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Three Essays in Spatial Economics

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Contents

Contents i

Overview v

1 Urban Functional Specialization and the Interplay between Firm's Communication Costs. 1

1.1 Introduction . . . 2

1.2 The model . . . 7

1.2.1 Preferences . . . 7

1.2.2 City structure . . . 8

1.2.3 Technology . . . 9

1.3 City formation . . . 13

1.4 Urban configurations and the interplay between communication costs . . . 16

1.4.1 Communication costs' thresholds . . . 16

1.4.2 Discussion . . . 18

1.5 Concluding remarks . . . 25

Appendices

1.A Break even conditions . . . 27

1.B Land developer's maximisation problem . . . 28

1.C City sizes (Proof of Lemma 2) . . . 31

1.C.1 Case (b) . . . 31

1.C.2 Case (e) . . . 32

1.C.3 Case (f) . . . 33

1.D Thresholds (Proof of Proposition 1) . . . 33

1.D.1 From spatial configuration 1 to 2 . . . 33

1.D.2 From spatial configuration 1 to 3 . . . 35

1.D.3 From spatial configuration 3 to 4 . . . 36
1.D.4 From spatial configuration 2 to 4 . . . 37

2 Trade Liberalisation between Asymmetric Countries with Environmentally Concerned Consumers 39
2.1 Introduction . . . 40
2.2 The model . . . 43
2.2.1 Autarkic equilibrium . . . 44
2.2.2 The free trade equilibrium . . . 45
2.2.3 Trade liberalisation effects . . . 46
2.3 Trade policy . . . 49
2.3.1 Import Tariff . . . 49
2.3.2 Subsidisation and trade reversal . . . 52
2.3.3 Discussion . . . 56
2.4 The larger country is brown . . . 58
2.4.1 Trade liberalisation effects . . . 59
2.5 Concluding remarks . . . 60

Appendices
2.A Autarky and free trade . . . 63
2.A.1 Equilibrium magnitudes . . . 63
2.A.2 Proof of Proposition 1 . . . 63
2.A.3 Proof of Proposition 2 . . . 64
2.A.4 Proof of Proposition 7 . . . 64
2.B Trade policy . . . 65
2.B.1 Equilibrium magnitudes . . . 65
2.B.2 Optimal tariff, other effects . . . 66
2.B.3 Sub-optimal tariff . . . 67
2.B.4 Proof of Proposition 6 . . . 68
2.C The effects of trade liberalisation with different trade policies . . . 68

3 Trade Costs, FDI Incentives, and the Intensity of Price Competition 71
3.1 Introduction . . . 72
3.2 The model . . . 73
3.3 Results . . . 73
3.4 Concluding remarks . . . 78

Bibliography **79**

Overview

This doctoral thesis contributes to the field of spatial economics in that it addresses three research questions which are naturally interrelated with the geographical dimension of the economic space. This research will address these questions from a theoretical point of view where some policy prescriptions will also be outlined. To this regard, it embraces three distinct modelling approaches, belonging to different strands of the theoretical literature.

The first chapter of the present work deals with the theory of systems of cities, focusing, in particular, on the degree of functional specialisation that the latters may attain in equilibrium, in the light of Duranton and Puga (2005). With regards to this, my purpose is to rationalise the existence of regional capitals, which are generally medium-size cities, and cannot be properly defined as global cities hosting sophisticated/advanced business services sectors, nor as purely manufacturing cities. The idea is that the reasons for the emergence of this urban typology may be found in the joint decreasing dynamic of two types of communication cost: the cost of managing production at distance and the cost of buying/providing business service at distance, both formally borne by the firms' headquarters facilities. According to this, I present a theoretical model in which the changes in urban system's degree of functional specialisation are linked to (i) firms' organisational choices, since firms decide whether splitting into headquarter and production plant or remaining integrated in a single establishment, and to (ii) firms' location decision with regards to the proximity with the tradable advanced business services providers. I model two types of communication costs, one between headquarters and advanced tradable business services providers (ABS) and one between headquarters and production plants. The interplay between the two types of communication costs is shown to have effects on the transition process from an "integrated" urban system where each city hosts every different functions to a "functionally specialised" urban system where each city is either a primary business center (hosting advanced business services providers, a secondary business center or a pure manufacturing city and all this city-types coexist in equilibrium.

In particular, I find that (i) maximum functional specialisation of the urban system turns out to be feasible only if firms face a very high share of the total costs represented by their heaquarter spending, (ii) in most of the cases the maximum functional specialisation can be reached only if the economy is already partially specialised, that is, already encompassing for primary business centers (iii) a non-linear substitution effect between communication costs: when the extra cost associated to buying advanced business services at distance is sufficiently low, the spatial separation between firms' headquarters and production plants is more likely to occur.

As to the theoretical side, this first line of research properly belongs to classical urban economics, where the inner space of the city is modelled in order to accounting for agglomeration and dispersion forces, which lead to city formation and determine the equilibrium size of cities. In particular, commuting costs, and land rent, which constitute the relevant variables of the inner city's spatial dimension are the sole to be explicitly accounted for into the model. As a consequence, this general equilibrium framework does not encompass for trade cost and the final good's market is assumed to be perfectly competitive.

The remaining chapters are concerned with the theory of international trade in which the spatial component is essentially represented by trade/transport costs.

In particular, the second chapter investigates the impact of free trade on welfare in a two-country world modelled as an international Hotelling duopoly with quadratic transport costs and asymmetric countries, where a negative environmental externality is associated with the consumption of the good produced in the smaller country. Countries' relative sizes as well as the intensity of negative environmental externality affect potential welfare gains of trade liberalisation. In line with Lambertini (1997a) we show that, as long as no trade policy is undertaken by the government of the larger country, trade liberalisation is not feasible since the latter always loses from opening to trade. A subsidy policy in favour of the firm producing the clean good is, on the contrary, shown to give both countries the right incentives to liberalise trade. Allowing for redistributive transfers between countries further extends the parametric range for which trade liberalisation is feasible under the subsidy scheme. The alternative situation, in which the green firm is based in the larger country, is also briefly sketched to find that free trade does give rise to a global welfare increment with no need of accompanying trade policies.

The third chapter focuses on the paradox, recently underlined by Collie (2011), by which, contrary to theoretical predictions, empirical evidence shows that an increase in trade liberalisation (i.e. a decrease in international transport costs) causes an increase in foreign direct investments (FDIs). Here we propose an explanation to this apparent puzzle by exploiting the approach of Dastidar (1995), which delivers a continuum of Bertrand-Nash equilibria ranging above marginal cost pricing. In our setting, two Bertrand firms, supplying a homogeneous good with a convex cost function, enter the market of a foreign country. We show that allowing for a softer price competition may indeed more than offset the standard effect generated by a decrease in trade costs, thereby restoring FDI incentives.

Chapter 1

Urban Functional Specialization and the Interplay between Firm's Communication Costs.

1.1 Introduction

In the existing theoretical literature on systems of cities, the spatial economies are predominantly seen as composed by two urban typologies: large and sectorally diversified cities hosting a highly educated workforce - which is exclusively occupied in managing tasks or in the service sector - and small and sectorally specialised manufacturing cities.[1]

As a matter of fact, at the world level, economies encompass different and more complex types of urban configurations. In particular, national urban systems are progressively melting in supranational/international systems where even some large national capitals - which can be broadly read as business and policy-decision centers - are relegated to a secondary functional role, while more sophisticated business services, finance, insurance, real estate (the so-called FIRE) sectors (henceforth *advanced business services*, ABS), gather in a little bunch of metropolis (or *central business centers*, henceforth PBC).

These *secondary urban centers*, whose size may be characterised by a high variance, are not production-intensive nor specialised in the service sector, and, at the same time, sectorally diversified w.r.t. manufacturing. Moreover, they represent a large subset of the urban universe, seemingly including regional capitals, which compete at some federal level for subsidies and grants. This may be actually puzzling, unless we give them recognition of a specific role which may, of course, be linked to non-economic dimensions, such as political or historical. As an alternative to these "exogenous" explanations we may think about a specific economic functional role. In order to tackle the problem, it is useful to observe that these centers are often seen by firms, especially by those belonging to manufaturing sectors, as the right places for locating their headquarters.

We could then argue why this happens referring to what the recent empirical literature suggests as headquarters' location determinants. According to Strauss-Kahn and Vives (2009), in fact, the managers benefit from the presence of good airport facilities, low corporate taxes, amenities, such as recreational services, low average wages and high levels of business services and agglomeration of headquarters in the same sector of activity. As further stressed by Lovely, Rosenthal, and Sharma (2005), the latter determinant is explicable by considering the fact that co-location of headquarters reduces the cost of the informations relative to foreign export makets or, more in general, as pointed out by Davis and Henderson (2008), benefits are to be accounted to an own sector external scale effect. Anyway, these authors find out that scale effects alone cannot explain high concentrations of headquarters in some larger cities, and diversity of local service inputs

[1] With regards to this issue, see Duranton and Puga (2001).

(i.e. sharing differentiated standard business banking or equipment leasing services) is claimed as an additional force leading the agglomeration process. Finally, for Aarland, Davis, Henderson, and Ono (2007) the firms are attracted by the availability of highly educated white collars[2] while the latters (managers) benefit from a low degree of noise and pollution with respect to pure manufacturing cities.[3]

An additional element to be accounted for, is the fact that regional and secondary national capital cities are generally well connected with large physical communication (point or network) infrastructures such as highways, railways and airports. With regards to the latter point, it is worth to recall the importance of the distance-managing cost for firm's spatial organisation choice: firms may decide whether split up into production plants and headquarters (multi-location organisational form) or keep its establishments together (integrated organisational form) according to its level. As far as this managing cost is function of the urban accessibility, it also leads headquarters localisation choices: *ceteris paribus*, fims will choose to locate headquarters in the best connected city, in order to keep the managing side relatively close to the production one in a way that minimise the cost of coordinating the production at distance. The dematerialisation of this cost component may, on a side, imply a cost reduction - which leads to a proliferation of the multi-location model - and on the other side, separate the location problem from the infrastructural endowment of cities, arguably linking it to other variables such as the local cost of inputs.

At the same time, since advanced business services are an undoubtedly significant component of headquarters' cost function, their tradability also, necessarily, affects headquarters' location choices. Regional capitals will then become attractive the more the headquarters will be able to buy sophisticated business services from distance. Since the latters are essentially immaterial, their tradability exclusively involve a transaction/communication cost, that is, the ability of business services providers to correctly understand and face firms' problems from a distant place.

What stated so far would suggest that the dynamics of the managing cost at distance, and that of the transaction cost between the firm's headquarter and the advanced business services providers are the key determinants of firms' organisational and localisation choices. Moreover, this could imply that highly functionally specialised urban configura-

[2]On the contrary Strauss-Kahn and Vives (2009) find that the level of human capital, as proxied by the percent of labor force with a bachelor degree is highly correlated with the level of business services and not significant.

[3]See also Defever (2006, 2010).

tions where "manufacturing", "headquarters" and "advanced/tradable business services" cities coexist, may be the result of the exploiting of localisation incentives at firms' level.

Accordingly, the theoretical model on functional specialisation in systems of cities that I propose here tries to fit the dynamics of urban configuration transformation by assigning a predominant role to changes in firms' spatial organisation. I formally lay on the Duranton and Puga (2005) general equilibrium model, with Henderson-type floating-island cities and agglomeration economies in local (standard) business services and intermediate goods' producers. In my framework firm organisational choice is not only affected by the level of communication costs between headquarters and production plants but also by the level of communication costs between headquarters and advanced business services providers. The latter feature can be read as the central and innovative one since, as previously underlined, theoretical literature hardly go beyond a first classification of urban functions (management/production) and provide a clear methodological distinction between different kinds of business services providers.

In other words, in the present model I let firms decide concerning localisation of headquarters with respect to business service providers: firms would move headquarters away from business services providers only if the additional transaction costs they face in buying business services from distance is low enough. The interaction between the additional managing cost due to firms internal spatial separation and the additional transaction cost due to firms location decision determines the conditons under which the different urban configurations are feasible in equilibrium. Both costs are intended as extra headquarter requirements in case of spatial separation. The decline of managing/communication costs over the last decades is thus supposed to be the main force delivering the transition from a functionally diversified urban environment to a specialised one.

While business services' characterisation has been substantially disregarded in the literature, only a few among the past theoretical works, apart from the above cited Duranton and Puga (2005), explicitly deal with the effects of communication costs' dynamics on the spatial organisation of consumers/workers and firms at urban system's level. In particular Ioannides, Overman, Rossi-Hansberg, and Schmidheiny (2008) make use of the Rossi-Hansberg and Wright (2007) dynamic model of cities and growth in order to analyze the effects of ICT on the distribution of city-size. Authors find that increases in the number of telephone lines per-capita lead to a more concentrated distribution of city sizes and so to a more dispersed distribution of economic activities in the space (a steeper Zipf curve). In other words, an improvement in ICT corresponds to a decrease in the number of large cities. This is substantially due to the fact that improvements in ICT reduce externalities generated by human capital and employment in an industry and, in so doing, reduce the incentives for economic activities to agglomerate.

Rossi-Hansberg, Sartre, and Owens III (2009) propose a theory of urban structure that emphasises the location and the internal structure decision of firms in the light of my model so as firms can decide whether spatially separating headquarters and operation plants or keeping them integrated; however this is only possible in different regions of the city and no system of cities is modelled. Moreover, authors do not view changes in communication technology as the force underlying changes in urban structure but theyinstead identify the population growth as the key process. Their model is able to replicate several empirical regularities regarding the evolution of the urban structures in the largest U.S. metropolitan areas in the 80s, such as an increase in residents at city centers and city boundaries, a reduction in the share of employment and residents in the central region of cities, a concentration of managers relative to non-managers at the center, an increase in establishments in both areas of the city (city center and edge), a decrease in establishment shares at the center, a decline in establishment size both at the center and at the edge of cities.

Another interesting contribution is the theoretical work by Cavailhés, Gaigné, Tabuchi, and Thisse (2007) which, in order to rationalise urban polycentricity, points on the interplay between three types of spatial frictions: trade, commuting and communication costs. They develop a two-region model in which, for low commuting and communication costs, intra-city secondary centers may arise to accommodate part of the total urban employment and, in so doing, alleviate the burden of urban costs without losing those benefits which stem from agglomeration. In authors' view, this allows the larger cities to maintain their predominance even in the presence of fairly low (inter-regional) trade costs which may in principle favor a relocation of the workforce from the larger and more dense urban areas to the smaller ones.

Fujita and Thisse (2006) set up a model of firm fragmentation in an international framework with trade costs, their main focus is on the redistributive effects of the process of fragmentation and/or integration triggered, again, by the dynamics of communication costs levels. Finally, the work from Wen-Chi (2012) focus on inshoring of business support services by firms, providing evidences of a process for which these activities are increasingly shifting away from big cities to smaller ones and separating from managerial jobs. Author provides an explanation based on new ICT technology development, which increases marginal productivity of workers employed in business services activities even in smaller or peripheral areas.

Turning back to empirical works, Aarland, Davis, Henderson, and Ono (2007) find that light manufacturing industries are more likely to spatially separate managing from production and that for economies characterised by a significant number of firms belonging to the non-service sector, with plants in three or more countries, the probability of having a Central Administrative Office is very low. The latter result is well fitted by my model since I show that the spatial equilibrium configuration encompassing integrated firms located in a different city w.r.t. business services providers, no further reduction of the remote managing cost can lead to an headquarters and plants separation, except for the case in which firms are characterised by a very high share of total costs represented by labor directly employed in their headquarters.[4] The same authors point out on two more aspects which are worth of being mentioned: the first one is that for headquarters, outsourcing is not properly replacing in-house production since headquarters that outsource legal services, accounting or advertising have a 2-3-fold higher percentage of employees working internally at that function; the second one is that between the US counties analyzed functional specialisation in headquarter activity result to be more frequent in mid-density counties, while larger ones are less headquarters centers than business services centers exporting services to the rest of the country. These results reinforce the idea that headquarters activity and highly specialised business services providers are not spatially inextricable. Accordingly, Diacon and Klier (2003) document a trend of dispersion of headquarters from large to medium-sized, fast growing metropolitan areas, especially concerning manufacturing firms. The same point is made up by Henderson and Ono (2008) which show how, across US counties, the relative concentration of headquarters in medium and smaller size cities contrast with the geographical distribution of business service industries; headquarters are not disproportionately concentrated in large metro areas as commonly thought. Anyway, the way Audretsch, Falck, and Heblich (2011) interpret these latter results is opposite to mine. They argue that a considerable number of manufacturing firms choose not to split their organisation and, consequently, that headquarters in medium-size cities belong to integrated firms, while I suppose that headquarter dispersion is due to a further functional specialisation: while advanced business services providers undoubtedly benefit from agglomerating in large metro areas, headquarters may find regional capitals a better place.

[4]So, arguably, except for the case of multi-location firms belonging to the service sector.

Finally Ono (2003, 2007) uncover the phenomenon of outsourcing business services by Central Administrative Offices; author find that firms may benefit by separating CAO from production plants to locate them in larger and thicker local markets and rely on them to save on outsourced business services.

The remainder of the paper is organised as follows. The model is presented in section 2 while in section 3 equilibrium types and sizes of cities are characterised. Section 4 identifies the relevant communication costs thresholds and discutes the results. Section 5 concludes.

1.2 The model

I adopt a general equilibrium framework, where consumers/workers inelastically supply one unit of labor and can choose between occupations and cities while final goods firms belonging to one of the m sector existing in the economy, produce a sectorally homogeneous good, which is freely traded across cities. The spatial equilibrium is defined by the sizes and types of the existing cities, where the types are defined on the basis of the degree of sectoral and functional specialisation of the workforce living in the city.

1.2.1 Preferences

Utility function of the representative consumer is defined over a composite final good M which is aggregation of the m final goods produced in the economy. Each of this goods enters with equal shares, in a Cobb-Douglas fashion, in the utility function:

$$U = f(M) \quad where \quad M = \prod_{h=1}^{m} (x^h)^{1/m}. \tag{1.1}$$

As in the standard urban economics literature, no measure of the distance between cities is included in the analysis, that is, cities are intended as “floating islands”. In other words, there are no distance sensitive trade or transport costs in the market of the final good, nor workers' relocation costs.[5] This implies that the consumer/worker's location choice may affect her utility uniquely via her (nominal) income. The indirect utility of a consumer working in occupation h in city i then writes as:

$$V_i = \frac{e_i^h}{P}, \tag{1.2}$$

[5] See Fujita and Mori (1997) and Fujita, Krugman, and Mori (1999) for a NEG approach to the systems of cities in which trade costs between cities are formally taken into account.

where the price index P for the composite final good is the aggregation of sectoral prices:

$$P = \prod_{h=1}^{m} (P^h)^{1/m}, \tag{1.3}$$

while e_i^h denotes consumption expenditure of an individual living in city i with occupation h[6]:

$$e_i^h = f(w_i^h, T_i^h, R_i, CC_i), \tag{1.4}$$

where the positive determinants are represented by w_i^h, the wage of an individual living in city i with occupation h, and T_i^h, a monetary transfer provided by the city government (see below), while the total commuting costs CC_i borne by the consumer/worker and the land rent R_i, both function of the consumer location *within* the city, are the negative determinants. According to the literature, the latters can be addressed as *urban costs*.

The maximisation of own consumption expenditure by the individuals determines equilibrium city size and, obviously, involves individuals' city choice as well as within city location choice.

By choosing a city, individuals choose a nominal wage and a level of transfers. Moreover, since the space between cities is not modelled here, the choice of the city is formally equivalent to the *choice of the city-type*, where, again, the types are defined over the set of sectoral and functional characteristics rather than according to spatial fetaures (such as physical relative distance).[7] Then, location inside the city is the sole proper *spatial* control variable of individuals' income. Focusing on the latter amounts to defining the urban internal spatial structure.

1.2.2 City structure

Each city is composed by a *Central Business District* (henceforth CBD), where every economic activity takes place, and a surrounding residence area of unit length. Residents necessarily commute to the CBD and, in so doing, lost a fraction of their work supply equal to 2τ times the distance of their residence from the CBD, that is z, so that:

$$CC_i = 2\tau z \cdot w_i^h. \tag{1.5}$$

In this sense, τ must be intended as an iceberg commuting cost. Since lot size is assumed to be fixed, choosing a location z within the city is equivalent to choosing the level of

[6]See below for a definition of possible occupations.

[7]See below for a complete description of city types of the economy.

urban costs[8] to maximise the net income, given the wage and the amount of monetary transfers.

$$e_i^h(z) = w_i^h(1 - 2\tau z) - R_i(z) + T_i^h. \tag{1.6}$$

The residents with the same wage, thus facing the same opportunity cost of commuting time, will have the same bid-rent function and the same willingness to pay for land. Perfect arbitrage ensures that at residential equilibrium they'll end up with the same level of the urban costs so that they will necessarily sort according to their wage, with better paid workers located close to the CBD.

Moreover, at the residential equilibrium, none of the city residents will have the incentive to move from chosen z: high paid workers and low paid ones will face a different composition but the same level of urban costs. I call L_i the city size (i.e. the number of its residents), then total land rent is the integral of land rent function over the unit length city:

$$R_i = \int_{-L_i/2}^{L_i/2} R_i(z)d(z), \tag{1.7}$$

where right and left sides of the city are symmetric and accommodate half of the total city population $L_i/2$; since each resident consumes a single lot of space this is equivalent to saying that $L_i/2$ represents the maximum distance from the CBD, or the city edge.

