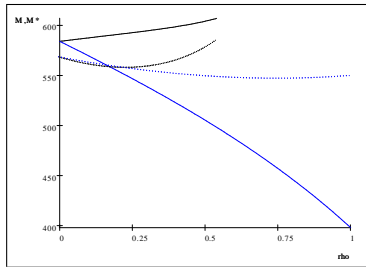


Figure 8. M (—) and M^* (...)
 $L = 1000, v = 0.7$
 Black line: $f_X = 0.2$
 Blue line: $f_X = 0.8$

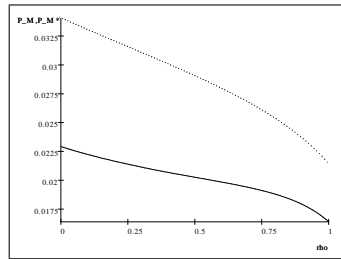


Figure 9. P_M and P_M^*
 $L = 2000, v = 0.5, f_X = 0.2$
 Continuous line: P_M
 Dotted line: P_M^*

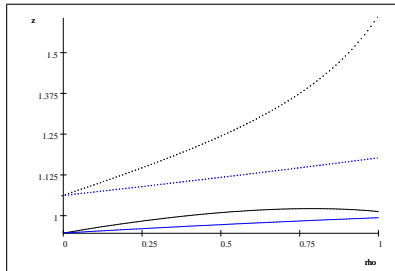


Figure 10.a. \bar{q}_D and \bar{q}_D^*
 $v = 0.5$
 — \bar{q}_D vs ... \bar{q}_D^*
 Black lines: $f_X = 0.2$
 Blue lines: $f_X = 0.8$

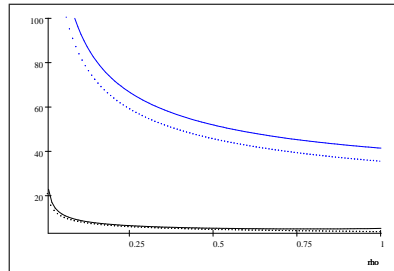


Figure 10.b. \bar{q}_X and \bar{q}_X^*
 $v = 0.5$
 — \bar{q}_X vs ... \bar{q}_X^*
 Black lines: $f_X = 0.2$
 Blue lines: $f_X = 0.8$

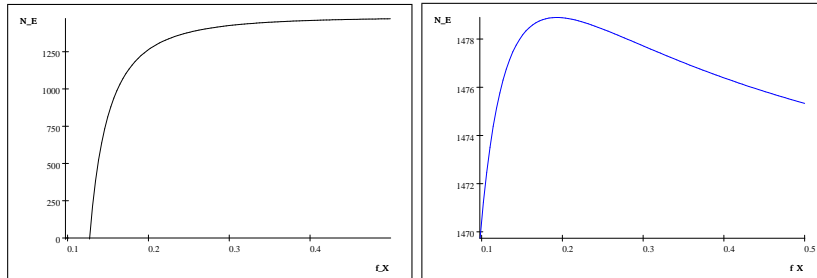


Figure 11. N_E
 $L = 2000, v = 0.5$
 Black line: $\rho = 0.7$
 Blue line: $\rho = 0.2$

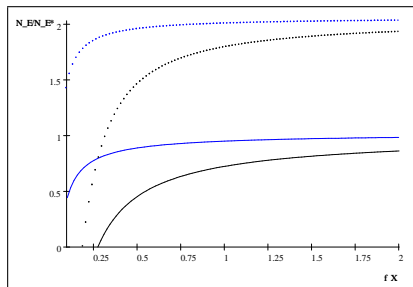


Figure 12. N_E/N_E^*
 $v = 0.7$
 — $L = 1000$ vs ... $L = 2000$
 Black lines: $\rho = 0.7$
 Blue lines: $\rho = 0.2$

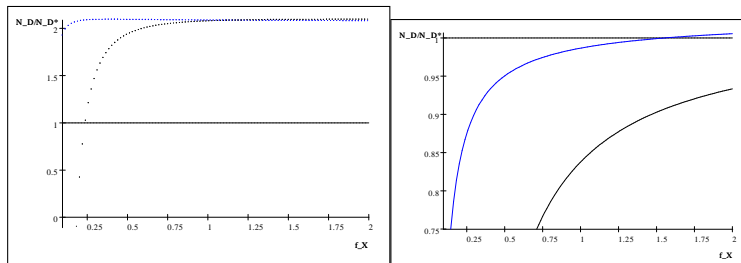


Figure 13. N_D/N_D^*
 $v = 0.7$
 — $L = 1000$ vs ... $L = 2000$
 Black lines: $\rho = 0.7$
 Blue lines: $\rho = 0.2$