1.2.3 Technology

In order to characterise the remaining determinants of individual consumption expenditure e_i^h, I need to move to the supply side of the model. This does not formally encompass any localisation economy for the firms which produce final goods. Moreover, since the market is perfectly competitive and each of these firms earns zero profits in equilibrium, the agglomeration forces of the model, in the light of Abdel-Rahman and Fujita (1990), are represented by localisation economies *à la* Ethier (1982), that is, aggregate increasing returns arise from the productive advantages of sharing a large number of local varieties of intermediate inputs suppliers (see below). Final good firms buy from two different types of input suppliers, each one specific to one of their facilities. The final good firms' technology, in fact, combines a headquarter and a production plant component (henceforth, respectively, HQ and PP) so that the Cobb-Douglas production function can be written

[8] In this sense we do not have here the standard result of the equilibrium population density decreasing from the the CBD to the urban fringe: consumers/residents cannot trade more space for housing against a lower accessibility to the CBD given fixed lot size. This also implies that the land rent at the city edges is not zero; in the model it is thus normalised to zero without loss of generality.

as:

$$x^h = (x^h_{hq})^\eta (x^{m+h}_{pp})^{1-\eta} \tag{1.8}$$

where x^h denotes output of a firm belonging to sector h with $h = 1, ..., m$, while x^h_{hq} and x^{m+h}_{pp} are, respectively the quantities of HQ's and PP's service inputs.[9] Unit production cost function thus writes as:

$$c^h = \left(H^h\right)^\eta \left(Q^{m+h}\right)^{1-\eta} \tag{1.9}$$

where H^h represents the HQ's sub-cost while Q^{m+h} the PP's one.

Each of the firm's facilities (HQs and PPs) use specific intermediate inputs: in the case of HQs these are business services (banking and legal services, advertising), and these outsourced business services and HQs specific labor force (managers) enter the Cobb-Douglas production function with shares μ and $1 - \mu$ respectively. The relative sub-cost function is therefore specified as:

$$H^h = (w^h)^\mu (Q^0)^{1-\mu} \tag{1.10}$$

where w^h_i is the unitary labor cost in city i and sector h while Q^0_i is business services' composite price index.[10] For what concerns the PPs, the only inputs which enter in the sub-production function are the sector specific intermediates, which can be broadly read as semi-processed products or technical components of the final good. The PP sub-cost function Q^{m+h}_i therefore coincides with the composite price index for intermediates.

I can thus say that the model encompasses $2m + 1$ occupations for workers: workers may be directly occupied in the headquarters of sector h, in the production of business services, or in the production of intermediates specific to sector h.

The mass of varieties of business services produced in city i is endogenously determined and indicated as s^0_i and all varieties enter in the headquarters' technology with constant elasticity of substitution $(\theta + 1)/\theta$, where $\theta > 0$. The relevant price index of business services can therefore be expressed as:

$$Q^0_i = \left[\int_0^{s^0_i} [q^0_i(k)]^{-1/\theta}\right]^{-\theta} \tag{1.11}$$

[9]Superscript $m + h$ is always assigned to variables which refers to PPs while those referring to HQs are indexed with h with $h = 1, ..., m$.

[10]The superscript 0 always refers to the business services sector. Note that the fact that the superscript $h = 0$ is associated with business services' variables is due to a specific assumption of the model: while the intermediates used by the PPs are sector-specific, the same business services are used by the HQs in all sectors.

where $q_i^0(k)$ is the price of variety k of the business services produced in city i. While the cost function of a firm producing a single variety is:

$$C_i^0(k) = \left[\alpha^0 + \beta^0 y_i^0(k)\right] w_i^0 \tag{1.12}$$

where $y_i^0(k)$ denotes firm's output, α and β respectively denotes the fixed and variable labor requirements.[11]

Since the cost function relative to a single variety involves a fixed labor requirement and since all the varieties of both business service suppliers and intermediate producers enter in the final good production function with the same constant elasticity of substitution (respectively $(\theta{+}1)/\theta$ and $(\epsilon{+}1)/\epsilon$), the more labor is employed in the specific intermediate sector or in the business service sector, the more varieties will result in equilibrium and will therefore lower the correspondent composite price.

The process of specialisation is limited by the size of the labor market l_i as well as by the presence of a fixed component of the unit labor requirement α. The equilibrium number of varieties also rises with the degree of product differentiation which characterise the sector (higher θ, ϵ). This effect results as clearer if we express the production plant and headquarter sub-cost functions as:[12]

$$\begin{cases} Q_i^{m+h} & = \left(l_i^{m+h}\right)^{-\epsilon} w_i^{m+h} \\ Q_i^0 & = \left(l_i^0\right)^{-\theta} w_i^0 \end{cases} \tag{1.13}$$

Where l_i^{m+h} and l_i^0 represent the net labour available for production in city i.[13] The degree of localisation economies, that is the increasing returns at the sector-city level (or the cost advantages stemming from co-location of inputs producers belonging to the same sector) is thus increasing with ϵ and θ. Since Q_i^0 and Q_i^{m+h} enter the Cobb-Douglas production function of HQs and final good firms, it is useful to define $\sigma = \theta(1-\mu)$, and $\gamma = \eta\sigma + (1-\eta)\epsilon$ where σ and ϵ indicate the localisation economies for business services and intermediates while γ indicates the average localisation economies. These parameters may thus be interpreted as a direct measure of the elasticities of the local sectoral productivities to the sector specific workforce: the higher σ and ϵ, the stronger will be the negative effect of a marginal increase in the local workforce on the relevant price index of intermediate inputs.

[11] To obtain corresponding definitions for intermediates entering PPs production function is sufficient to replace superscript 0 with $m+h$ and θ with $\epsilon > 0$.

[12] See Duranton and Puga (2005) Lemma 1 and 2.

[13] Remember that each individual inelastically supply one unit of labour but have to commute to the city CBD to effectively work in a firm. This implies that a fraction τ of the total city work supply get lost and $\sum_{h=0}^{2m} l_i^h = L_i(1-\tau L_i)$.

Since both HQs and PPs have a physical location (we identify the location of a final good firm with the location of its headquarter), the final good entrepreneurs belonging to different sectors face the same organisational problem that is choosing between a spatially integrated or multi-location organisational form, but they also face a location problem, that is choosing to locate headquarters in the same city where advanced business services (ABS) are located (the PBC), or in a different city. In fact, as already pointed out in section 1, differently from the standard business services (SBS) and the intermediates, ABS are tradable, in that HQs can make use of ABS provided by firms located in a different city by facing a fixed communication cost. Correspondingly, there are four possible cost functions for the firm belonging to the sector h, having its HQ in the city i:[14]

1. Integrated Firms in the PBC:

$$C^h_{i,i,i} = \left(H^h_{i,i,i}\right)^\eta \left(Q^{m+h}_i\right)^{1-\eta} x^h_{i,i,i} = \left[\left(w^h_i\right)^\mu \left(Q^0_i\right)^{1-\mu}\right]^\eta \left(Q^{m+h}_i\right)^{1-\eta} x^h_{i,i,i}; \quad (1.14)$$

2. Integrated firms, outside the PBC:

$$C^h_{i,i,z} = (K)^\eta \cdot \left(H^h_{i,i,i}\right)^\eta \left(Q^{m+h}_i\right)^{1-\eta} x^h_{i,i,z}; \quad (1.15)$$

3. Multi-location firms with HQ in the PBC:

$$C^h_{i,j,i} = (\rho)^\eta \cdot \left(H^h_{i,i,i}\right)^\eta \left(Q^{m+h}_i\right)^{1-\eta} x^h_{i,j,i}; \quad (1.16)$$

4. Multi-location Firms with HQ in the SBC:

$$C^h_{i,j,z} = (K \cdot \rho)^\eta \cdot \left(H^h_{i,i,i}\right)^\eta \left(Q^{m+h}_i\right)^{1-\eta} x^h_{i,j,z}; \quad (1.17)$$

where $\rho > 1$ and $K > 1$ are the iceberg-type extra-headquarter costs respectively associated with the transmission of headquarter services to a PP located in a different city (the *managing costs*) and with the transmission of business services from business services suppliers to headquarters located away from the PBC (the *transaction costs*). A multi-location firm is thus supposed to face both these iceberg costs and has its headquarter sub-cost function multiplied by a factor $\rho \cdot K > K, \rho$.

[14] First subscript indicates the city where firm's HQ is located, the second the city where PP is located and the third indicates the PBC.

1.3 City formation

In section 1.2 I have defined the consumption expenditure income of a consumer/worker in the spatial economy (see equation (1.6)) and this has been shown to be function of both spatial and market features. Since individuals face no spatial relocation costs and no costs in shifting from an occupation to another, they will move to the city which grants them the higher wage and the lower urban costs. A spatial equilibrium is then reached when a consumer has no incentive to move from a city to another; from the model's assumptions on consumers preferences, this means that she/him will get the same consumption expenditure income everywhere, given the location choices of other consumers and the organisational and location choices of firms. In the model, attraction and repulsion forces - which are the basis of cities' existence - are thus exclusively affecting consumers/workers: the agglomeration economies, in fact, stem from the gathering of an occupation-specific workforce, while the countervailing (dispersion) force is represented by the commuting costs.[15]

In the present model, a "land development companies" mechanism leads to the formation of cities and, therefore, determines equilibrium city sizes.[16] The prefectly competitive land development companies (henceforth LD) seek to maximise total land rent in the city by choosing a population target and an occupation specific monetary transfer scheme. The latter is defined as the $(2m+1)$-dimensional vector $T_i = \{T_i^0, T_i^1, ..., T_i^h, ...T_i^m, ..., T_i^{m+h}, ..., T_i^{2m}\}$ whose components represent the amount of money which a worker will get from the LD if she/him moves to the city i. This amounts to saying that each LD maximises the following objective function:

$$\max_{\{L_i^h, T_i^h\}} \Pi_i, \quad \Pi_i = R_i - \sum_{h=0}^{2m} L_i^h T_i^h$$

subject to workers in each active occupation in the city obtaining the highest consumption income available elsewhere, $\bar{e}$:

$$L_i^h e_i^h = L_i^h \bar{e}, \quad L_i^h \geq 0$$

[15] No final goods' price index effect, which is the one acting as dispersion force in the standard framework of the New Economic Geography, is modelled here, since final good is homogenous and freely traded across locations.

[16] With regards to this issue see Henderson and Becker (2000). In the literature, two main approaches to city formation and size may be distinguished: *self-organisation* and *perfectly competitive land development companies*. The main advantage of the latter setting lies on the fact that it allows to get rid of inefficient spatial equilibria arising under coordination failure between agents.

and subject also to firms adopting each of the possible configurations breaking even.[17] Moreover, following Duranton and Puga (2005), developer's programme may be rewritten as:

$$\max_{l_i^h} \Pi_i, \quad \Pi_i = \sum_{h=0}^{2m} w_i^h l_i^h - L_i \bar{e} \tag{1.18}$$

subject to (A.1-A.6), $l_i^h \geq 0$ and $\sum_{h=0}^{2m} l_i^h = L_i(1 - \tau L_i)$. From (1.18)
If the break even conditions for final good firms hold, one can state what follows.

Lemma 1 *[Multi-location HQs and PPs separation.] In equilibrium, the stand alone headquarters and the stand-alone production plants belonging to any type of multi-location firms (i.e. those with HQs in the PBC and those with HQs outside the PBC) do not coexist in the same city.*

Proof. The HQs of a multi-location firm which are located outside the PBC cannot co-exist with the PPs of a different multi-location firm. In fact, this would imply that an integrated firm located in the same city would have the chance to get HQ's and PP's services at the lowest cost though saving the communication cost associated to the managing at distance. As a consequence, this firm, would make positive profits equal to $P^h - (H_{i,i,i}^h)^\eta (Q_i^{m+h})^{1-\eta} = (1 - 1/(K\rho)^\eta) P^h > 0$, which contradicts (A.1-A.2). ■

While the latter Lemma rules out the city types encompassing stand-alone HQs and stand-alone PPs (i.e. if a city is supposed to host both facilities, then these must belong to the same integrated final good firm), from the definition of the maximisation problem in (1.18)[18], we can exclude the co-presence of integrated firms and HQs or PPs belonging to multi-location firms. That is, whether in the PBC or not, in equilibrium, integrated firms cannot co-exist with either HQs or PPs of multi-location firms belonging to the same sector. This leads to the definition of the the city-types which are feasible in equilibrium:

(a) HQs (belonging to multi-location firms) and business service suppliers of both types;

(b) HQs of multi-location firms;

[17]This implies that each firm's establishment, whether it is a production plant a headquarter of a multi-location firm or an integrated firm, has to break even, wherever it is located. See Appendix 1.A for the definition of the necessary conditions associated to all the possible cases.

[18]See also (B.14) for a different formulation of the maximisation problem. From this it also results as straightforward the result for which each city end up as sectorally specialised in equilibrium, regardless of the degree of functional specialisation associated to each of the feasible urban configurations.

(c) PPs (belonging to multi-location firms) and intermediate suppliers;

(d) integrated firms, business service suppliers of both types and intermediates suppliers;

(e) integrated firms and intermediates suppliers;

(f) ABS suppliers.

Note that, from now on, this labeling will also characterise city-type specific variables (as an example, L_a will be unsed to indicate th total equilibrium population of a city hosting HQs and business service suppliers). I may now determine equilibrium city sizes:

Lemma 2 *[Equilibrium city sizes] The spatial equilibrium city-sizes are*

$$L_a = \frac{\sigma}{\tau(1+2\sigma)}, \quad L_c = \frac{\epsilon}{\tau(1+2\epsilon)}, \quad L_d = \frac{\gamma}{\tau(1+2\gamma)},$$

$$L_b = \frac{1+\mu}{\tau(1+2\mu)}, \quad L_e = \frac{\epsilon(1-\eta)}{\tau[1+2\epsilon(1-\eta)]}, \quad L_f = \frac{\sigma}{\tau(1-\mu+2\sigma)}.$$

Proof. See Appendix 1.C. ■

Once defined city types and the relative sizes I can define the equilibrium configurations as, alternatively, encompassing:

1. only type (d)-cities (firms face the cost function of (1.14));
2. type (e) and (f) cities (firms face the cost function of (1.15));
3. type (a) and (c) cities (firms face the cost function of (1.16));
4. type (e), (f) and (c) cities (firms face the cost function of (1.17)).

Figure 1.1 represents the four equilibrium configurations. Dotted lines indicate integrated firms, while arrows indicates additional costs ρ and K faced by headquarters under different spatial equilibria.

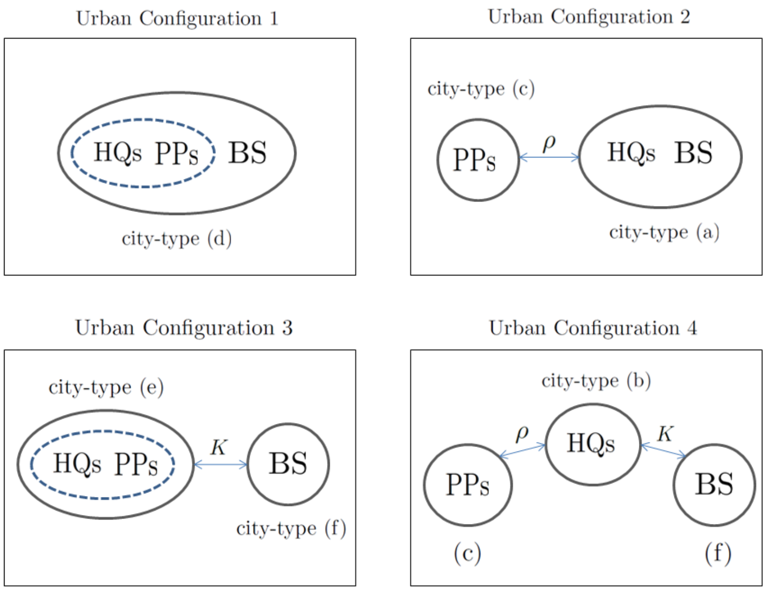

Figure 1.1: Spatial economy's feasible equilibria

1.4 Urban configurations and the interplay between communication costs

1.4.1 Communication costs' thresholds

The following proposition identifies the conditions, expressed in terms of the level of the two communication costs, under which the four configurations listed in the latter section will result as equilibrium outcomes.

Proposition 1 *[Equilibrium firm organisation and urban structure] For $\rho > \hat{\rho}$, where*

$$\hat{\rho} = \left[\frac{(1+2\gamma)^{1+2\gamma}\sigma^{\eta\sigma}\epsilon^{(1-\eta)\epsilon}}{\gamma^{\gamma}\left[\eta^{\sigma}(1+2\sigma)^{1+2\sigma}\right]^{\eta}\left[(1-\eta)^{\epsilon}(1+2\epsilon)^{1+2\epsilon}\right]^{1-\eta}} \right]^{1/\eta} \tag{1.19}$$

then all firms adopt the fully integrated organisational form of (1.14), and all cities specialise by sector, hosting headquarters, production plants, business services and intermediates suppliers. If instead $\rho < \hat{\rho}$, then all firms adopt the partial multi-location organisational form of (1.16) keeping headquarters in the business service center, with a share

$$\frac{\eta\epsilon(1+2\sigma)}{\eta\epsilon(1+2\sigma)+(1-\eta)(1+2\epsilon)\sigma}$$

of cities hosting headquarters and business services suppliers, and the rest of cities hosting production plants plus intermediate suppliers.
For $K > \hat{K}$, where

$$\hat{K} = \left[\frac{(1+2\gamma)^{1+2\gamma}[\epsilon(1-\eta)]^{\epsilon(1-\eta)}[1-(1-\mu)\eta]^{1-\eta(1-\mu)}(1-\mu)^{\eta(1-\mu)}\sigma^{\eta\sigma}}{(1+2\sigma-\mu)^{\eta(1+2\sigma-\mu)}[1+2\epsilon(1-\eta)]^{1+2\epsilon(1-\eta)-\eta(1-\mu)}\gamma^{\gamma}\mu^{\mu\eta}\eta^{\eta\sigma}} \right]^{1/\eta} \tag{1.20}$$

then all firms adopt the fully integrated organisational form of (1.14) and all cities specialise by sector, hosting headquarters, production plants, business services and intermediates suppliers. If instead $K < \hat{K}$, then all firms adopt the partial multi-location organisational form of (1.15) (keeping headquarters together with production plants while facing an additional cost to get business services from outside the city) with a share

$$\frac{\epsilon\eta(1-\mu)(1+2\sigma-\mu)}{\epsilon\eta(1-\mu)^2+\sigma+2\epsilon\sigma(1-\mu\eta)}$$

of PBC, and the rest of cities hosting headquarters, production plants and intermediate suppliers.For $\rho < \hat{\rho}$ and $K < \hat{K}$ all firms necessarily adopt the multi-location organisational form of of (1.17).
For $K < \hat{K}$ and $\rho > \overline{\rho}$, where

$$\bar{\rho} = \left[\frac{[1+2\epsilon(1-\eta)]^{1+2\epsilon(1-\eta)-\eta(1-\mu)}[1-(1-\mu)\eta]^{\eta(1-\mu)-1}(\mu^2\eta)^{\mu\eta}}{(1-\eta)^{2\epsilon(1-\eta)+\eta\mu}(1+2\epsilon)^{(1+2\epsilon)(1-\eta)}[(1+\epsilon)(1+2\mu)]^{\mu\eta}} \right]^{1/\eta} \tag{1.21}$$

then all firms adopt the partial multi-location organisational form of (1.15). If instead $\rho < \overline{\rho}$, then all firms shift from the organisational form of (1.15) to that of of (1.17) with a share

$$\frac{\epsilon(1-\mu)(1+\mu)\eta(1+2\sigma-\mu)}{\epsilon(1-\mu)^2(1+\mu)\eta+\epsilon[2+\mu(2-\eta)]+(1+\mu)(1-\eta)\sigma}$$

of PBC hosting only business services suppliers, and a share

$$\frac{\epsilon\mu\eta\sigma(1+2\mu)}{\epsilon(1-\mu)^2(1+\mu)\eta+\{\epsilon[2+\mu(2-\eta)]+(1+\mu)(1-\eta)\}\sigma}$$

of cities hosting only headquarters. If $\rho < \hat{\rho}$ and $K > \bar{K}$, where

$$\bar{K} = \left[\frac{(1-\mu)^{\eta(1-\mu)}\mu^{\mu\eta}(1+2\sigma)^{\eta(1+2\sigma)}}{(1-\mu+2\sigma)^{\eta(1-\mu+2\sigma)}(1+2\mu)^{\eta\mu}} \right]^{1/\eta} \tag{1.22}$$

then all firms adopt the partial multi-location organisational form of (1.16). If instead $K < \bar{K}$, then all firms shift from the organisational form of (1.16) to that of (1.17).

Proof. See Appendix 1.D. ■

1.4.2 Discussion

In the latter subsection I have presented the main result of the paper, which consists in the identification of the communication costs critical levels (1.19-1.22). According to the model hypotesis, held constant the magnitude of the localisation economies, the emergence of one of the four feasible types of system of cities is determined by the level of communication costs faced by firms. The way communication costs affect firms decisions depends on the starting urban configuration, that is, co-location of headquarters and ABS is affected by the level of the additional cost of buying ABS from distance, but also by the level of the managing cost. The reverse relation is also proven to hold: even firms' integration is affected by both communication costs. Thus headquarters' location w.r.t. ABS affects the organisational decision of firms. This amount to saying that:

$$\rho^* \equiv \begin{cases} \hat{\rho} & \forall\, K > \hat{K} \\ \bar{\rho} & \forall\, K < \hat{K} \end{cases} \quad ; \qquad K^* \equiv \begin{cases} \hat{K} & \forall\, \rho > \hat{\rho} \\ \bar{K} & \forall\, \rho < \hat{\rho} \end{cases} \quad .$$

Where ρ^* and K^* represents the relevant thresholds. Moreover, note that since we have not so far imposed any restriction on the parameters' values, nothing in the model prevents each threshold to assume values below unity. This would obviously imply their non-existence. In fact, in the presence of a threshold below unity, the correspondent communication cost should turn negative in order to deliver any spatial separation. Furthermore, the relative position of each of the four thresholds is not a priori defined, so that, in principle, $\bar{K} \lesseqgtr \hat{K}$ and $\bar{\rho} \lesseqgtr \hat{\rho}$. Figure 1.2a illustrates the four feasible urban configurations (with correspondent city-types in parenthesis) as functions of the levels of communication costs ρ and K, in the space definded by $\rho > 1$ and $K > 1$.

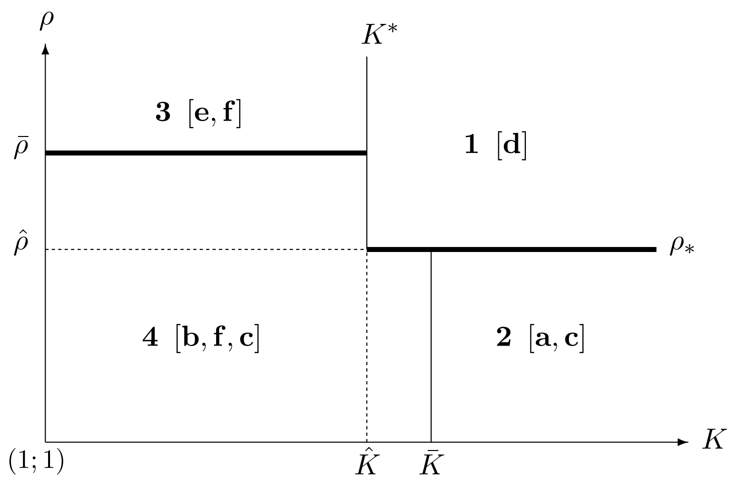

Figure 1.2a: Feasible spatial configurations and relevant thresholds

According to what stated so far, if the ABS communication cost K falls below the threshold $\hat{K}$, while the managing cost ρ stays above the threshold $\bar{\rho}$, the economy shifts from the integrated configuration 1 to the configuration 3, where firms adopt an integrated organisational form but locate in a different city w.r.t. the ABS providers. Once this equilibrium is reached, no further decrease of K can deliver the urban configuration of maximum functional specialisation 4: firms' separation into headquarters and production plants is worthwhile for the economy only if ρ falls below $\bar{\rho}$.
On the other side, only if K stays above $\hat{K}$ and ρ falls below $\hat{\rho}$ the economy shifts from the integrated configuration 1 to the configuration 2 where firms split into PPs and HQs but keep the latters in the PBC. Starting from this partially specialised configuration, no further decrease of ρ can lead to maximum functional specialisation 4: only a decrease of K under the threshold $\bar{K}$ pushes headquarters away from the PBC. Thus, in order for maximum functional specialisation to be a feasible spatial equilibrium, the conditions $K < \bar{K}$ and $\rho < \bar{\rho}$ have to be jointly met.

However, figure 1.2a is not the unique representation of equilibrium configurations in the ρ -K parameters' space. From Proposition 1, in fact, each threshold is a function of the parameters σ, ϵ, γ, μ and η. Thus, according to their values, a situation in which $\hat{K} > \bar{K}$ and/or $\hat{\rho} > \bar{\rho}$ may arise.
In order to provide a numerical example, we may assume the following: $\theta = 0.2$, $\epsilon = 0.05$, $\mu = 0.6$ and $\eta = 0.2$. This amount to saying that a 1% increase in employment in a city hosting ABS raises local productivity by 1.08% (note that $\sigma = \theta(1 - \mu) = 0.08$) while a

1% increase in employment in a city hosting PPs and intermediates suppliers raises local productivity by 1.05%. Moreover, the share of the total firm's cost represented by headquarters' services is quite low (20%) and the workforce directly occupied in the headquarter account for the larger part of the corrsepondent sub-cost function (60%)[19]. In correspondence of these parameters'values, we find that $\hat{\rho} = 1.17$, $\hat{K} = 1.15$, $\bar{\rho} = 0.22$ and $\bar{K} = 0.51$.

This results depict a spatial economy in which urban configuration 4 is not sustainable for any level of ρ and K (figure 1.2b).[20]

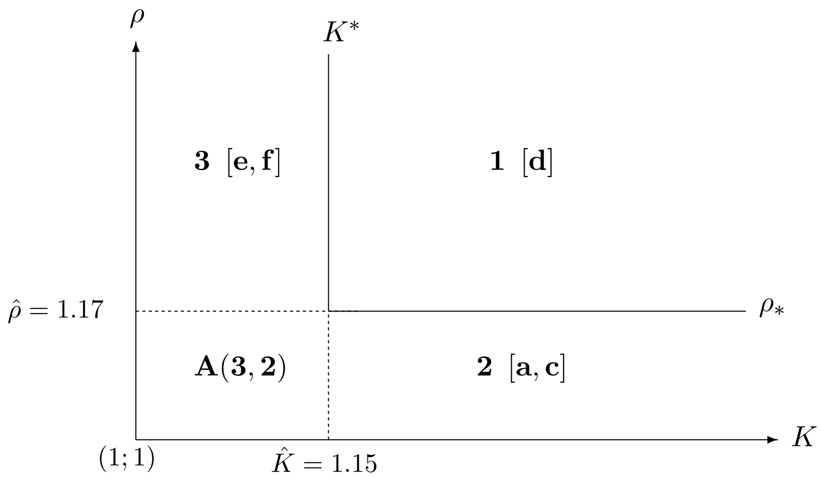

Figure 1.2b: Feasible spatial configurations and relevant thresholds for $\theta = 0.2$, $\epsilon = 0.05$, $\mu = 0.6$ and $\eta = 0.2$

Note that the parameters' space represented by area A in figure 1.2b may, alternatively, deliver configuration 3 or 2 depending on the starting levels of ρ and K. This implies that once reached configuration 3 or 2 from 1, no further decrease of ρ or K, respectively below $\hat{\rho}$ and $\hat{K}$, may lead to a different spatial equilibrium. This latter result is particularly interesting, since it entails a sort of spatial lock-in effect. Since this effect arises when $\bar{\rho} < 1 < \hat{\rho}$ or $\bar{K} < 1 < \hat{K}$, it is useful to investigate under which parameters' ranges the latters conditions hold. To this regard, repeated numerical simulations have shown that:

(i) $\hat{\rho} \geq 1$ for all admissible paramers' values.;

[19] In the following I always assume that $\mu \geq 0.6$ which is consistent with the empirical results provided by Aarland, Davis, Henderson, and Ono (2007).

[20] In the limit case in which all the thresholds are below unity, neither configurations 2 and 3 are feasible and the spatial economy is necessarily characterised by cities of the integrated type d: sectoral specialisation and no functional specialisation.

(ii) $\bar{\rho} > 1$ for $\eta \geq 0.8$;

(iii) if $\bar{\rho} > 1$ holds, then $\bar{\rho} > \hat{\rho}$ also holds;

(iv) $\bar{K} \leq 1$ for all admissible paramers' values;

(v) $\hat{K} > 1$ for $\sigma > 0.01$.

I start by analysing the former three points which concern the managing cost ρ. With regards to this, in Figure 1.3, $\bar{\rho}$ and $\hat{\rho}$ are plotted as functions of η.

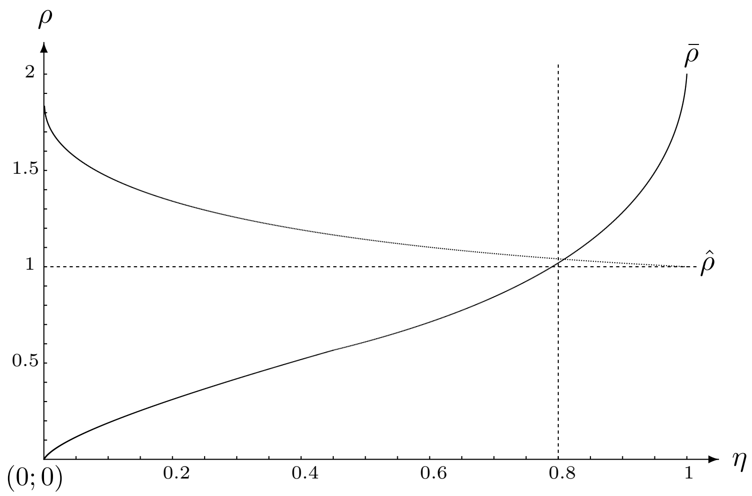

Figure 1.3: Determinants of ρ-thresholds given $\epsilon = 0.05$ and $\mu = 0.6$

I.e., held constant the values of the remaining parameters, $\bar{\rho} > 1$ for all $\eta > 0.8$, while $\hat{\rho} > 1$ holds in the whole admissible parameters' range. The conclusion that we can draw from this result is that configuration 4 is feasible if and only if $\eta > 0.8$. Moreover, (point (ii)) for sufficiently high values of η, a substitution effect between ρ and K exists in shifting from 1 to 4 via 3. This amounts to saying that the lower ρ, the more likely is for HQs to locate away from PBC.

In fact, if we assume that $\eta = 0.8$, we have that $\hat{\rho} = 1.04$ and $\bar{\rho} = 1.08$: the shift from configuration 1 to 2 then becomes feasible if the additional cost of managing production from distance falls below 4% of the managing cost for an integrated firm, while an 8% threshold is fixed w.r.t. the shift from configuration 3 to 4. As η rises this substitution effect rises, together with the spread between $\bar{\rho}$ and $\hat{\rho}$. In order to better understanding why this happens, let's focus on the determinants of both thresholds, starting from the case of $\hat{\rho}$. According to the simulations's results, and limiting the analysis to the relevant case $\eta \geq 0.8$ in order to keep things simple, we have that:

$$\frac{\partial \hat{\rho}}{\partial \sigma} > 0, \forall \sigma \in [0, \frac{\epsilon}{2}]; \; \frac{\partial \hat{\rho}}{\partial \eta} < 0; \; \frac{\partial \hat{\rho}}{\partial \epsilon} > 0. \tag{1.23}$$

Note that from (1.23), the intuitive result for which the more localisation economies in the ABS sector, the more the multi-location firm's organisational form is supposed to become worthwhile, holds as long as $\sigma < \frac{\epsilon}{2}$. In order to understanding why the magnitude of these localisation economies have to keep low relative to those associated to the production of intermediates we may consider, first of all, that we are restricting the analysis to a portion of the parameters' space in which η is relatively high. In this specific case, the benefits accruing to firms from the geographical separation between HQs and PPs are very low ($\frac{\partial \hat{\rho}}{\partial \eta} < 0$), since local productivities are not significantly hindered by the mixing between the different workforces which arises in case of spatial integration. The latter consideration is confirmed by the sign of the following cross derivatives w.r.t. η:

$$\frac{\partial \hat{\rho}}{\partial \sigma \partial \eta} < 0; \; \frac{\partial \hat{\rho}}{\partial \epsilon \partial \eta} < 0.$$

These imply that a rising η lowers the effect exerted by the localisation economies on the firm's organisational decision. Secondly, as σ rises, the congestion associated to the a-type cities rises more than proportionately than that associated to the d-type ones.
For what concerns $\bar{\rho}$ instead, the sign of the derivatives can be determined on the whole parameters' range. Accordingly, we have that:

$$\frac{\partial \bar{\rho}}{\partial \sigma} = 0, \; \frac{\partial \bar{\rho}}{\partial \eta} > 0 \, \forall \, \mu \in [0.15, 1]; \; \frac{\partial \bar{\rho}}{\partial \mu} > 0 \, \forall \, \eta \in [0.8, 1]; \; \frac{\partial \bar{\rho}}{\partial \epsilon} < 0 \, \forall \, \eta \in [0.8, 1]. \tag{1.24}$$

Note that the derivative w.r.t. the parameter σ is null. This threshold is in fact associated to the shift from configuration 3 to 4, which entails spatial separation between HQ and PP, while ABS are already agglomerated in the same city (f-type). Firms has thus just exploited the localisation economies represented by σ, that is, they have benefit from the increase in productivity which stems from locating HQs away from business services. Figure 1.4 illustrates the results in (1.24).

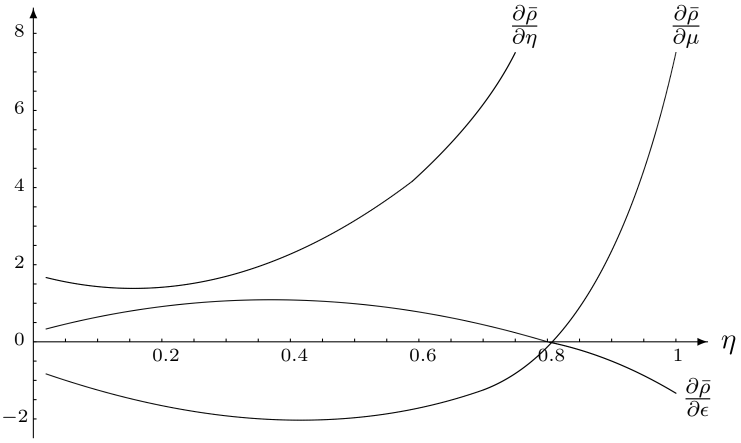

Figure 1.4: Determinants of $\bar{\rho}$ given $\epsilon = 0.05$ and $\mu = 0.6$

Thus, as far as $\eta < 0.8$, this threshold is decreasing in μ and increasing in ϵ while the opposite is true for $\eta > 0.8$. To understand why this happens, consider that Lemma 2 also implies:[21]

$$L_b > L_f > L_a > L_d > L_c > L_e$$

so that shifting from configuration 3 to 4 is not only associated to a lower price for intermediates[22] but also to a higher level of congestion, since $L_b + L_c > L_e$ always holds. A higher number of workers directly occupied in the HQs thus entails an increase in the size of b-type cities.[23] When $\eta < 0.8$ this is sufficient to explain why a higher μ is supposed to negatively affect the threshold value $\bar{\rho}$, while the intuition for the sign of $\frac{\partial\bar{\rho}}{\partial\epsilon}$ is straightforward: a higher degree of localisation economies, favour firm's spatial separation. Anyway, once η is sufficiently high, μ becomes a positive determinant of the level of $\bar{\rho}$. This happens nothwithstanding the fact that a higher μ is still associated with larger b-type cities. This loss in terms of congestion associated to the shifting to configuration 4, in fact, is now more than compensated by a gain in terms of higher localisation economies for the production of intermediates. That is, the change in the sign of $\frac{\partial\bar{\rho}}{\partial\mu}$ is due to the fact that an higher η has a negative effect on the degree of localisation economies

[21] In particular, for any value of μ, τ and for $\sigma > \epsilon$, $L_b > L_f > L_a > L_d > L_c > L_e$ holds, while for $\sigma < \epsilon$ and for $1 - 10\sigma < \mu < 1$, $L_b > L_f > L_c > L_d > L_a > L_e$ holds.

[22] This is due to the fact that in configuration 4 the co-existence of HQs and PPs is avoided and the model only encompasses localisation economies for intermediates producers.

[23] Note that σ is an inverse function of μ, so that a rise in μ is necessarily associated to a lower degree of localisation economies in the ABS sector. Notwithstanding this, we have already explained that changes in σ do not affect the feasibility of configuration 4 starting from 3.

in configuration 3, since it jointly reduces the size of e-type cities and increases their share of headquarters workforce. As a consequence, a rise of μ, as well as a decrese of ϵ, exacerbates this negative effects thereby favouring the urban configuration which encompasses for maximum functional specialisation.

To sum up, if HQ's sub cost function represents a sufficiently large share of total cost function and, moreover, if the labor force directly employed in HQs is a sufficiently high share of the headquarters' sub-cost function, the potential gains for firms and LDs which stem from shifting from configuration 3 to 4 are greater than the losses, and the threshold is greater than unity. In the opposite case, the shift from 3 to 4 would not free enough resources with respect to the additional congestion it would induce, and the threshold would thus be likely to disappear. The spread between the two thresholds ($\bar{\rho} - \hat{\rho}$) only affects the extent of the (ρ, K) range in which configuration 4 is feasible and represents a good measure of the degree of substitutability between the two types of communication costs. This spread is supposed to be strictly increasing in the magnitude of localisation economies, that is, in σ and ϵ. This is essentially due to the fact that while $\hat{\rho}$ is stricly decreasing w.r.t. the latters, $\bar{\rho}$ is constant over σ and, moreover, $\mid \frac{\partial \bar{\rho}}{\partial \epsilon} \mid < \mid \frac{\partial \hat{\rho}}{\partial \epsilon} \mid$ for all the admissible parameters' values.

We may now move to point (iv) and (v), which concern the remaining thresholds $\hat{K}$ and $\bar{K}$. Point (iv) implies that the only way an economy may reach configuration 4 is through 3, provided that $\bar{\rho} \geq 1$. In different terms, multi-location firms won't ever find it profitable to move HQs to a SBC. This result is particularly significant: as far as we accept the hypothesis that change in the spatial organisation of firms are predominantly led by the exogenous dynamics of communication costs, it implies that some urban systems may result stuck in a partially specialised spatial equilibrium as long as the remaining determinants, which attain to the degree of substitutability between varieties and to the cost functions of final good firms, do not change. Furthermore, point (v) allows us to conclude that, unless the localisation economies associated with ABS are very low, a transition from the integrated configuration 1 to 2 is always feasible. The level of $\hat{K}$ is obviously strictly increasing in σ and η.

Finally, in order to further characterise single equilibrium configurations, in the following table I present the shares of each of the city type, given the benchmark parameters' values.

By comparing configuration 3 with 4 we can clearly notice that, fixed the number of cities specialised in business services, no sensible change occurs in the number of cities

	Configuration		
	2	3	4
L_a	0.16	-	-
L_b	-	-	0.01
L_c	0.84	-	0.96
L_e	-	0.97	-
L_f	-	0.03	0.03

Table 1.1: Shares of total cities for city-type and equilibrium urban configuration

specialised in the production of intermediates: from 97% to 96%. The remaining 1% is represented by headquarters' urban centers. Configuration 2 is instead characterised by a lower degree of spatial agglomeration, due to the equilibrium dimension of a-type cities, which is significantly lower than that of f-type and b-type ones.

1.5 Concluding remarks

The model presented in this paper extends the work of Duranton and Puga (2005) according to which the functional specialisation of urban systems is intended as the outcome of coordinated spatial organisation decisions of firms producing final goods. In the original model firms could only decide whether remaining integrated or splitting up into headquarters and production plants, where the latter option necessarily implied locating the two facilities in different cities. According to their framework, the decision was in fact predominantly lead by the level of the communication cost between the two facilities, i.e. the cost of managing production plants at distance. The novel part of my model consists in the introduction of an additional dimension to the firm's spatial problem. In my model firms may also decide whether locating their headquarters in the business service center with business sector or in a different city where they can release some congestion costs at the expense of an additional communication cost. The latter must be intended as a transaction cost or, equivalently, as an higher price for advanced business services. This enriched framework allows me to investigate the effects of the interplay between both types of communication costs dynamics on the urban structure.

I find that the spatial equilibrium characterised by maximum functional specialisation and by the emergence of secondary business centers is not feasible for a large set of parameters' values. In most of the cases, in fact, the economy is likely to shift from an integrated spatial organisation where all the cities host all the functions to a partially specialised one which alternatively encompasses cities hosting integrated firms and cities hosting advanced business services providers or cities hosting production plants and cities hosting headquarters and advanced business services providers.

Moreover, numerical simulations have shown that maximum functional specialisation turns out to be feasible only for those economies which are characterised by the presence of final good firms with a relatively small share of their cost function represented by production plants. This suggests, as expected, that only service oriented economies are worth of reaching the highest level of functional specialisation.

Another remarkable result is that, even when feasible, maximum functional specialisation can be reached only if economy is already partially specialised, that is, already encompassing for primary business centers. This happens if the communication costs with the advanced business services providers are sufficiently low, while firms have not enough incentives to separate managers from production plants. On the contrary, the alternative partially specialised spatial equilibrium encompassing for small manufacturing cities and cities hosting business service providers and headquarters is a stable one in the sense that, once reached, no further decrease in communication costs can make the economy shift to an higher degree of functional specialisation. This could be the case of an economy mainly characterised by multinational firms with managing separated from production and headquarters located in global cities. In this case, the model predicts no sufficient incentives for these firms to proceed in further spatial diversification by moving headquarters away from that business centers.

Finally, when perfect functional specialisation is feasible the model also predicts a non-linear substitution effect between communication costs: when the extra cost associated to buying advanced business services at distance is sufficiently low, the spatial separation between firms' headquarters and production plants is more likely to occur. The extent of localisation economies for business services and intermediate producers only affects the magnitude of the degree of substitutability between communication costs.
Notwithstanding the fact that this paper does not include any welfare analysis, it is worthwhile to stress that these results can be very important from a policy point of view, in that policies aiming at supporting the emergence of "regional urban systems" characterised by an high degree of functional specialisation have to take into account the level of both communication costs and the non-linear effects associated with their dynamics.

Appendices

1.A Break even conditions

(i) HQs and PPs of a firm integrated in the PBC;

$$x^h_{i,i,i}[P^h - (H^h_{i,i,i})^\eta (Q^{m+h}_i)^{1-\eta}] = 0, \quad P^h - (H^h_{i,i,i})^\eta (Q^{m+h}_i)^{1-\eta} \leq 0,$$
$$x^h_{i,i,i} \geq 0 \tag{A.1}$$

(ii) HQs and PPs of a firm integrated outside the PBC (establishment integrated in a SBD);

$$\left(\int_{z\neq i} x^h_{i,i,z} dz\right) [P^h - (K \cdot H^h_{i,i,i})^\eta (Q^{m+h}_i)^{1-\eta}] = 0,$$
$$P^h - (K \cdot H^h_{i,i,i})^\eta (Q^{m+h}_i)^{1-\eta} \leq 0, \quad \int_{z\neq i} x^h_{i,i,z} dz \geq 0 \tag{A.2}$$

(iii) HQs of a multi-location firm, located in the PBC;

$$\left(\int_{j\neq i} x^h_{i,j,i} dj\right) [P^h - (\rho \cdot H^h_{i,i,i})^\eta (\underline{Q}^{m+h})^{1-\eta}] = 0,$$
$$P^h - (\rho \cdot H^h_{i,i,i})^\eta (\underline{Q}^{m+h})^{1-\eta} \leq 0, \quad \int_{j\neq i} x^h_{i,j,i} dj \geq 0 \tag{A.3}$$

(iv) HQs of a multi-location firm, located outside the PBC;

$$\left(\int_{z\neq i}\int_{j\neq i} x^h_{i,j,z} dj dz\right) [P^h - (K\rho \cdot H^h_{i,i,i})^\eta (\underline{Q}^{m+h})^{1-\eta}] = 0,$$
$$P^h - (K\rho \cdot H^h_{i,i,i})^\eta (\underline{Q}^{m+h})^{1-\eta} \leq 0, \quad \int_{z\neq i}\int_{j\neq i} x^h_{i,j,z} dj dz \geq 0 \tag{A.4}$$

(v) PPs of a multi-location firm, with HQs located in the PBC;

$$\left(\int_{j\neq i} x^h_{i,j,i} dj\right) [P^h - (\rho \cdot \underline{H}^h)^\eta (Q^{m+h}_j)^{1-\eta}] = 0,$$
$$P^h - (\rho \cdot \underline{H}^h)^\eta (Q^{m+h}_j)^{1-\eta} \leq 0, \quad \int x^h_{i,j,i} dj \geq 0 \tag{A.5}$$

(vi) PPs of a multi-location firm, with HQs located outside the PBC;

$$\left(\int_{z\neq i}\int_{j\neq i} x^h_{i,j,z}djdz\right)[P^h - (K\rho\cdot \underline{H}^h)^\eta (Q^{m+h}_j)^{1-\eta}] = 0,$$
$$P^h - (K\rho\cdot \underline{H}^h)^\eta (Q^{m+h}_i)^{1-\eta} \leq 0, \quad \int_{z\neq i}\int_{j\neq i} x^h_{i,j,z}djdz \geq 0 \tag{A.6}$$

where integrals $\int_{z\neq i}\int_{j\neq i} x^h_{i,j,z}djdz$, $\int_{j\neq i} x^h_{i,j,i}dj$, $\int_{z\neq i} x^h_{i,i,z}dj$ aggregate respectively the output of multi-location firms, of multi-location firms with headquarters located in the PBC and of integrated firms located outside the PBC; $K\rho\underline{H}^h$, $K\underline{H}^h$, $\rho\underline{H}^h$ and $\underline{Q}^{m+h}$ represent respectively lowest sub-cost functions for stand-alone HQ, for HQ located outside the PBC, for stand-alone HQ located in the PBC and for stand-alone production plants.

1.B Land developer's maximisation problem

In the following I derive an equivalente definition of the developer's problem of (1.18). By Shepard's Lemma:

$$\begin{aligned}
l^h_i =& \frac{\partial C^h_{i,i,i}}{\partial w^h_i}\\
l^h_i =& \eta\mu (w^h_i)^{\eta\mu-1}(w^0_i)^{\eta(1-\mu)}(w^{m+h}_i)^{1-\eta}(l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)}\\
\Rightarrow& (l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)} = \frac{(l^h_i)(w^h_i)^{1-\eta\mu}(w^0_i)^{\eta(\mu-1)}(w^{m+h}_i)^{\eta-1}}{\eta\mu};
\end{aligned}\tag{B.1}$$

$$\begin{aligned}
l^0_i =& \frac{\partial C^h_{i,i,i}}{\partial w^0_i}\\
l^0_i =& \eta(1-\mu)(w^h_i)^{\eta\mu}(w^0_i)^{\eta(1-\mu)-1}(w^{m+h}_i)^{1-\eta}(l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)}\\
\Rightarrow& (l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)} = \frac{(l^0_i)(w^h_i)^{-\eta\mu}(w^0_i)^{1-\eta(1-\mu)}(w^{m+h}_i)^{\eta-1}}{\eta(1-\mu)};
\end{aligned}\tag{B.2}$$

$$\begin{aligned}
l^{m+h}_i =& \frac{\partial C^h_{i,i,i}}{\partial w^{m+h}_i}\\
l^{m+h}_i =& \eta\gamma(w^h_i)^{\eta\mu}(w^0_i)^{\eta(1-\mu)}(w^{m+h}_i)^{1-\eta}(l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)}\\
\Rightarrow& (l^0_i)^{-\eta\sigma}(l^{m+h}_i)^{-\epsilon(1-\eta)} = \frac{(l^{m+h}_i)(w^h_i)^{-\eta\mu}(w^0_i)^{\eta(\mu-1)}(w^{m+h}_i)^{\eta}}{1-\eta};
\end{aligned}\tag{B.3}$$

then, from (B.1) and (B.2), it follows that

$$w_i^h l_i^h = \frac{\mu}{1-\mu} w_i^0 l_i^0, \tag{B.4}$$

while, from (B.2) and (B.3)

$$w_i^0 l_i^0 = \frac{\eta(1-\mu)}{1-\eta} w_i^{m+h} l_i^{m+h}, \tag{B.5}$$

and, then,

$$\begin{cases} w_i^h l_i^h = \frac{\mu}{1-\mu} w_i^0 l_i^0 \\ w_i^{m+h} l_i^{m+h} = \frac{1-\eta}{\eta(1-\mu)} w_i^0 l_i^0 \end{cases}. \tag{B.6}$$

By (1.13) we have

$$w_i^h = (w_i^0)^{-(1-\mu)/\mu} \left[H_{i,i,i}^h (l_i^0)^\sigma \right]^{1/\mu}; \tag{B.7}$$

now, from (B.7) and, given that $w_i^h l_i^h = \sum_{h=1}^m w_i^h l_i^h$,

$$\begin{cases} w_i^0 l_i^0 = (\sum_{h=1}^m w_i^h l_i^h) \frac{1-\mu}{\mu} \\ w_i^h = (w_i^0)^{-(1-\mu)/\mu} \left[H_{i,i,i}^h (l_i^0)^\sigma \right]^{1/\mu} \end{cases}. \tag{B.8}$$

We can now manipulate the first equation in (B.8)[24] to obtain the total wage bill accruing to 0-type workers as a function of l_i^0 and l_i^h:

$$\begin{aligned}
w_i^0 l_i^0 &= \frac{(w_i^0)^{-(1-\mu)/\mu} (l_i^0)^{\sigma/\mu} [\sum_{h=1}^m (H_{i,i,i}^h)^{1/\mu} l_i^h]}{\mu/(1-\mu)} \\
\Rightarrow (w_i^0 l_i^0)^\mu &= [(1-\mu)/\mu]^\mu (w_i^0)^{(\mu-1)} (l_i^0)^\sigma \left[\sum_{h=1}^m (H_{i,i,i}^h)^{1/\mu} l_i^h \right]^\mu \\
\Rightarrow w_i^0 (l_i^0)^\mu &= [(1-\mu)/\mu]^\mu (l_i^0)^\sigma \left[\sum_{h=1}^m (H_{i,i,i}^h)^{1/\mu} l_i^h \right]^\mu \\
\Rightarrow w_i^0 (l_i^0)^\mu (l_i^0)^{1-\mu} &= [(1-\mu)/\mu]^\mu (l_i^0)^\sigma (l_i^0)^{1-\mu} \left[\sum_{h=1}^m (H_{i,i,i}^h)^{1/\mu} l_i^h \right]^\mu \\
\Rightarrow w_i^0 l_i^0 &= [\mu/1-\mu]^{-\mu} \underbrace{(l_i^0)^{1+\sigma-\mu} H_{i,i} \left(\sum_{h=1}^m l_i^h \right)^\mu}_{\psi}.
\end{aligned} \tag{B.9}$$

then, substituting (B.4) [25]into (B.9), and remembering that

$$\sum_{h=0}^{m+1} w_i^h l_i^h = \left(\sum_{h=1}^m w_i^h l_i^h \right) + w_i^0 l_i^0,$$

[24]Note that the last step is allowed since profit maximisation by LD requires $H_{i,i,i}^h = H_{i,i}$ for all h such that $l_i^h \geq 0$.

[25]Note that $\sum_{h=1}^m w_i^h l_i^h = w_i^h l_i^h$.

we get

$$\sum_{h=0}^{m} w_i^h l_i^h = \mu^{-\mu}(1-\mu)^{-(1-\mu)}\psi. \tag{B.10}$$

We can now define the maximisation problem of this component, that is, the LD's programme for given $\sum_{h=0}^{m} l_i^h$ writes as:

$$\max_{\{l_i^0, l_i^h\}} \quad \sum_{h=0}^{m} w_i^h l_i^h = \mu^{-\mu}(1-\mu)^{-(1-\mu)}(l_i^0)^{1+\sigma-\mu} H_{i,i}\left(\sum_{h=1}^{m} l_i^h\right)^{\mu}, \tag{B.11}$$

$$s.t \quad \sum_{h=0}^{m} l_i^h = Z.$$

where Z is a constant. Note that $Z = \left(\sum_{h=1}^{m} l_i^h\right) + l_i^0 \Rightarrow \sum_{h=1}^{m} l_i^h = Z - l_i^0$. Define now: $\Delta = \mu^{-\mu}(1-\mu)^{-(1-\mu)}H_{i,i}$; then, using $\sum_{h=1}^{m} l_i^h = Z - l_i^0$ and taking the μ-root, the maximand becomes:

$$\Delta^{\frac{1}{\mu}} Z(l_i^0)^{\frac{1+\sigma-\mu}{\mu}} - \Delta^{\frac{1}{\mu}}(l_i^0)^{\frac{1+\sigma}{\mu}}. \tag{B.12}$$

by manipulating the first derivative w.r.t. l_i^0 we get the following relation between the i-city HQ and ABS specific workforces:

$$\frac{\partial \sum_{h=0}^{m} w_i^h l_i^h}{\partial l_i^0} = 0 \Rightarrow \sum_{h=1}^{m} l_i^h = \frac{\mu}{(1+\theta)(1-\mu)} l_i^0 = \frac{\mu}{1+\sigma-\mu} l_i^0. \tag{B.13}$$

Then, by substituting (B.13) in the maximand (B.11), we get

$$\sum_{h=0}^{m} w_i^h l_i^h = \frac{(1+\theta)^{-\mu}}{1-\mu} H_{i,i}(l_i^0)^{1+\theta(1-\mu)};$$

and, from (1.13)

$$\sum_{h=1}^{m} w_i^{m+h} l_i^{m+h} = \sum_{h=1}^{m} Q_i^{m+h}(l_i^{m+h})^{1+\epsilon}.$$

We can now substitute the latter two summations into the developer programme of (1.18)

$$\Pi_i = \sum_{h=0}^{m} w_i^h l_i^h + Q_i^{m+h}(l_i^{m+h})^{1+\epsilon} - L_i \bar{e},$$

so that the LD's objective function writes as

$$\max_{\{l_i^0, l_i^h, l_i^{m+h}\}} \Pi_i, \quad \Pi_i = \frac{(1+\theta)^{-\mu}}{1-\mu} H_{i,i}(l_i^0)^{1+\theta(1-\mu)} + Q_{i,i}^{m+h}(l_i^{m+h})^{1+\epsilon} - L_i \bar{e}. \tag{B.14}$$

1.C City sizes (Proof of Lemma 2)

The proof of Lemma w.r.t. to cases (a), (c), and (d) traces back to Duranton and Puga (2004) and Duranton and Puga (2005).

1.C.1 Case (b)

Consider a city hosting only headquarters of multi-location firms,the equilibrium unit production cost for firms in sector h is:

$$c_b^h = (\rho \cdot K)^\eta (w_b^h)^{\eta\mu} (w_b^0)^{\eta(1-\mu)} (w_b^{m+h})^{1-\eta} (l_b^0)^{-\eta\sigma} (l_b^{m+h})^{-\epsilon(1-\eta)} \tag{C.1}$$

By Shepard's Lemma:

$$w_b^0 = \frac{(1-\mu) w_b^h l_b^h}{\mu l_b^0} \tag{C.2}$$

Substituting (C.2) into (C.1) yields:

$$c_b^h = (\rho \cdot K)^\eta [w_b^{m+h} (l_b^{m+h})^{-\epsilon}]^{(1-\eta)} (w_b^h)^\eta \left(\frac{1-\mu}{\mu}\right)^{\eta(1-\mu)} (l_b^0)^{-\eta(1-\mu+\sigma)} (l_b^h)^{\eta(1-\mu)} \tag{C.3}$$

then, given that $c_b^h = P^h$:

$$\sum_{h=0}^{2m} w_b^h l_b^h = w_b^h l_b^h = \left\{ \frac{P^h (\mu)^{\eta(1-\mu)} (l_b^0)^{\eta(1-\mu+\sigma)} (l_b^h)^{\eta\mu}}{(\rho \cdot K)^\eta [w_b^{m+h} (l_b^{m+h})^{-\epsilon}]^{(1-\eta)} (w_b^h)^\eta (1-\mu)^{\eta(1-\mu)}} \right\}^{1/\eta} \tag{C.4}$$

and,

$$l_b^h = L_b^h (1 - \tau L_b^h) \tag{C.5}$$

so as:

$$Max_{l_b^h, l_b^{m+h}} \; \Pi_b, \quad \Pi_b = \left\{ \frac{P^h (\mu)^{\eta(1-\mu)} (l_b^0)^{\eta(1-\mu+\sigma)} (l_b^h)^{\eta\mu}}{(\rho \cdot K)^\eta [w_b^{m+h} (l_b^{m+h})^{-\epsilon}]^{(1-\eta)} (w_b^h)^\eta (1-\mu)^{\eta(1-\mu)}} \right\}^{1/\eta} - L_b^h \bar{e} \tag{C.6}$$

subject to (C.5), is the equivalent developer's programme of (1.18). First order conditions for (C.6) together with (C.5) and $\Pi_b^h = 0$ yield equilibrium population for any city hosting only headquarters as:

$$L_b = \frac{1+\mu}{\tau(1+2\mu)} \tag{C.7}$$

1.C.2 Case (e)

Consider a city hosting only integrated firms and intermediates suppliers,the equilibrium unit production cost for firms in sector h is:

$$c_e^h = K^\eta (w_e^h)^{\eta\mu} (w_e^0)^{\eta(1-\mu)} (w_e^{m+h})^{1-\eta} (l_e^0)^{-\eta\sigma} (l_e^{m+h})^{-\epsilon(1-\eta)} \tag{C.8}$$

By Shepard's Lemma[26]:

$$w_e^0 l_e^0 = \frac{1-\mu}{\mu} w_e^h l_e^h = \frac{\eta(1-\mu)}{1-\eta} w_e^{m+h} l_e^{m+h} \tag{C.9}$$

By Shepard's Lemma and (B.13):

$$w_e^0 = \frac{w_e^h}{1+\theta}, \qquad w_e^h = \frac{\eta\mu}{1-\eta} \frac{w_e^{m+h} l_e^{m+h}}{l_e^h} \tag{C.10}$$

Substituting (C.10) into (C.8) yields:

$$c_e^h = w_e^{m+h} l_e^{m+h} K^\eta \,(1+\theta)^{-\eta(1-\mu)}\, (l_e^0)^{-\eta\sigma} (l_e^h)^{-\eta)} (l_e^{m+h})^{(-\epsilon(1-\eta)-1} \tag{C.11}$$

then, given that $c_e^h = P^h$:

$$\begin{aligned}\sum_{h=0}^{2m} w_e^h l_e^h = w_e^h l_e^h + w_e^{m+h} l_e^{m+h} = \frac{-\mu}{(1-\eta)} w_e^{m+h} l_e^{m+h} = \\ = \frac{(1-\eta) P^h (l_e^0)^{\eta\sigma} (l_e^h)^\eta (l_e^{m+h})^{1+\epsilon(1-\eta)}}{-\mu K^n \,(1+\theta)^{\eta(1-\mu)}}\end{aligned} \tag{C.12}$$

and,

$$l_e^h + l_e^{m+h} = L_e^h (1 - \tau L_e^h) \tag{C.13}$$

so as:

$$Max_{l_e^h}\ \Pi_e, \quad \Pi_e = \frac{(1-\eta) P^h (l_e^0)^{\eta\sigma} (l_e^h)^\eta (l_e^{m+h})^{1+\epsilon(1-\eta)}}{-\mu K^n \,(1+\theta)^{\eta(1-\mu)}} - L_e^h \bar{e} \tag{C.14}$$

subject to (C.13), is the equivalent developer's programme of (1.18). First order conditions for (C.14) together with (C.13) and $\Pi_e^h = 0$ yield equilibrium population for any city hosting only headquarters as:

$$L_e = \frac{\epsilon(1-\eta)}{\tau[1 + 2\epsilon(1-\eta)]} \tag{C.15}$$

Total population then splits between occupations as:

$$l_e^h = \frac{\eta}{1+\epsilon(1-\eta)} L_e^h (1 - \tau L_e) \tag{C.16}$$

$$l_e^{m+h} = \frac{(1+\epsilon)(1-\eta)}{1+\epsilon(1-\eta)} L_e^h (1 - \tau L_e) \tag{C.17}$$

[26] See (B.6).

1.C.3 Case (f)

Consider a city hosting only business service providers,the equilibrium unit production cost for a multi-location (or integrated [27]) firm in sector h buying business services from that city is:

$$c_f^h = (\rho \cdot K)^\eta (w_f^h)^{\eta\mu} (w_f^0)^{\eta(1-\mu)} (w_f^{m+h})^{1-\eta} (l_f^0)^{-\eta\sigma} (l_f^{m+h})^{-\epsilon(1-\eta)} \tag{C.18}$$

From (B.6):

$$w_f^h = \frac{\mu w_f^0 l_f^0}{(1-\mu) l_f^h} \tag{C.19}$$

Substituting (C.19) into (C.18) yields:

$$c_f^h = (\rho \cdot K)^\eta (w_f^0)^{(1-\mu)\eta} (l_f^0)^{-\eta\sigma} (w_f^{m+h})^{1-\eta} (l_f^{m+h})^{-\epsilon(1-\eta)} (w_f^h)^{\mu\eta} \tag{C.20}$$

then, given that $c_f^h = P^h$:

$$\sum_{h=0}^{2m} w_f^h l_f^h = w_f^0 l_f^0 = \left\{ \frac{P^h (l_f^0)^{\eta(1-\mu+\sigma)} (l_f^{m+h})^{\epsilon(1-\eta)}}{(\rho \cdot K)^\eta (w_f^h)^{\mu\eta} (w_f^{m+h})^{1-\eta}} \right\}^{1/\eta(1-\mu)} \tag{C.21}$$

and,

$$l_f^0 = L_f^h (1 - \tau L_f^h) \tag{C.22}$$

so as:

$$Max_{l_f^0}\ \Pi_f, \quad \Pi_f = \left\{ \frac{P^h (l_f^0)^{\eta(1-\mu+\sigma)} (l_f^{m+h})^{\epsilon(1-\eta)}}{(\rho \cdot K)^\eta (w_f^h)^{\mu\eta} (w_f^{m+h})^{1-\eta}} \right\}^{1/\eta(1-\mu)} - L_f^h \bar{e} \tag{C.23}$$

subject to (C.22), is the equivalent developer's programme of (1.18). First order conditions for (C.23) together with (C.22) and $\Pi_f^h = 0$ yield equilibrium population for any city hosting only headquarters as:

$$L_f = \frac{\sigma}{\tau[1 - \mu + 2\sigma]} \tag{C.24}$$

1.D Thresholds (Proof of Proposition 1)

1.D.1 From spatial configuration 1 to 2

The equilibrium unit production cost for multi-location firms with headquarters co-located with business service providers is:

$$c_a^h = (\rho)^\eta (w_a^h)^{\eta\mu} (w_a^0)^{\eta(1-\mu)} (w_c^{m+h})^{1-\eta} (l_a^0)^{-\eta\sigma} (l_c^{m+h})^{-\epsilon(1-\eta)} \tag{D.1}$$

[27] In this case $(\rho \cdot K)^\eta$ should be replaced by K^η, yelding the same results.

Dividing this by the unit production cost for fully integrated firms yields:

$$\frac{c_a^h}{c_d^h} = \left(\frac{\rho}{\hat{\rho}}\right)^{\eta} \tag{D.2}$$

where:

$$\hat{\rho} = \left[\left(\frac{w_d^h}{w_a^h}\right)^{\eta\mu}\left(\frac{w_d^0}{w_a^0}\right)^{\eta(1-\mu)}\left(\frac{w_d^{m+h}}{w_c^{m+h}}\right)^{1-\eta}\left(\frac{l_d^0}{l_a^0}\right)^{-\eta\sigma}\left(\frac{l_d^{m+h}}{l_c^{m+h}}\right)^{-\epsilon(1-\eta)}\right]^{\frac{1}{\eta}} \tag{D.3}$$

By Shepard's Lemma and (B.13):

$$\frac{w_a^h}{w_a^0} = 1+\theta; \quad \frac{w_a^{m+h}}{w_a^0} = \frac{(1-\eta)l_a^0}{\eta(1-\mu)l_a^{m+h}}; \tag{D.4}$$

The developer programme of (1.18), together with the exhaustion of developers' profits due to free entry imply:

$$\frac{1}{\eta(1-\mu)}w_d^0 l_d^0 = L_d\bar{e}; \quad \frac{1}{1-\mu}w_a^0 l_a^0 = L_a\bar{e}; \quad w_c^{m+h}l_c^{m+h} = L_c\bar{e} \tag{D.5}$$

From (D.4) and (D.5),

$$\frac{w_d^h}{w_a^h} = \frac{w_d^0}{w_a^0} = \frac{\eta L_d l_a^0}{L_a l_d^0}; \quad \frac{w_d^{m+h}}{w_c^{m+h}} = \frac{(1-\eta)L_d l_c^{m+h}}{L_c l_d^{m+h}} \tag{D.6}$$

Then, from $\sum_{h=0}^{2m} l_i^h = L_i(1-\tau L_i)$ and (B.13):

$$l_a^0 = \frac{1+\sigma-\mu}{1+\sigma}L_a^h(1-\tau L_a^h) \tag{D.7}$$

$$l_c^{m+h} = L_c(1-\tau L_c) \tag{D.8}$$

while, from Lemma 2,

$$l_d^0 = \frac{\eta(1+\sigma-\mu)}{1+\gamma}L_d^h(1-\tau L_d^h) \tag{D.9}$$

$$l_d^{m+h} = \frac{(1-\eta)(1+\epsilon)}{1+\gamma}L_d^h(1-\tau L_d^h) \tag{D.10}$$

Substituting (D.6), (D.7), (D.8), (D.9), (D.10) and Lemma 2 into (D.3) and simplifying yields the value of $\hat{\rho}$ given in the proposition. When $\rho < \hat{\rho}$,and if no other functional specialisation trend is present, total mass of cities split between cities of type (a) and type (c). We denote by N_a the mass of cities that host headquarters of multi-location firms plus advanced business services and by N_c the mass of cities that host production plants of multi-location firms. By Shepard's Lemma,

$$\frac{w_a^0 l_a^0 N_a}{w_c^{m+h} l_c^{m+h} N_c} = \frac{\eta(1-\mu)}{1-\eta}$$

Combining this with (D.6) yields the share of cities hosting only headquarters of multi-location firms plus advanced business services when $\rho < \hat{\rho}$ as

$$\frac{\eta\epsilon(1+2\sigma)}{\eta\epsilon(1+2\sigma)+(1-\eta)\sigma(1+2\epsilon)}$$

Remaining cities specialise in production and, by symmetry, there are equal proportions of cities specialised in each of the m sectors.

1.D.2 From spatial configuration 1 to 3

The equilibrium unit production cost for integrated firms buying business services from abroad is:

$$c_e^h = (K)^\eta (w_e^h)^{\eta\mu} (w_f^0)^{\eta(1-\mu)} (w_e^{m+h})^{1-\eta} (l_f^0)^{-\eta\sigma} (l_e^{m+h})^{-\epsilon(1-\eta)} \tag{D.11}$$

Dividing this by the unit production cost for fully integrated firms yields:

$$\frac{c_e^h}{c_d^h} = \left(\frac{K}{\hat{K}}\right)^\eta \tag{D.12}$$

where:

$$\hat{K} = \left[\left(\frac{w_d^h}{w_e^h}\right)^{\eta\mu} \left(\frac{w_d^0}{w_f^0}\right)^{\eta(1-\mu)} \left(\frac{w_d^{m+h}}{w_e^{m+h}}\right)^{1-\eta} \left(\frac{l_d^0}{l_f^0}\right)^{-\eta\sigma} \left(\frac{l_d^{m+h}}{l_e^{m+h}}\right)^{-\epsilon(1-\eta)}\right]^{\frac{1}{\eta}} \tag{D.13}$$

By Shepard's Lemma,

$$\frac{w_d^0}{w_d^h} = \frac{1-\mu}{\mu}\frac{l_d^h}{l_d^0} \tag{D.14}$$

The developer programme of (1.18), together with the exhaustion of developers' profits due to free entry imply:

$$w_d^h l_d^h = \eta\mu L_d \bar{e}; \quad w_f^0 l_f^0 = L_f \bar{e}; \quad w_e^{m+h} l_e^{m+h} = \frac{1-\eta}{1-\eta+\mu\eta} L_e \bar{e};$$
$$w_d^{m+h} l_d^{m+h} = (1-\eta) L_d \bar{e}; \quad w_e^h l_e^h = \frac{\mu\eta}{1-\eta+\mu\eta} L_e \bar{e}; \quad w_d^0 l_d^0 = \eta(1-\mu) L_d \bar{e} \tag{D.15}$$

From (D.14) and (D.15),

$$\frac{w_d^h}{w_e^h} = \frac{[1-\eta(1-\mu)] L_d l_e^h}{L_e l_d^h}; \quad \frac{w_d^{m+h}}{w_e^{m+h}} = \frac{[1-\eta(1-\mu)] L_d l_e^{m+h}}{L_e l_d^{m+h}}; \quad \frac{w_d^0}{w_f^0} = \frac{\eta(1-\mu) L_d (1-\tau L_f)}{l_d^0} \tag{D.16}$$

Then, from $\sum_{h=0}^{2m} l_i^h = L_i(1-\tau L_i)$ and (B.13):

$$l_f^0 = L_f(1-\tau L_f) \tag{D.17}$$

Substituting (D.9), (D.10),(D.16), (D.17) and Lemma 2 into (D.13) and simplifying yields the value of $\hat{K}$ given in the proposition. When $K < \hat{K}$,and if no other functional specialisation trend is present, total mass of cities split between cities of type (e) and type (f).

1.D.3 From spatial configuration 3 to 4

The equilibrium unit production cost for firms adopting multi-location of (1.17) is:

$$c_b^h = (\rho \cdot K)^{\eta}(w_b^h)^{\eta\mu}(w_f^0)^{\eta(1-\mu)}(w_c^{m+h})^{1-\eta}(l_f^0)^{-\eta\sigma}(l_c^{m+h})^{-\epsilon(1-\eta)} \tag{D.18}$$

Dividing this by the unit production cost for partially integrated ex-CD firms yields:

$$\frac{c_b^h}{c_e^h} = \left(\frac{\rho}{\bar{\rho}}\right)^{\eta} \tag{D.19}$$

where:

$$\bar{\rho} = \left[\left(\frac{w_e^h}{w_b^h}\right)^{\eta\mu}\left(\frac{w_e^{m+h}}{w_c^{m+h}}\right)^{1-\eta}\left(\frac{l_e^{m+h}}{l_c^{m+h}}\right)^{-\epsilon(1-\eta)}\right]^{\frac{1}{\eta}} \tag{D.20}$$

By Shepard's Lemma we have that $w_e^h l_e^h = \frac{\mu\eta}{1-\eta} w_e^{m+h} l_e^{m+h}$ and,

$$\frac{w_e^h}{w_e^{m+h}} = \frac{\mu\eta}{1-\eta}\frac{l_e^{m+h}}{l_e^h} \tag{D.21}$$

The developer programme of (1.18), together with the exhaustion of developers' profits due to free entry, implies:

$$w_b^h l_b^h = L_b\bar{e}; \quad w_c^{m+h} l_c^{m+h} = L_c\bar{e}; \quad w_e^{m+h} l_e^{m+h} = \frac{1-\eta}{1-\eta+\mu\eta} L_e\bar{e} \tag{D.22}$$

From (D.21), (D.22),

$$w_e^h = \frac{\mu\eta}{1-\eta+\mu\eta}\frac{L_e\bar{e}}{l_e^h} \tag{D.23}$$

From (D.21), (D.22), (D.23),

$$\frac{w_e^h}{w_b^h} = \frac{\mu\eta}{1-\eta+\mu\eta}\frac{L_e(1-\tau L_b)}{l_e^h}; \quad \frac{w_e^{m+h}}{w_c^{m+h}} = \frac{1-\eta}{1-\eta+\mu\eta}\frac{L_e(1-\tau L_c)}{l_e^{m+h}}; \tag{D.24}$$

Substituting (C.17), (D.8) and Lemma 2 into (D.20) and simplifying yields the value of $\bar{\rho}$ given in the proposition. When $\rho < \bar{\rho}$, total mass of cities split between cities of type (b), type (f) and type (c).

1.D.4 From spatial configuration 2 to 4

Dividing the equilibrium unit production cost of (D.18) by the equilibrium unit production cost for firms adopting multi-location organisational form of (1.16) yields:

$$\frac{c_b^h}{c_a^h} = \left(\frac{K}{\bar{K}}\right)^{\eta} \tag{D.25}$$

where:

$$\bar{K} = \left[\left(\frac{w_a^h}{w_b^h}\right)^{\eta\mu}\left(\frac{w_a^0}{w_f^0}\right)^{\eta(1-\mu)}\left(\frac{l_a^0}{l_f^0}\right)^{-\eta\sigma}\right]^{\frac{1}{\eta}} \tag{D.26}$$

The developer programme of (1.18), together with the exhaustion of developers' profits due to free entry imply:

$$w_a^0 l_a^0 = (1-\mu)L_a\bar{e}; \quad w_a^h l_a^h = \mu L_a \bar{e}; \quad w_b^h l_b^h = L_b\bar{e}; \quad w_f^h l_b^f = L_f\bar{e} \tag{D.27}$$

From (D.27),

$$\frac{w_a^h}{w_b^h} = \mu\frac{L_a(1-\tau L_b)}{l_a^h}; \quad \frac{w_a^0}{w_f^0} = (1-\mu)\frac{L_a(1-\tau L_f)}{l_a^0} \tag{D.28}$$

Again, from $\sum_{h=0}^{2m} l_i^h = L_i(1-\tau L_i)$ and Lemma 2,

$$l_a^h = \frac{\mu}{1+\sigma}L_a^h(1-\tau L_a^h) \tag{D.29}$$

Substituting (D.7), (D.17), (D.29) and Lemma 2 into (D.25) and simplifying yields the value of $\bar{K}$ given in the proposition. When $K < \bar{K}$, total mass of cities split between cities of type (b), type (f) and type (c).

Chapter 2

Trade Liberalisation between Asymmetric Countries with Environmentally Concerned Consumers

2.1 Introduction

In the last two decades, economists have massively contributed to the discussion on the environmental effects of trade liberalisation and the effects of countries' environmental conditions on their competitivity. This task has been carried out taking into consideration different industrial configurations, either Bertrand or Cournot competition as well as different definitions of the environmental damage.

What we propose here is an additional contribution that formally tackles the problem relying on a spatial framework *à la* Hotelling, were two firms produce an horizontally differentiated good. The comparatively small theoretical literature existing in this area (see Lambertini (1997a); and Tharakan and Thisse (2002)) has indeed pointed out the presence of interesting asymmetric effects on welfare, arising in that specific, partial equilibrium framework. In the spatial framework, in fact - if transport costs are quadratic in distance - the smaller country has been shown to undoubtedly benefit from free trade by increasing its own firm's sales: its firm's profits increase at the expenses of the consumer surplus of the larger country. This also implies that trade liberalisation, although improving welfare at the world level, necessarily has a negative impact on the welfare of the larger among the two countries: if firms can preserve market power via endogenous differentiation, the geographical size matters and trade liberalisation asymmetric effects on welfare are mainly driven by profits dynamics. Our intention is to verify whether taking environmental issues into account may modify this conclusion in favour of a positive symmetric effect of trade liberalisation which, obviously, is a necessary condition for free trade to emerge spontaneously at equilibrium. In our model, asymmetry in size and horizontal product differentiation combine with a few additional features: (i) consumers in larger of the two countries are environmentally concerned, while their fellow consumers abroad are not; as a result, (ii) the firm based in the environmentally aware market is green from the outset, while her equivalent based abroad is brown; and (iii) pollution is taken to be a consequence of consumption, so that it is not transboundary under autarky, while any penetration of the environmentally aware country on the part of the brown firm causes environmentally concerned consumers to experience some degree of environmental externality, increasing in the volume of imports. To this regard, a few aspects require some clarification. First, since in the real world larger countries are generally net exporters of polluting products, in our model, country size is to be intended as the number of consumers with a sufficiently high disposable income which are then supposed to share a similar consumption pattern with analogous consumers worldwide. This allows us to say that large emerging countries (China, India and Brazil) are, *de facto*, small relative to developed countries such that those of Western Europe. Second, the fact that in our model the smaller (poorer) country's firm is the one producing a brown good may be justified by resorting to the so-called *pollution haven hypothesis*: poorer countries have a comparative advantage in the production of brown goods, given their laxer pollution policies.[1]

Finally, even if the model encompasses exclusively the special case of contiguous countries, it is perfectly able to account for trade liberalisation effects in the case of geographically distant countries, provided that the negative externality is generated by consumption rather than by production. Our model is therefore suitable for approaching some policy issues: may consumers' environmental awareness, *per se*, change the distribution of gain and losses stemming from trade liberalisation by limiting the demand of the brown good? Must a tariff/subsidy policy intervene to correct or eliminate altogether this externality? We find that the large country can gain from trade liberalisation only if a reversal of the pattern of trade is feasible, that is, if the smaller country is not so small. In that case, in fact, the former can always adopt a subsidy policy to induce the trade reversal and this, in addition to setting the home emission level to zero, reduces its level abroad.

Our work draws on three strands of the theoretical literature: the first on spatial competition *à la* Hotelling, the second on the environmental effects of international trade (in the presence of a trade policy) and the third on the environmental effects of consumers' environmental awareness. Suitable background for the first one is available in standard references such as D'Aspremont, Gabszewicz, and Thisse (1979), Lambertini (1997b) and Tabuchi and Thisse (1995) as well as in Lambertini (1997a) and Tharakan and Thisse (2002). The latter two works specifically focus on the effects of international trade in a Hotelling international duopoly and, since they both encompass asymmetry in the size of countries, also represent the most appropriate comparative background for our model.[2]

The second strand of literature is particularly rich and contributions have proceeded in several directions. We may refer the reader to works which merely or primarily attempt to assess the links between trading regimes and environmental outcomes, these being defined in terms of level/incidence of pollution[3] or in terms of natural resources/environmental

[1] To this regard, see Copeland and Taylor (2004) for a review.

[2] The same question is posed in a similar framework by Shachmurove and Spiegel (1995), while Egger and Egger (2007, 2010) analyze the consequences of free trade in a spatial model allowing for a change in the industrial structure and in firms' organization.

[3] See Copeland and Taylor (2003, 2004) for an exhaustive review of the literature. As an example, the framework proposed by Copeland and Taylor (1994), is that of a static two-country model where each country produces a continuum of goods differentiated by the degree of greenness (here authors allow the government to set pollution taxes); they find that income is positively correlated with the degree of

capital depletion.[4] Secondly, a larger part of this literature has essentially faced policy issues, both in terms of environmental policies (price controls, emission tradable permits and pollution quotas) and trade policies. To this regard, comprehensive assessments are provided by Copeland and Taylor (2004) and Copeland (2011) referring both to what concerns the effects of trade liberalisation on environmental policy and the effects of environmental problems on trade policy.[5] To this regard, issues of particular interest are the use of trade policies to achieve environmental objectives and vice-versa, the adoption of environmental policy in order to distort trade flows. Moreover, a few contributions has focused on the relation between trade, transboundary pollution and climate change.[6]

Concerning the third strand of literature, despite the fact that our model includes a very simple modelisation of environmental awareness, it is reminiscent of previous important contributions such as Conrad (2005), tackling the problem of the effect of environmental awareness on equilibrium prices, product characteristics and market shares of two Hotelling-style firms. Again in a spatial framework, remarkable works are those of Rodríguez-Ibeas (2007) and Clemenz (2010), while Yakita and Yamauchi (2011) adopt a Cournot oligopoly framework with horizontal product differentiation. Papers by Eriksson (2004), Moraga-González and Padrón-Fumero (2002) and Bansal and Gangopadhyay (2003) are largely focus on the relation between the presence of environmentally concerned consumers and the efficacy of environmental policies, while Espinola-Arredondo and Zhao (2011) try to assess the welfare implications of subsidisation/taxation policies in a linear

environmental protection, while, in the presence of a sufficiently unequal distribution of income at the world level, free trade raises pollution. In a similar manner Antweiler, Copeland, and Taylor (2001) introduce a pollution tax which is shown to influence the pattern of trade, coherently with the *pollution haven hypothesis*: the higher the country's income, the stricter the pollution policy, the higher the comparative advantage in clean good. Finally, Fujiwara (2009) investigates the effects of free trade on global stock of pollution using a two-country differential game model. Additional contributions are the works from Zeng and Zhao (2009), Ederington, Levinson, and Minier (2004) and, in a purely empirical context, Frankel and Rose (2005).

[4] Here, primary references are the papers from Brander and Taylor (1997) and Copeland and Taylor (1999); the former concludes that trade may be welfare reducing for a small country net exporter of diversified resources since it enhances natural resources depletion, while the latter provides an explanation for trade based on spatial separation of incompatible industries due to production-production negative externalities in terms of reduction of environmental capital. Chichilnisky (1994) proposes an explanation of international (North-South) trade based on the difference in the definition of property rights on environmental resources, in her framework, taxing the use of resources in the South leads to increasing extraction. More Recent works are those of Taylor (2011) and Copeland and Taylor (2009). The former develops a model in which open access together with natural resource's fixed price and innovation can explain how international trade can bring about a rapid decline in the environmental capital of a country while the latter link the country's choice of the resource exploitation regime to the dynamics of world prices.

[5] With respect to the this issue other remarkable references are the works by Neary (2006), Haupt (2006), McAusland (2008) and Bagwell and Staiger (2001).

[6] To this regard see Copeland and Taylor (2005), Fischer and Fox (2009), Gros (2009), Keen and Kotsogiannis (2011) and Holland (2009).

city model very similar to ours, even if abstracting from the effects of trade.

The remainder of the paper is organized as follows. Section 2 presents the model, the autarkic equilibrium and the the effects of trade liberalisation. Section 3 shows how different trade policies can affect long run social welfare of both countries. Section 4 considers the opposite case in which the larger country is the one where the brown good is produced. Section 5 concludes.

2.2 The model

We rely on the general framework of D'Aspremont, Gabszewicz, and Thisse (1979) as modified by Lambertini (1997a) by introducing asymmetry in countries' size. Two firms operate in a linear world of unit length where firm 1 is necessarily located in country 1 and firm 2 in country 2. Consumers are uniformly distributed over $[0, 1]$ with density 1 and that a share α of them belongs to country 1 while the complement to 1 belongs to country 2. Since α is to be intended as the border, asymmetry in countries' sizes is ensured by limiting it in the interval $(0, 1/2)$ so as country 1 is smaller than country 2. A constant marginal cost of production is common to both firms[7] and no relocation costs are modelled. We extend the model by supposing existence of an additional asymmetry w.r.t. the environmental impact of consumption, in such a way that consuming the product supplied by firm 1 entails a negative externality, while the good supplied by firm 2 is green. We may justify this assumption by supposing that consumers in country 2 have developed an environmental awareness at some point in the past, while this does not apply to consumers living in country 1. This has two consequences. The first is the presence of a linear damage function such that country i's social welfare is reduced by an amount D_i which is equal to:

$$D_i = \beta y_{1i} \quad \text{with} \quad i = 1, 2,$$

where y_{1i} is country i's total consumption of the brown good produced by firm 1 while β represents the emission intensity. The second consequence is the representation of consumer preferences in the two countries. In both, each consumer has a unit demand and consumption yields a constant positive surplus s; net utility, however, will or will not account for pollution, depending on the location of a specific consumer. Consider first an individual based in country 1. For him/her, net utility is defined as:

$$U_1 = s - td_i^2 - p_i, \quad i = 1, 2, \tag{2.1}$$

[7] Here assumed to be nil without loss of generality.

where p_i is the price of variety i and td_i^2 is the transportation cost, quadratic in distance d_i from firm i; the latter is defined as:

$$d_i = m - x_i, \tag{2.2}$$

where m and x_i are, respectively, the generic consumer's and firm's i locations.
Looking instead at a consumer based in country 2, the corresponding net surplus is defined as:

$$U_2 = s - td_i^2 - p_i - D_2, \quad i = 1, 2, \tag{2.3}$$

where $D_2 = 0$ in autarky. For the sake of simplicity, and without further loss of generality, we also normalize the transportation cost rate t to one.

2.2.1 Autarkic equilibrium

autarky, the monopoly price set by each firm nullifies the net surplus U_i of the marginal consumers, i.e., those living at country borders 0, α or 1:

$$p_1^A = s - (\alpha - x_1^A)^2; \quad p_2^A = s - (1 - x_2^A)^2, \tag{2.4}$$

where $x_1^A = \alpha/2$ and $x_2^A = (\alpha+1)/2$ are the socially optimal locations in autarky (denoted by superscript A), minimizing total transportation costs in each country:

$$TC_1^A = \int_0^\alpha (d_1)^2 dm; \quad TC_2^A = \int_\alpha^1 (d_2)^2 dm. \tag{2.5}$$

These of course also appears in the definition of consumer surpluses:

$$CS_1^A = \int_0^\alpha [s - p_1 - (d_1)^2] dm; \quad CS_2^A = \int_\alpha^1 [s - p_2 - (d_2)^2] dm. \tag{2.6}$$

As for social welfare in country 1 and 2, respectively defined as:

$$SW_1^A = \pi_1^A + CS_1^A - \beta\alpha; \quad SW_2^A = \pi_2^A + CS_2^A;$$

the autarky equilibrium yields:

$$SW_1^A = \alpha \left(s - \frac{1}{12}\alpha^2 - \beta \right); \quad SW_2^A = (1-\alpha)[s - \frac{1}{12}(1-\alpha)^2]. \tag{2.7}$$

Note that while social welfare of country 1 is negatively affected by consumption of the brown good ($y_{11}^A = \alpha$), this does not affect social welfare of country 2 (since the externality is generated by consumption, no transboundary pollution is supposed to exist). Moreover, non negativity of both prices requires imposing a condition on the level of gross consumer surplus common to all consumers, which is (see Appendix A.1):

$$s \geq s_p^A = \frac{1}{4}\left(1 - 2\alpha + \alpha^2\right). \tag{2.8}$$

The autarkic equilibrium definitions of other relevant magnitudes are reported in Appendix A.

2.2.2 The free trade equilibrium

In this section we evaluate the consequences of trade liberalisation by allowing firms to relocate and adjust prices in order to maximize profits. The only restriction we pose is that firms cannot relocate outside the unit segment measuring the size of this two-country economy.[8] The first step consists in understanding whether the environmental externality can affect the equilibrium partition of demand under free trade, or not.

Lemma 1 *[Demand partition and environmental awareness] The position of the indifferent consumer is independent of emission intensity (or environmental awareness).*

Proof. The indifferent consumer's location $\hat{m}$ (i.e., the identity of the consumer which determining market shares) is identified by the following condition:

$$p_1^T + (\hat{m} - x_1^T)^2 + \beta(\hat{m} - \alpha) = p_2^T + (\hat{m} - x_2^T)^2 + \beta(\hat{m} - \alpha), \tag{2.9}$$

where superscript T stands for *free trade* and the term $\beta(\hat{m} - \alpha)$ represents the value of the damage function D_2 when $\hat{m} - \alpha$ consumers of country 2 buy from firm 1. This condition is then defined only for $\hat{m} > \alpha$ which implies the marginal consumer has to be located in country 2.

Solving (2.9) for $\hat{m}$ then yields:

$$\hat{m} = \frac{p_1^T - p_2^T + (x_1^T)^2 - (x_2^T)^2}{2(x_1^T - x_2^T)}. \tag{2.10}$$

Market demands are therefore defined as:

$$y_1^T = \hat{m} = \begin{cases} \hat{m} & iff \quad \hat{m} \in (0,1); \\ 1 & iff \quad \hat{m} \geq 1; \\ 0 & iff \quad \hat{m} \leq 0. \end{cases} \quad ; \quad y_2^T = 1 - \hat{m} = \begin{cases} 1 - \hat{m} & iff \quad 1 - \hat{m} \in (0,1); \\ 1 & iff \quad 1 - \hat{m} \geq 1; \\ 0 & iff \quad 1 - \hat{m} \leq 0. \end{cases} . \tag{2.11}$$

[8] In this respect, the present approach differs from what is typically accepted in other papers using the same model (Tabuchi and Thisse (1995); Lambertini (1997b)). The reason is that here the single spatial dimension necessarily accounts for both possible interpretations, as a geographical space and as the preference space.

■

That is, since consumers in country 2 incorporate the environmental externality irrespectively of their consumption choice (whether green or brown), the volume of firm 1's exports to country 2 is altogether unaffected by the environmental awareness of the recipients. As a consequence, the two-stage subgame perfect equilibrium in pure strategies arising under free trade coincides with Lambertini (1997a), with maximum differentiation at $x_1^T = 0$, $x_2^T = 1$ and equilibrium prices and profits $p_1^L = p_2^L = t = 1$; and $\pi_1^L = \pi_2^L = \frac{t}{2} = \frac{1}{2}$. And, of course, $\hat{m} = \frac{1}{2}$.
No additional condition on s, α, β is thus required to ensure the non-negativity of prices and profits while a new condition on gross surplus must hold in order for full market coverage to be sustainable, i.e.,

$$s \geq s_{MC}^T = \frac{1}{4}[5 + 2\beta(1 - 2\alpha)], \tag{2.12}$$

where

$$s_{MC}^T > s_p^A \qquad \forall \alpha \in]0, 1/2[, \beta \in]0, 1[,$$

so as condition for market coverage in the long run also ensures non-negativity of prices in autarky. Concerning *price dynamics* in the shift from autarky to free trade, we have that $p_1^L < p_1^A$ and $p_2^L < p_2^A$ $\forall \alpha \in (0, 1/2), \beta \in (0, 1)$. Remaining magnitudes are reported in Appendix A.

2.2.3 Trade liberalisation effects

The results described in the previous subsections allow us to analyze the effects of trade liberalisation in terms of changes in the relevant magnitudes. These are summarised in the following

Proposition 1 *[Welfare] Trade liberalisation causes (i) an increase in the welfare of the smaller country if the latter is sufficiently small; (ii) a decrease in the welfare of the larger country; (iii) a decrease in the welfare at the world level.*

Proof. See Appendix A. ■

Hence, since free trade is unambiguously detrimental for the larger country (regardless of the degree of asymmetry in size and the emission intensity), trade opening is a strictly dominated strategy for the latter. From this it follows that trade liberalisation is unlikely to occur, which is true even if allowing for side payments, since the gain in social welfare for the smaller country is never high enough to compensate for the loss borne by the larger one.

In order to understand why trade liberalisation has always a negative impact on the larger country's welfare as well as on the smaller country's welfare in most of the cases, we now proceed to decompose the effects on social welfare into two separate elements, namely, the consequences of trade on firms' profits as well as on consumer surpluses. As to the latter magnitude, the following holds:

Proposition 2 *[Consumer Surplus] Trade liberalisation, by decreasing both prices, determines an increase in consumer surplus in both countries.*

Proof. See Appendix A. ■

With free trade, instantaneous firms' relocation in correspondence of the world economy's borders entails an increase in transportation costs for both countries. Thus, the positive effect on worldwide consumer surplus has to be necessarily determined by the decrease in prices, due to the Bertrand competition arising in the international duopoly setting.

We now move to consider how trade liberalisation affects profits in the long run.

Proposition 3 *[Profits] Free trade brings about an increase in the profit accruing to the firm based in the smaller country provided that the latter is sufficiently small, while it always hurts the firm based in the larger country.*

Proof. As far as firm 2 is concerned, the statement contained in in Proposition 3 is intuitive: since trade liberalisation entails diminishing demand, the negative quantity effect sums up to the negative price effect and profits shrink, regardless of α and β. As to Firm 1 we have that:

$$\begin{aligned} \pi_1^T - \pi_1^A &= \frac{1}{4}\left[2-\alpha\left(4s-\alpha^2\right)\right] > 0, \\ iff \quad s < s_1^T &= \frac{2+\alpha^3}{4\alpha}, \end{aligned} \tag{2.13}$$

where s_1^T is strictly decreasing in α, with $s_1^T \in]\infty, \frac{17}{16}[$ as $\alpha \in]0, \frac{1}{2}[$. Moreover $s < s_1^T$ is necessary but not sufficient condition for (2.13) to hold in equilibrium since also $s_1^T > s_{MC}^T$, which ensures non-negativity of prices and full market coverage, has to be met. The latter is verified for $\alpha \in]0, -1+\sqrt{2} \simeq 0.414[$ and $\beta \in]0, \min[\frac{2-5\alpha+\alpha^3}{2\alpha-4\alpha^2}, 1][$.[9]

[9] This also implies that (2.13) holds, regardless of the level of β, for $\alpha \in]0, \frac{1}{2}(\sqrt{33}-5) \simeq 0.372[$.

Thus, as far as firm 1 is concerned, the gain in profits associated to trade liberalisation is decreasing in α. An higher α, in fact, strengthens price competition and, moreover, reduces the positive quantity effect of trade liberalisation $(\frac{1}{2} - \alpha)$: since equilibrium location of the marginal consumer is not affected by the relative size of country 1, the gain in demand accruing to firm 1 is decreasing in α.
Moreover, from (2.13), the gain in profits is decreasing in the individual consumer surplus s too. This is due to the fact that a higher s, via an increase in the price of the brown variety, raises profits autarkic equilibrium level, though leaving unaffected the corresponding level in free trade.[10] This also formally explains the existence of a substitution effect between the asymmetry in size and the individual consumer surplus, that is, why threshold s_1^T is decreasing in α: when countries are very similar in size, the autarkic profits must be very low to preserve the existence of a gain associated to trade liberalisation, since the latter entails a lower quantity effect .
Lastly, if country 1 is sufficiently large ($\alpha > 0.372$), we have identified an upper threshold for the emission intensity ($\beta = \frac{2-5\alpha+\alpha^3}{2\alpha-4\alpha^2}$). If $\beta > \frac{2-5\alpha+\alpha^3}{2\alpha-4\alpha^2}$, it follows that $s_1^T < s_{MC}^T$ that is for all levels of s which ensure non-negativity of prices and full market coverage firm 1 cannot gain from free trade. ■

Hence, trade liberalisation has asymmetric effects on firms' profits: while it unambiguously implies a loss for firm 2 it may favour firm 1. Since free trade brings about a decrease in both equilibrium prices, this is necessarily due to the difference in the sign of the quantity effect which is clearly negative for the larger country and positive for the smaller. Propositions 1-3 have been summarised in Table 1.

	Country	
	1	2
TC	$\uparrow$	$\uparrow$
CS	$\uparrow$	$\uparrow$
p	$\downarrow$	$\downarrow$
y	$\uparrow$	$\downarrow$
π	$\updownarrow$	$\downarrow$
SW	$\updownarrow$	$\downarrow$

Table 2.1: Trade liberalisation, signs of magnitudes' variations.

[10] Since, when duopolistic competition arises, exactly the same effect is shown to be entirely transferred to consumer surpluses (see Appendix (A.1) and (A.2)).

To conclude, the shift from autarkic to free trade equilibrium has not univocal implications from the point of view of social welfare of country 1: until country 1 is small enough ($\alpha < 0.4735$), in fact, the gain in consumer surplus for its inhabitants outweighs any loss in firm's profits, regardless of the level of β and s; for higher α the opposite is true: the dynamic of profits is unambiguously negative and the gain in consumer surplus is reduced. The intuition behind the latter effect is straightforward: the price that firm 1 can sustain in autarky is decreasing in α due to the fact that she must compensate for higher transportation costs borne by consumers, while is constant in free trade; this sums up with the fact that α has a stronger positive effect on the free trade equilibrium level of transportation costs as compared to those of autarky.
For what concerns country 2, we conclude that, though welfare reducing, trade liberalisation acts in favour of a redistribution of welfare from the firm to the consumers: the price effect stemming from duopolisitic competition raises the consumer surplus, and, together with an output reduction, implies a decrease in the profits accruing to the domestic firm.

2.3 Trade policy

We now proceed to analyze the long-run consequences of trade liberalisation when the government of country 2, which is otherwise unambiguously suffering from the opening of trade, implements a trade policy. To this end we define two policies: a linear tariff weighted by the emission intensity - which is indeed formally equivalent to a Pigouvian tax on imports - and a subsidy for firm 2, where the latter is supposed to be financed by an equivalent decrease in country 2's social welfare.

2.3.1 Import Tariff

We first suppose that country 2's government levies a tariff $\tau > 0$ on the negative externality generated by the volume of the imported brown variety, so that the profits of firm 1 are lowered by an amount equal to:[11]

$$\tau\beta(\hat{m}_{T\tau} - \alpha).$$

We can then write:

$$\pi_1^{T\tau} = p_1^{T\tau}\hat{m}_{T\tau} - \tau\beta(\hat{m}_{T\tau} - \alpha), \tag{3.1}$$

[11]Note that this formulation implies that the optimal tariff may effectively result in a trade policy instrument and not only in an environmental policy one since, in principle, its level may be either more or less than compensate the value of the damage function D_2.

and

$$SW_2^{T\tau} = \pi_2^{T\tau} + CS_2^{T\tau} - \beta(\hat{m}_{T\tau} - \alpha) + \tau\beta(\hat{m}_{T\tau} - \alpha), \tag{3.2}$$

where $T\tau$ stands for *trade with tariff.* In equilibrium, social welfare of country 2 is thus supposed to be augmented by an amount equal to the gross tariff income; the definition of all other magnitudes is unchanged w.r.t. the case described in section 3. Again, the equilibrium arising is such that $x_1^{T\tau} = 0$ and $x_2^{T\tau} = 1$, implying the following marginal consumer's equilibrium location:

$$\hat{m}_{T\tau} = \frac{1}{6}(3 - \beta\tau); \tag{3.3}$$

while equilibrium prices are $p_1^{T\tau} = 1 + \frac{2\beta\tau}{3}$; $p_2^{T\tau} = 1 + \frac{\beta\tau}{3}$. From the condition of non negativity of country 2's imports ($\hat{m}_{T\tau} - \alpha > 0$) we can derive the maximum admissible level of the tariff τ:

$$\bar{\tau} = \frac{3 - 6\alpha}{\beta}. \tag{3.4}$$

For each $\tau > \bar{\tau}$, the model thus predicts a reversal of trade flows with $\hat{m}_{T\tau} < \alpha$; this would formally translate the tariff into a subsidy for firm 1, which, clearly, is not among the feasible policies available to country 2's government, and would invalidate the definition of the demand system. Full market coverage is now ensured if consumers' gross surplus is greater than:

$$s_{MC}^{T\tau} = \frac{1}{36}\left(45 + 18\beta - 36\alpha\beta + 18\beta\tau - 6\beta^2\tau + \beta^2\tau^2\right), \tag{3.5}$$

where, again, $s_{MC}^{T\tau} > s_p^A \; \forall\alpha \in]0, 1/2[, \;\; \beta \in]0, 1[, \;\; \tau > 0$; while the non negativity of both prices is always verified.

The objective function of the government of country 2 is then:

$$\max_{\tau} SW_2^{T\tau} \qquad s.t. \qquad \tau < \bar{\tau}, \tag{3.6}$$

which yields:

$$\tau^* = \frac{2 - 2\alpha + \beta}{\beta} \qquad \forall \;\alpha \in]0, \frac{1}{4}[, \;\; \beta \in]0, 1 - 4\alpha[.$$

Note that optimal tariff τ^* is decreasing in both β and α. For $\tau = \tau^*$ the marginal consumer locates at:

$$\hat{m}_{T\tau}^* = \frac{1 + 2\alpha - \beta}{6}. \tag{3.7}$$

Thus, for $\beta \in]1 - 4\alpha, 1[$, country 2's government cannot implement τ^* since $\tau^* > \bar{\tau}$, it will then necessarily choose a sub-optimal tariff $\tau = \bar{\tau}$ in order to maximize social welfare.[12]

[12] Note that, $\alpha \in]\frac{1}{4}, \frac{1}{2}[$ is sufficient but not necessary condition for $\tau^* > \bar{\tau}$.

Indeed, for all $0 < \tau < \tau^*$:

$$\frac{\partial SW_2^{T\tau}}{\partial \tau} = \frac{1}{12}\left[2\beta(2-2\alpha+\beta) - 2\beta^2\tau\right] > 0 \qquad \forall\ \alpha \in]0, \frac{1}{4}[,\ \ \beta \in]1-4\alpha, 1[.$$

The reason for optimal tariff never restoring autarky for $\beta < 1 - 4\alpha$, is that, in correspondence of $\tau = \tau^* < \bar{\tau}$, a higher tariff would imply, via higher prices, a reduction in consumers' surplus of country 2 strictly greater than the gain in firm 2 profits and in gross tariff revenues. For very low α and β a full import substitution obtained through a tariff is thus not feasible, implying a too high cost to be borne by consumers. Equilibrium definitions of magnitudes relatives to both $\tau = \tau^*$ and $\tau = \bar{\tau}$ cases are reported in Appendix B.

If the government of country 2 levies the optimal tariff $\tau = \tau^*$, we can state what follows:

Proposition 4 *[Tariff] There exists no import tariff whereby the larger country's welfare exceeds its autarkic level.*

Proof. In order to prove the proposition it is sufficient to observe that:

$$SW_2^{T\tau} - SW_2^A = \frac{1}{12}\left[\alpha + 7\alpha^2 + 3\alpha^3 + 8\alpha\beta + (\beta-2)\beta - 2\right]; \tag{3.8}$$

is strictly negative over the admissible range of parameters α and β. ■

Hence, for what concerns country 2, an optimal tariff is never effective in determining an increase in social welfare of the same country as compared to the autarkic equilibrium. The reason basically lies in the fact that the tariff itself does not suffice to raise free trade profits over the autarkic equilibrium level. An optimal tariff, in fact, never restores autarky, and then, always implies a negative quantity effect for firm 2 sales, associated with trade liberalisation.[13]

What stated so far, obviously holds even in the case a suboptimal tariff $\tau = \bar{\tau}$ is levied, for $\alpha \in]0, \frac{1}{2}[$ and $\beta \in]max[1-4\alpha, 0], 1[$. As for country 1, see Appendix B for a detailed assessment of the effects of trade liberalisation in the presence of an optimal tariff τ^*.

[13]Notwithstanding this, with a tariff, a smaller part of consumers living in country 2 switches to firm 1, and price competition is undoubtedly relaxed. This implies that trade liberalisation necessarily reduces profits of firm 2 by a lesser amount as compared to the case in which no tariff is levied. On the consumers' side, the decrease in surplus due to higher prices is partially compensated by the gross tariff revenues. Since the positive effect exerted by the tariff on profits is not fully compensated by the corresponding negative effect on consumer surplus, we can state that, with regards to the larger country, the tariff acts in limiting the negative effect of trade liberalisation on the social welfare.

2.3.2 Subsidisation and trade reversal

In the last subsection we have identified the parametric range in which an optimal tariff can be levied by the government of country 2. We have also stated that, outside this range, if the government wants to impose an import tariff, it must choose a sub-optimal level of the latter, that is the one restoring autarky, $\tau = \bar{\tau}$. As an alternative to this, the government may undertake an export subsidy policy. The latter is obviously defined only for $\hat{m} - \alpha < 0$, that is, the marginal consumer has to be located in country 1. This also implies that the demand system has to be newly defined, in order to account for the trade flow reversal. Marginal consumer is thus now identified by solving the following condition:

$$p_1^{T\theta} + (\hat{m}_{T\theta} - x_1^{T\theta})^2 + \beta\hat{m}_{T\theta} = p_2^{T\theta} + (\hat{m}_{T\theta} - x_2^{T\theta})^2 + \beta\hat{m}_{T\theta}, \tag{3.9}$$

where apex $T\theta$ stands for *trade with subsidy*. The latter condition, by Lemma 1, yields the same results as in (2.10-2.11).

If we now suppose that country 2's government provides to firm 2 a subsidy $\theta > 0$ for each of the $\alpha - \hat{m}_{T\theta}$ units of green good export to country 1, profits of firm 2 become:

$$\pi_2^{T\theta} = p_2^{T\theta}\hat{m}_{T\theta} + \theta(\alpha - \hat{m}_{T\theta}); \tag{3.10}$$

while countries' social welfares:

$$SW_1^{T\theta} = \pi_1^{T\theta} + CS_1^{T\theta} - \beta\hat{m}_{T\theta}; \quad SW_2^{T\theta} = \pi_2^{T\theta} + CS_2^{T\theta} - \theta(\alpha - \hat{m}_{T\theta}); \tag{3.11}$$

From (3.11), equilibrium social welfare of country 2 is supposed to be reduced by an amount equal to the subsidy provided to firm 2; this amount can be higher or lower than the negative externality suffered by the community in case of importing the brown good. As for country 1, the externality in consumption hurts social welfare by a lesser amount w.r.t. the framework analyzed in section 2 (see (2.9)), since now a part of consumers switches to the green good produced by firm 2. Again, the equilibrium arising is such that $x_1^{T\theta} = 0$ and $x_2^{T\theta} = 1$, implying the following marginal consumer's equilibrium location:

$$\hat{m}_{T\theta} = \frac{3-\theta}{6}; \tag{3.12}$$

where the latter is obviously decreasing in θ, while equilibrium prices are: $p_1^{T\theta} = 1 - \frac{\theta}{3}$; $p_2^{T\theta} = 1 - \frac{2\theta}{3}$. Note that both prices are decreasing in θ, that is the subsidy strengthens the price competition stemming from trade liberalisation; this obviously happens since subsidised firm 2 can now sustain a lower price. Non negativity of both prices is verified for $\theta \in]0, \frac{3}{2}[$. From the condition of non-negativity of country 1's imports ($\hat{m}_{T\theta} - \alpha < 0$) we can derive minimum level of the subsidy θ:

$$\bar{\theta} = 3 - 6\alpha. \tag{3.13}$$

The latter condition is necessary since, similarly to what underlined in the preceding subsection, for each $\theta < \bar{\theta}$ the model would predict a reversal of trade flows with $\hat{m}_{T\theta} > \alpha$; which would, again, invalidate the demand system and translate the subsidy into a tariff for firm 2, proportional to the externality generated by the consumption of firm 1's imported output. Full market coverage is now ensured if consumers' surplus is greater than:

$$s_{MC}^{T\theta} = \frac{1}{36}\left(45 - 18\beta + 36\alpha\beta - 18\theta + 6\beta\theta + \theta^2\right), \tag{3.14}$$

where, again, $s_{MC}^{T\theta} > s_p^A \; \forall \;\; \alpha \in]0, 1/2[, \;\; \beta \in]0, 1[, \;\; \theta \in]0, \frac{3}{2}[$.
Country 2' governments objective function is then:

$$\max_{\theta} SW_2^{T\theta} \qquad s.t. \qquad \theta \geq \bar{\theta}, \tag{3.15}$$

which yields:

$$\theta^* = \frac{3}{4}(3 - 4\alpha) \qquad \forall \;\; \alpha \in]\frac{1}{4}, \frac{1}{2}[, \;\; \beta \in]0, 1].$$

For $\theta = \theta^*$ the marginal consumer locates at:

$$\hat{m}_{T\theta}^* = \frac{4(1+\alpha) - 3}{8}.$$

Note that, for higher α, the gain in demand for firm 2 ($\alpha - \hat{m}_{T\theta}^*$) is necessarily higher; this amounts to saying that θ can be fixed to a lower level in order to obtain an equivalent rise in profits ($\frac{\partial \theta^*}{\partial \alpha} < 0$). For $\theta > \theta^*$, in fact, firm 2' s demand would rise, accompanied by an even higher price competition; the consequent increase in consumer surplus of inhabitants of country 2 would then be not high enough to repay the increase in subsidy expenditure plus the decrease in firm 2 profits. The subsidy, though directly accruing to firm 2, is undoubtedly acting in favour of a redistribution from firm 2's profits to consumer surplus. For $\alpha \in]0, 1/4[$ country 2's government cannot implement θ^* since $\theta^* < \bar{\theta}$, nor a non-optimal tariff $\theta = \bar{\theta}$, since the latter would imply a negative price for the brown good.

Under the hypothesis that Government of country 2 levies a θ^* tariff, we can thus state what follows:

Proposition 5 *[Welfare with Subsidy]The long-run effect of trade liberalisation on social welfare consists in: (i) an increase in the welfare of the smaller country for a sufficiently* *high emission intensity and a sufficiently small asymmetry in size between the two countries; (ii) an increase in the welfare of the larger country if the asymmetry in size is sufficiently small and (iii) an increase in the welfare at the world level for a wider parameters' range w.r.t. the one assuring that both (i) and (ii) hold.*

Proof. In order to prove part (i) of Proposition 1 is sufficient to observe that, for $\theta = \theta^*$, $\alpha \in]\frac{1}{4}, \frac{1}{2}[$ and $\beta \in]0, 1[$:

$$SW_1^{\mathbf{T}\theta} - SW_1^A = \frac{1}{64}[3 - 8\alpha(1 + 2\alpha(1 + \alpha) - 4\beta) - 8\beta] > 0$$
$$iff \quad \beta \in]\frac{3 - 8\alpha[1 + 2\alpha(1 + \alpha)]}{8 - 32\alpha}, 1[; \tag{3.16}$$

while, for what concerns part (ii):

$$SW_2^{\mathbf{T}\theta} - SW_2^A = \frac{1}{12}\left[\alpha + 7\alpha^2 + 3\alpha^3 + 8\alpha\beta + (\beta - 2)\beta - 2\right] > 0$$
$$iff \quad \alpha \in]0.452, 0.5[. \tag{3.17}$$

For what concerns the last claim in the proposition:

$$SW^{\mathbf{T}\theta} - SW^A = \frac{1}{64}[8\alpha(1 + 4\beta) - 9 - 8\beta] > 0$$
$$iff \quad \alpha \in]0.425, 0.5[, \quad \beta \in]\frac{8\alpha - 9}{8 - 32\alpha}, 1[. \tag{3.18}$$

■

The way trade liberalisation affects profits and consumer surpluses is summarised in the following:

Proposition 6 *[Profits and Consumer Surpluses with Subsidy] Free trade, through price effect, brings about (i) an increase in consumer surpluses of both countries; (ii) a decrease in profits accruing to both firms.*

Proof. See Appendix B. ■

Hence, differently from the import tariff policy (see Proposition 4), the subsidy policy may entail a rise in the social welfare of country 2 without necessarily hurting country 1; this requires country 1 to be sufficiently large and the emission intensity to be sufficiently high.

A higher α, through a lower equilibrium subsidy θ^* implies a lower transfer from consumers/inhabitants of country 2 to firm 2; moreover, it limits the negative effect on firm 2 profits and the positive effect on consumer surplus associated with any positive subsidy, since price competition is relaxed. The former two effects are shown to be always stronger than the latter[14] implying that the marginal effect of α on free trade social welfare of country 2 is strictly positive. Moreover, this is shown to be always greater than the marginal effect on the social welfare in autarky, since $\frac{\partial SW_2^A}{\partial \alpha} < 0$; in that case, in fact, a reduction in the asymmetry between countries entails a decrease in the profits and in the consumer surplus of country 2, where the former effect is driven by the decrease in demand and the latter by the increase in the price of the green good.

For what concerns country 1, the effect of α is not a priori defined and depends on the level of β.[15] Consequently, for a higher β, we observe an increase in the burden of externality borne by inhabitants of country 1 which is clearly higher in autarky than in free trade. In the latter case, in fact, some of them switch to the clean good. Thus, given

$$\frac{\partial SW_1^A}{\partial \beta} < \frac{\partial SW_1^{T\theta}}{\partial \beta} < 0,$$

a higher emission intensity, though strictly depressing the social welfare, is always associated with an increase in the differential between its post and pre trade liberalisation equilibrium values.

Proven that β is high enough to account for this positive effect of trade liberalisation, even α has to be high enough. Size of the smaller country in fact: (i) raises free trade equilibrium profits through an increase in price and demand ($\frac{\partial \hat{m}_{T\theta}^*}{\partial \alpha} > 0$), (ii) raises consumer surplus (proven that $s > \frac{1}{8}\left(3 + 12\alpha + 8\alpha^2\right)$) and (iii) it determines an increase in the burden of externality borne by the inhabitants of country 1.

Consequently, for high β and low α the gains from trade liberalisation accruing to country 1 only consist in lower emissions and in a higher consumer surplus, which are not enough to compensate for the loss in profits; for a high α and a low β the opposite is true: both the loss in profits and the emissions are strongly reduced by trade liberalisation, but this is accompanied by a higher reduction in consumer surplus. The latter considerations entails claim (i) in Proposition 5.

[14] $\left|\frac{\partial \pi_2^{LS}}{\partial \alpha}\right| > \left|\frac{\partial CS_2^{LS}}{\partial \alpha}\right|$.

[15] From Appendix (A.1), (B.3), in fact, α enters in the autarkic and free trade equilibrium definition of SW_1 multiplied by a factor β.

2.3.3 Discussion

Along this section we have analyzed the effects of trade liberalisation under the hypothesis of country 2 alternatively undertaking two policies in order to contain trade liberalisation's negative effect, the latter being even reinforced by the externality stemming from consumption of the imported brown good (see section 2). We may now take a closer look at the feasibility of trade liberalisation itself, considered as the outcome of a game where both countries' payoffs are represented by social welfare gains w.r.t. the autarkic equilibrium. Figure 2.1 provides an exhaustive summary of the parameters' ranges characterizing different results in terms of social welfare dynamics from autarky to free trade, for both countries. We may firstly distinguish three ranges, delimiting the feasibility of both policies. According to results so far provided, for $\alpha \in]0, 0.25[$ and $\beta \in]0, 1-4\alpha[$, the feasible policy is an optimal tariff $\tau = \tau^*$; for $\alpha \in]0, 0.25[$ and $\beta \in]1-4\alpha, 1[$, only a sub-optimal tariff policy is allowed and, lastly, for $\alpha \in]0.25, 0.5[$, the government may only choose between an optimal subsidy $\theta = \theta^*$ or a suboptimal tariff $\tau = \bar{\tau}$. Moreover, in the second range, since $\Delta SW_2^{A,T\theta} > \Delta SW_2^{A,T\bar{\tau}}$, the government will necessarily choose a subsidy policy.[16]

In addition to this, from Proposition 4 and 6, the parameters' range corresponding to area A:

$$\alpha \in]0.452, 0.5[; \qquad \beta \in]\frac{3 - 8\alpha[1 + 2\alpha(1+\alpha)]}{8 - 32\alpha}, 1[;$$

is the only one which is compatible with a Nash bargaining solution, since it is associated with strictly positive $\Delta SW_1^{A,T\theta}$ and $\Delta SW_2^{A,T\theta}$. Both countries have therefore incentive to open to trade, and trade liberalisation yields:

$$\Delta SW_1^{A,T\theta} = \Delta SW_2^{A,T\theta} = \frac{\Delta SW^{A,T\theta}}{2}.$$

The required side payment is in favour of country 2 for

$$\alpha \in]0.452, 0.478[; \qquad \beta \in]\frac{15 - 8\alpha[3 + 4\alpha(1+\alpha)]}{8 - 32\alpha}, 1[;$$

since in correspondence of this range we have that $\Delta SW_1^{A,T\theta} > \Delta SW_2^{A,T\theta}$. The opposite is true for the range which is complementary to A.

Anyway, this is not the unique range in which trade liberalisation may be mutually beneficial. From Proposition 5 total world welfare is shown to be strictly increasing in the

[16] $\Delta K_i^{A,j}$ with $i = 1, 2$, $j = T, T\tau, T\theta$, and $K = SW, CS, TC, p, \pi$, indicates the value of the differential from the autarkic equilibrium to the j-equilibrium for what concerns the magnitude K in country i.

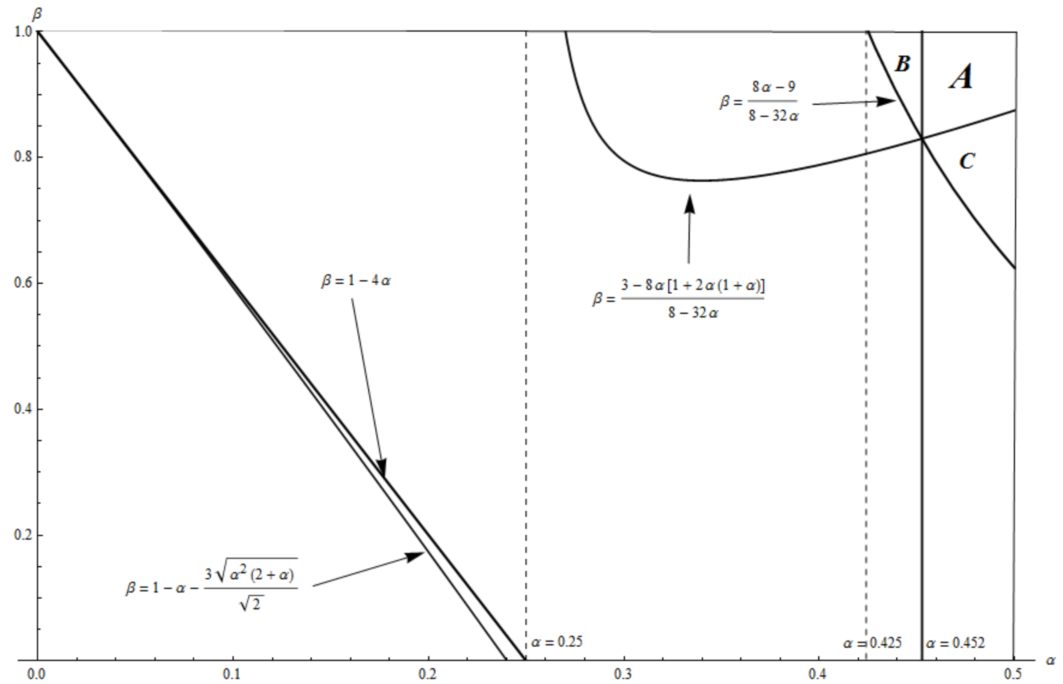

Figure 2.1: Welfare effects of trade liberalisation with tariff and subsidy, parameters' ranges

following parameter ranges:

$$\alpha \in]0.425, 0.452[;\ \beta \in]\frac{8\alpha - 9}{8 - 32\alpha}, 1[; \qquad \alpha \in]0.452, 0.5[;\ \beta \in]\frac{8\alpha - 9}{8 - 32\alpha}, \frac{3 - 8\alpha[1 + 2\alpha(1+\alpha)]}{8 - 32\alpha}[;$$

respectively labeled as areas B and C in Figure 2.1 . In correspondence of these ranges the sign of the welfare differential is negative for at least one of the two countries: while area B is characterized by a gain for country 1 and a loss for country 2, the opposite is true for area C. In a supergame played over an infinite horizon, this problem could be effectively solved to generate a Pareto-efficient outcome. Applying Friedman (1971), i.e., the perfect folk theorem, the relevant condition is:

$$\frac{1}{1-\delta}(\Delta SW_i^{A,T\theta} - Tr_i) \geq \Delta SW_i^{A,T\theta} + \frac{\delta}{1-\delta} SW_i^A, \tag{3.19}$$

where Tr_i is the required side payment and $i = 1, 2$ respectively in B and C. It is straightforward to show that (3.19) requires

$$\delta \geq \hat{\delta}_i = \frac{Tr_i}{SW_i^{T\theta} - 2SW_i^A}. \tag{3.20}$$

Condition (3.20) reveals that $SW_i^{T\theta} < 2SW_i^A$ suffices to ensure the sustainability of the Pareto-efficient equilibrium outcome at the subgame perfect equilibrium of the supergame.

The latter condition is shown to hold for each α and β in C and for each α, β and $s > \frac{9-24\alpha-48\alpha^2-32\alpha^3-24\beta+288\alpha\beta}{192\alpha}$ in B. If instead $s^{T\theta}_{MC} < s < \frac{9-24\alpha-48\alpha^2-32\alpha^3-24\beta+288\alpha\beta}{192\alpha}$, the threshold value of the discount rate $\hat{\delta}_1$ is positive and it remains to be checked whether it lies below 1. This happens for all $Tr_1 < SW_1^{T\theta} - 2SW_1^A$, whose r.h.s. is linear and decreasing in s. Therefore, region B also hosts an additional subset of parameters in which the long run equilibrium generated by the supergame is Pareto-efficient:

$$s \in \left(s^{T\theta}_{MC}, \overline{s}\right); \, Tr_1 \in \left(0, SW_1^{T\theta} - 2SW_1^A\right)$$

where

$$\overline{s} \equiv \frac{9-24\alpha-48\alpha^2-32\alpha^3-24\beta+288\alpha\beta}{192\alpha}.$$

This portion of the parameter space is illustrated in Figure 2.2.

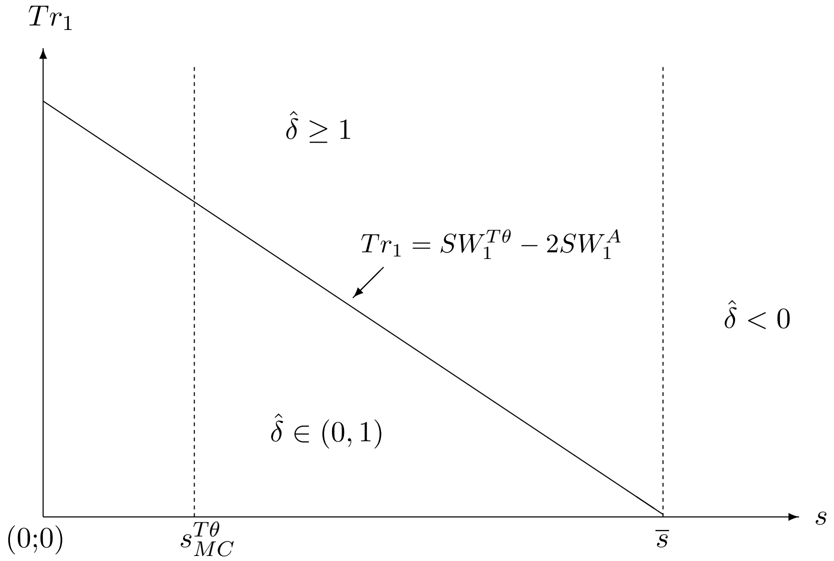

Figure 2.2: Threshold discount rate and side-payment, country 1, region B

2.4 The larger country is brown

As we have fully characterized the case in which the smaller country hosts the firm producing the brown good, we may now investigate the opposite case: the brown good is produced in the larger among the two countries. This implies no change in the autarkic equilibrium level of all magnitudes except for social welfare:

$$SW_1^A = \pi_1^A + CS_1^A; \quad SW_2^A = \pi_2^A + CS_2^A - \beta(1-\alpha).$$

At equilibrium, the above expressions write as follows:

$$SW_1^A = \alpha(s - \frac{t\alpha^2}{12} - \beta); \quad SW_2^A = \frac{1}{12}(1-\alpha)[12s - t(1-\alpha)^2]. \tag{4.1}$$

Note that, while the social welfare of country 2 is negatively affected by the consumption of the brown good ($y_{22}^{A1} = 1-\alpha$), this does not affect the social welfare of country 1. Non negativity of both prices still requires imposing (2.8).

At the free trade equilibrium, Lemma 1 still obviously holds, together with (2.9-2.11). Full market coverage is now ensured if:

$$s \geq s_{MC}^T = \frac{1}{4}[5 + 2\beta], \tag{4.2}$$

where again

$$s_{MC}^T > s_p^A \qquad \forall \alpha \in]0, 1/2[, \beta \in]0, 1[,$$

so that the condition for full market coverage in the long run also suffices to ensure the non-negativity of prices in autarky. We still have that, in equilibrium, $x_1^{T1} = 0$, $x_2^{T1} = 1$, $p_1^{T1} = p_2^{T1} = 1$, $\hat{m} = 1/2$ and $\pi_1^{T1} = \pi_2^{T1} = 1/2$. Since the location of the marginal consumer is the same as in (2.10), the resulting total transportation costs and consumer surpluses are those in A.2, while social welfare levels are:

$$SW_1^T = \frac{1}{2} - \alpha(1-s) - \frac{1}{3}\alpha^3; \; SW_2^T = s(1-\alpha) + \alpha(1 + \frac{1+\alpha^2}{3}) - \frac{6\beta+7}{12}. \tag{4.3}$$

2.4.1 Trade liberalisation effects

In view of the above considerations about the location of the indifferent consumer at the free trade equilibrium, the present framework fully retains the statements contained in Proposition 2-3.[17] Notwithstanding this, from (4.1) and (4.3) we can state what follows:

Proposition 7 *[Welfare] Trade liberalisation causes (i) an increase in the welfare of the smaller country if the latter is sufficiently small; (ii) a decrease in the welfare of the larger country, irrespective of countries' relative size; and (iii) an increase in the welfare at the world level for sufficiently high intensity of the emissions stemming from the consumption of the brown good and sufficiently small asymmetry in size between the two countries.*

[17] Note that in the case of profits, (2.13) still holds, but $s_1^T > s_{MC}^T$, which ensures non-negativity of prices and full market coverage, is now met for $\alpha \in]0, -1+\sqrt{2} \simeq 0.414[$ and $\beta \in]0, \min[\frac{2-5\alpha+\alpha^3}{2\alpha}, 1[$. This now implies that (2.13) holds, regardless of the level of β, for $\alpha \in]0, 0.289[$.

Proof. See Appendix A. ■

Proposition (7) thus implies that, when the polluting good is produced in the larger country, trade liberalisation may be, *per se*, welfare improving at the world level. Recalling (3.19) this applies provided that $SW_1^T < 2SW_1^A$ which is trivially shown to hold for each α, β and $s > \frac{3-6\alpha-\alpha^3}{6\alpha}$.

The elementary intuition for this result is that, if the brown firm is based in the larger country and the position of the indifferent consumer under trade liberalisation is independent of the location of the brown production, then free trade here implies that the green firm necessarily penetrates the larger country and therefore some consumers in the latter have access to the green good. This reshuffling of aggregate demand at the world level in favour of the green variety reduces global pollution and opens the way to a welfare increase at the world level.

2.5 Concluding remarks

We have investigated how the environmental negative externality stemming from consumption affects trade in an international Hotelling duopoly where two firms, that differ in the greenness of their production, are located in asymmetric countries. We have shown that this kind of externality does not affect equilibrium demand partition: the firm located in the smaller country, whether producing a "brown" good or not, exports to the larger.

Our results can be contrasted with the original formulation of the model, where no environmental issues enter the picture (Lambertini (1997a)). In our primary framework (in which it is assumed that the brown good is produced in the smaller country), consumers' environmental awareness only implies a reduction in the social welfare of the smaller country under autarky, and a decrease in the social welfare of the larger country in case of trade liberalisation. On the contrary, in the same framework, the adoption of a trade policy by the government of the larger country has been shown to be effective in determining a change in the distribution of gains and losses stemming from bilateral opening to trade. In particular, there are admissible parameter ranges in which a Pigouvian tax on imports implies losses for the smaller country even when the latter is very small, while improving the performance of the larger one. More interestingly, an export subsidy for the firm producing the green good delivers a net gain from trade liberalisation accruing to both countries, provided that the asymmetry in size is sufficiently small and the emission intensity is sufficiently high. Hence, the presence of a significant negative externality in consumption may be crucial in convincing larger country's government to subsidise the firm producing a green good; the reason for this does not consist, as expected, in classic export subsidy arguments of import substitution, but rather in the fact that consuming a certain amount of the green good may turn out to be beneficial for the smaller country too, since benefits directly accruing to the society through reduction in local emissions may outweigh the decrease in firm's profits.

The alternative scenario, based on the assumption that the green firm be located in the larger country, yields intuitive results. Since market shares after trade liberalisation are the same as in the former setting, here we reach the straightforward conclusion that free trade indeed generates a welfare improvement at the world level because a portion of the population of consumers previously compelled to buy the brown variant turn to the green one.

Appendices

2.A Autarky and free trade

2.A.1 Equilibrium magnitudes

Autarkic equilibrium, relevant magnitudes others than social welfares:

$$\begin{aligned}
&p_1^A = s - \frac{1}{4}\alpha^2; \quad p_2^A = s - \frac{1}{4}(1-\alpha)^2; \\
&\pi_1^A = \frac{\alpha}{4}(4s - \alpha^2); \quad \pi_2^A = \frac{1-\alpha}{4}[4s - (1-\alpha)^2]; \\
&TC_1^A = \frac{1}{12}\alpha^3; \quad TC_2^A = \frac{1}{12}(1-\alpha)^3; \\
&CS_1^A = \frac{1}{6}\alpha^3; \quad CS_2^A = \frac{1}{6}(1-\alpha)^3.
\end{aligned} \tag{A.1}$$

Free trade equilibrium, relevant magnitudes others than prices and profits:

$$\begin{aligned}
&TC_1^T = \frac{\alpha^3}{3}; \qquad TC_2^T = \frac{1}{12}\left(1 - 4\alpha^3\right); \\
&CS_1^T = \alpha\left(s - 1 - \frac{1}{3}\alpha\right); \qquad CS_2^T = s(1-\alpha) + \frac{1}{3}\left(3\alpha + \alpha^3 - \frac{13}{4}\right); \\
&SW_1^T = \frac{1}{2} \ - \alpha\left(1 - s + \beta + \frac{1}{3}\alpha^2\right); \\
&SW_2^T = \frac{1}{12}\left\{-3 - 4(1+\beta) - 2\left[6s(-1+\alpha) - 2\alpha\left(3+\alpha^2\right) + (1-6\alpha)\beta\right]\right\}.
\end{aligned} \tag{A.2}$$

2.A.2 Proof of Proposition 1

Proof. In order to prove part (i) of Proposition 1 is sufficient to observe that:

$$\begin{aligned}
SW_1^T - SW_1^A = \frac{1}{4}\left[2 - \alpha\left(4 + \alpha^2\right)\right] > 0 \\
iff \quad \alpha \in]0, 0.4735[,
\end{aligned} \tag{A.3}$$

while, for what concerns part (ii) and (iii):

$$SW_2^T - SW_2^A = \frac{1}{4}\left[\alpha\left(3+\alpha+\alpha^2+4\beta\right)-2(1+\beta)\right];$$
$$SW^T - SW^A = \frac{1}{4}[\alpha(\alpha+4\beta-1)-2\beta]; \tag{A.4}$$

where SW^j is the social welfare at the world level, in correspondence of the j-equilibrium (with $j = A, T, T\tau, T\theta$). Both equations in (A.4) are strictly negative over the admissible range of parameters α and β. ■

2.A.3 Proof of Proposition 2

Proof. Consumer surpluses differentials w.r.t. autarky are defined as:

$$CS_1^T - CS_1^A = \alpha(s-1) - \frac{1}{2}\alpha^2; \quad CS_2^T - CS_2^A = \frac{1}{4}\left[6\alpha + 2(1-\alpha)\left(2s-\alpha^2\right)-5\right]. \tag{A.5}$$

Both strictly positive over the admissible parameter range $\alpha \in]0, \frac{1}{2}[$, $\beta \in]0,1[$. Then, since

$$TC_1^T - TC_1^A = \frac{\alpha^3}{4}; \quad TC_2^T - TC_2^A = \frac{1}{4}\alpha\left(1-\alpha-\alpha^2\right); \tag{A.6}$$

are also positive over the admissible parameter range, trade liberalisation always determines an increase in transportation costs. This implies that, for both countries, the positive effect on consumers' surplus determined by the decrease in prices is strong enough to offset the negative one stemming from the dynamic of transportation costs. ■

2.A.4 Proof of Proposition 7

Proof. In order to prove part (i) of Proposition 1 is sufficient to observe that, again:

$$SW_1^{T1} - SW_1^{A1} = \frac{1}{4}\left[2-\alpha\left(4+\alpha^2\right)\right] > 0$$
$$iff \quad \alpha \in]0, 0.4735[, \tag{A.7}$$

while, for what concerns part (ii):

$$SW_2^{T1} - SW_2^{A1} = \frac{1}{4}\left[\alpha\left(3+\alpha+\alpha^2-4\beta\right)-2(1-\beta)\right]; \tag{A.8}$$

where the latter is strictly negative over the admissible range of parameters α and β. With regards to part (iii) of the proposition, concerning welfare at the world level, we have that:

$$SW^{T1} - SW^{A1} = \frac{1}{4}\left[2\beta - \alpha\left(1-\alpha+4\beta\right)\right] > 0$$
$$iff \quad \alpha \in]0, 0.438[, \ \beta \in]\frac{\alpha(1-\alpha)}{2-4\alpha}, 1[\tag{A.9}$$

■

2.B Trade policy

2.B.1 Equilibrium magnitudes

Free trade equilibrium, relevant magnitudes for $\tau = \tau^*$:

$$
\begin{aligned}
&p_1^{T\tau} = \frac{1}{3}(7-4\alpha+2\beta); \quad p_2^{T\tau} = \frac{1}{3}(5-2\alpha+\beta);\\
&\pi_1^{T\tau} = \frac{1}{18}\left[-32\alpha^2+(1-\beta)^2+2\alpha(20+7\beta)\right]; \quad \pi_2^{T\tau} = \frac{1}{18}(5-2\alpha+\beta)^2;\\
&TC_1^{T\tau} = \frac{\alpha^3}{3}; \quad TC_2^{T\tau} = \frac{1}{36}\left[3-12\alpha^3+(2-2\alpha+\beta)^2\right];\\
&CS_1^{T\tau} = \frac{\alpha[3s+(4-\alpha)\alpha-2\beta-7]}{3};\\
&CS_2^{T\tau} = \frac{36s(1-\alpha)+4\alpha[28-\alpha(11-3\alpha)]-14\beta+20\alpha\beta+\beta^2-71}{36};\\
&SW_1^{T\tau} = \frac{1}{18}\left[2\alpha(1-9s+8\beta)-8\alpha^2-6\alpha^3+(1-\beta)^2\right];\\
&SW_2^{T\tau} = \frac{1}{12}\left[12s(1-\alpha)+4\alpha\left(1+\alpha+\alpha^2\right)-2\beta+8\alpha\beta+\beta^2-3\right].
\end{aligned}
\tag{B.1}
$$

Free trade equilibrium, relevant magnitudes for $\tau = \bar{\tau}$:

$$
\begin{aligned}
&p_1^{T\bar{\tau}} = 3-4\alpha; \quad p_2^{T\bar{\tau}} = 2(1-\alpha);\\
&\pi_1^{T\bar{\tau}} = (3-4\alpha)\alpha; \quad \pi_2^{T\bar{\tau}} = 2(1-\alpha)^2;\\
&TC_1^{T\bar{\tau}} = \frac{\alpha^3}{3}; \quad TC_2^{T\bar{\tau}} = \frac{1}{3}(1-\alpha)^3;\\
&CS_1^{T\bar{\tau}} = \frac{1}{3}\alpha[3s+(12-\alpha)\alpha-9]; \; CS_2^{T\bar{\tau}} = \frac{1}{3}(1-\alpha)\left(3s+8\alpha-\alpha^2-7\right);\\
&SW_1^{T\bar{\tau}} = s\alpha-\frac{1}{3}\alpha\left(\alpha^2+3\beta\right); \; SW_2^{T\bar{\tau}} = \frac{1}{3}\left(3s-(1-\alpha)^2\right)(1-\alpha);
\end{aligned}
\tag{B.2}
$$

Free trade equilibrium, relevant magnitudes for $\theta = \theta^*$:

$$
\begin{aligned}
&p_1^{T\theta} = \frac{1}{4}+\alpha; \quad p_2^{T\theta} = -\frac{1}{2}+2\alpha;\\
&\pi_1^{T\theta} = \frac{1}{32}(1+4\alpha)^2; \quad \pi_2^{T\theta} = \frac{1}{32}(1-4\alpha)(20\alpha-23);\\
&TC_1^{T\theta} = \frac{1}{3}(1-\alpha)^3; \quad TC_2^{T\theta} = \frac{1}{24}\alpha[15+2\alpha(4\alpha-9)]-\frac{7}{64};\\
&CS_1^{T\theta} = \frac{1}{64}-\frac{1}{24}\alpha\left(9-24s+18\alpha+8\alpha^2\right); \; CS_2^{T\theta} = \frac{1}{6}(1-\alpha)[1+6s-2\alpha(4+\alpha)];\\
&SW_1^{T\theta} = \frac{1}{64}(3-8\beta)-\frac{1}{24}\alpha\left(3-24s+6\alpha+8\alpha^2+12\beta\right); \; SW_2^{T\theta} = s(1-\alpha)+\frac{\alpha}{2}+\frac{\alpha^3}{3}-\frac{13}{48}.
\end{aligned}
\tag{B.3}
$$

2.B.2 Optimal tariff, other effects

In the presence of an optimal tariff, the long-run effect of trade liberalisation on country 1 still consists in an increase in her welfare for sufficiently low intensity of the emissions stemming from the consumption of the brown good. In fact, for $\tau = \tau^*$, $\alpha \in]0, \frac{1}{4}[$ and $\beta \in]0, 1-4\alpha[$:

$$SW_1^{T\tau} - SW_1^A = \frac{1}{36}\left[2(1-\beta)^2 - 16\alpha^2 - 9\alpha^3 - 4\alpha(1-\beta)\right],$$
$$iff \quad \beta \in]0, 1-\alpha - \frac{3\sqrt{\alpha^2(2+\alpha)}}{\sqrt{2}}[. \tag{B.4}$$

From Proposition 4 and (B.4) social welfare at the world level is strictly decreasing in the presence of an optimal tariff. For what concerns prices, transportation costs and consumer surpluses, the introduction of a tariff τ^* implies no differences in the sign of the dynamics from autarky to free trade, so as we can retain the claims of Proposition 2; for what concerns profits, on the other hand, free trade may bring about an increase in the profit accruing to the firm based in the smaller country if the latter is sufficiently small and the emission intensity is sufficiently small too, while it always hurts the firm based in the larger country. For what concerns firm 1, in fact, for $\tau = \tau^*$, $\alpha \in]0, \frac{1}{4}[$ and $\beta \in]0, 1-4\alpha[$:

$$\pi_1^{T\tau} - \pi_1^A = \frac{9\alpha^3 + 2(\beta - 1 - 2\alpha)^2 + 36\alpha(2 - 2\alpha + \beta)}{36} - s\alpha > 0,$$
$$iff \quad s < s_1^{T\tau} = \frac{2 + 80\alpha - 64\alpha^2 + 9\alpha^3 - 4\beta + 28\alpha\beta + 2\beta^2}{36\alpha}, \tag{B.5}$$

where $s_1^{T\tau}$ is strictly decreasing in α, with $s_1^{T\tau} \in]\infty, \frac{129}{64} + \frac{\beta(3+2\beta)}{9}[$ as $\alpha \in]0, \frac{1}{2}[$. Moreover $s < s_1^{T\tau}$ is necessary but not sufficient condition for (B.5) to hold in equilibrium since also $s_1^{T\tau} > s_{MC}^{T\tau}$, which assures non-negativity of prices and full market coverage, has to be met. The latter holds for $\alpha \in]0, 0.219[$ and $\beta \in]0, \frac{2(1-7\alpha^2)}{2+5\alpha} - 3\sqrt{\frac{\alpha^2+10\alpha^3+19\alpha^4}{(2+5\alpha)^2}}[$.
For what concerns firm 2:

$$\pi_2^{T\tau} - \pi_2^A = \frac{27 - 36s(1-\alpha) - 9\alpha[3 - (3-\alpha)\alpha] + 2(2 - 2\alpha + \beta)(8 - 2\alpha + \beta)}{36}, \tag{B.6}$$

strictly negative over the whole admissible parameter range.
Hence, these results are not substantially different from those claimed in Proposition 3, except for the fact that profits accruing to firm 1 are shown to increase with free trade uniquely in correspondence of a stricter range of α. For firm 1, in fact, the positive quantity effect of trade liberalisation $\hat{m} - \alpha$ is now decreasing in α by a factor $\frac{2}{3}$ (which is 1 for $\tau = 0$), implying that the advantage of being located in the smaller country is reduced by

$\frac{1}{3}$. In conclusion, differently from the claim contained in Proposition 1, social welfare of country 1 is shown to be decreasing even when the latter is very small (for $\alpha \in]0, 0.25[$), provided that β is high enough, that is $\beta \in]1 - \alpha - \frac{3\sqrt{\alpha^2(2+\alpha)}}{\sqrt{2}}, 1 - 4\alpha[$.
The emission intensity β, in fact, now enters in the long run equilibrium definition of all relevant magnitudes, through optimal tariff τ^*. This has implications with regards to the dynamics of the social welfare in country 1 inasmuch as a higher β is associated with a rise in the equilibrium price of the brown variety as well as with a decrease in demand accruing to firm 1. While the former effect unambiguously leads to a decrease in consumer surplus for country 1's consumers, the combination of the two effects may entail an increase in profits for firm 1, provided that α and β are sufficiently high.[18]
Since the negative effect on consumer surplus is always greater than the positive effect on firm's profits, the free trade equilibrium social welfare of country 1 is strictly decreasing in β:

$$\frac{\partial SW_1^{T\tau}}{\partial \beta} = \frac{1}{9}(-1 - 8\alpha + \beta) < 0 \qquad \forall \quad \alpha \in]0, \frac{1}{4}[, \quad \beta \in]0, 1 - 4\alpha[.$$

Moreover, since $\frac{\partial SW_1^A}{\partial \beta} = -\alpha$ (see 2.7), it is always true that $\frac{\partial SW_1^{T\tau}}{\partial \beta} < \frac{\partial SW_1^A}{\partial \beta} < 0$. Thus, as β rises, social welfare of country 1 is also necessarily reduced as compared to autarky.

2.B.3 Sub-optimal tariff

Trade liberalisation, in the presence of a sub-optimal tariff, brings about a decrease in both countries' social welfares. In fact, for $\tau = \bar{\tau}$, $\alpha \in]0, \frac{1}{2}[$ and $\beta \in]1-4\alpha, 1[$ we have that

$$SW_1^{T\bar{\tau}} - SW_1^A = -\frac{\alpha^3}{4}; \; SW_2^{T\bar{\tau}} - SW_2^A = \frac{1}{4}(\alpha - 1)^3; \tag{B.7}$$

are both strictly negative, which also implies $\Delta SW^{A,T\bar{\tau}} < 0$. For what concerns consumer surpluses we have that

$$CS_1^{T\bar{\tau}} - CS_1^A = -\frac{1}{6}\alpha\left[6(1-6s) + 4(3-6\alpha) + 3\alpha^2\right]; CS_2^{T\bar{\tau}} - CS_2^A = \frac{1}{2}(\alpha - 1)\left(5 - 2s - 6\alpha + \alpha^2\right). \tag{B.8}$$

Both differentials are strictly positive proven that $s > 3 - 4\alpha + \alpha^2$. For what concerns profits we have that

$$\pi_1^{T\bar{\tau}} - \pi_1^A = -s\alpha + \frac{1}{36}\left[36(3-6\alpha)\alpha + 72\alpha^2 + 9\alpha^3\right]; \tag{B.9}$$

$$\pi_2^{T\bar{\tau}} - \pi_2^A = \frac{27 + 2(3-6\alpha)(9-6\alpha) + 36s(-1+\alpha) - 9\alpha[3 + (-3+\alpha)\alpha]}{36};$$

[18] $\frac{\partial \pi_1^{T\tau}}{\partial \beta} < 0 \quad \forall \quad \alpha \in]0, \frac{1}{7}[, \quad \beta \in]0, 1 - 7\alpha[.$

where both differentials are strictly negative.

2.B.4 Proof of Proposition 6

Proof. For what concerns part (i), consider that strictly positive consumer surplus dynamics:

$$CS_1^{T\theta}-CS_1^A=\frac{1}{4}(1-\alpha)[4s-2\alpha(2+\alpha)-3];\quad CS_2^{T\theta}-CS_2^A=\frac{1}{64}-\frac{1}{8}\alpha\left(3-8s+6\alpha+4\alpha^2\right); \tag{B.10}$$

are necessarily driven by the decrease in both prices since

$$TC_1^{T\theta}-TC_1^A=\frac{8\alpha[5-2(3-\alpha)\alpha]-7}{64};\quad TC_2^{T\theta}-TC_2^A=\frac{1}{4}(1-\alpha)^3; \tag{B.11}$$

are strictly positive. For what concerns part (ii):

$$\pi_1^{T\theta}-\pi_1^A=\frac{1+8\alpha\left[(1+\alpha)^2-4s\right]}{32};\quad \pi_2^{T\theta}-\pi_2^A=\frac{8\alpha[11-\alpha(7+\alpha)]-15-32s(1-\alpha)}{32}; \tag{B.12}$$

both strictly negative over the whole admissible parameter range. ■

2.C The effects of trade liberalisation with different trade policies

A subsidy policy have been shown to be the sole allowing for free trade as an equilibrium outcome. Notwithstanding this, we may ask which are the distributive effect of different trade policies inside each country, independently of their effectiveness in fostering trade liberalisation. This, in order to assess the desirability of each policy for firms and consumers. In the following we have then compared, for each relevant magnitude, the differentials between autarky and free trade equilibrium values in both cases: whether country 2's government adopts one of the two policies or not. A few remarkable considerations follow:

- The negative change in both prices driven by trade liberalisation, namely the price effect, is strictly strengthened by the introduction of a subsidy while it is weakened by the introduction of a tariff.
- While the subsidy always determines a sharper increase in transportation costs of both countries, tariff acts only with regards to country 2.

- A subsidy policy always ensures maximum gain in *consumer surpluses*, while adoption of a tariff policy entails a decrease in consumer surpluses (positive) differential from autarky to long run.
- When feasible, a subsidy and a sub-optimal tariff $\tau = \bar{\tau}$ always entail minimum equilibrium firms' *profits* in free trade.

In detail, for $\alpha \in]0, 0.25[$ and $\beta \in]0, 1-4\alpha[$:

$$\Delta p_1^{A,T\tau} < \Delta p_1^{A,L} < 0; \qquad \Delta p_2^{A,T\tau} < \Delta p_2^{A,L} < 0;$$

$$\Delta TC_1^{A,T\tau} = \Delta TC_1^{A,L} > 0; \qquad \Delta TC_2^{A,T\tau} > \Delta TC_2^{A,L} > 0;$$

$$\Delta CS_1^{A,L} > \Delta CS_1^{A,T\tau} > 0; \qquad \Delta CS_2^{A,L} > \Delta CS_2^{A,T\tau} > 0;$$

$$\Delta \pi_1^{A,T\tau} \lesseqgtr \Delta \pi_1^{A,L}; \qquad 0 > \Delta \pi_2^{A,T\tau} > \Delta \pi_2^{A,L};$$

In this range the only feasible policy is a $\tau = \tau^*$ tariff policy which is detrimental for the free trade equilibrium value of all relevant magnitudes, except for firm 2's profits: it implies higher prices, higher or constant transport costs, lower consumer surpluses and lower firm 1's profits; it is straightforward to note that while social welfare of country 1 would be strictly higher in case no tariff is introduced, loss in social welfare of country 2 is reduced under a tariff scheme. This is due to the fact that the rise in firm 2 profits, together with the gross tariff revenues of country 2, more than compensate the reduction in consumer surplus.

In correspondence of area D, that is for $\alpha \in]0, 0.25[$ and $\beta \in]1-4\alpha, 1[$:

$$\Delta p_1^{A,L} < \Delta p_1^{A,T\bar{\tau}} < 0; \qquad \Delta p_2^{A,L} < \Delta p_2^{A,T\bar{\tau}} < 0.$$

$$\Delta TC_1^{A,T\bar{\tau}} = \Delta TC_1^{A,L} > 0; \qquad \Delta TC_2^{A,T\bar{\tau}} > \Delta TC_2^{A,L} > 0.$$

$$\Delta CS_1^{A,L} > \Delta CS_1^{A,T\bar{\tau}} > 0; \qquad \Delta CS_2^{A,L} > 0 > \Delta CS_2^{A,T\bar{\tau}}.$$

$$\Delta \pi_1^{A,L} > 0 > \Delta \pi_1^{A,T\bar{\tau}}; \qquad \Delta \pi_2^{A,L} > 0 > \Delta \pi_2^{A,T\bar{\tau}}.$$

Here, a $\bar{\tau}$ tariff policy still entails a redistribution of welfare from country 1 to country 2 which consists in a in a reduction of welfare loss for country 2 and in a welfare loss for country 1 that would have risen in the absence of a policy. Notwithstanding this, the choice between adopting a tariff or not has a significant implication from the point of view of the distribution of welfare between firms and consumers/inhabitants.

For what concerns country 1, reduction in welfare stems from a lower gain in consumer surplus (given a softer price effect) and from an even higher reduction in firm's profits (due to a contraction in demand).

For what concerns country 2, reduction in welfare loss stems from a higher decrease in consumer surplus (given a softer price effect) outweighed by a lower reduction in firm's profits (given a softer price effect and an increase in demand). Then, again, the tariff policy acts in favour of a redistribution from country 2 consumer surplus to firm 2 profits: the positive effect on aggregate surplus differential is due to a minor loss in firm 2 profits.

For $\alpha \in]0.25, 0.5[$:

$$\Delta p_1^{A,T\theta} < \Delta p_1^{A,L} < 0; \qquad \Delta p_2^{A,T\theta} < \Delta p_2^{A,L} < 0;$$

$$\Delta TC_1^{A,T\theta} > \Delta TC_1^{A,L} > 0; \qquad \Delta TC_2^{A,T\theta} > \Delta TC_2^{A,L} > 0;$$

$$\Delta CS_1^{A,T\theta} > \Delta CS_1^{A,L} > 0; \qquad \Delta CS_2^{A,T\theta} > \Delta CS_2^{A,L} > 0;$$

$$\Delta \pi_1^{A,T\theta} < 0 < \Delta \pi_1^{A,L}; \qquad \Delta \pi_2^{A,T\theta} < 0 < \Delta \pi_2^{A,L};$$

Here, the only feasible policy is a $\theta = \theta^*$ subsidy policy which, with respect to a no-policy scenario, has been shown to strengthen the positive effect of trade liberalisation on consumer surpluses and limit its negative effect on profits. With regards to country 2, this entails an improvement in social welfare as compared to autarky, which may result in a loss reduction or even in a gain. On the contrary, for country 1, the subsidy policy implies a worsening of the social welfare differential, until α and β are not high enough. For high α and β, in fact, the reduction of externality which stems from importing and consuming a clean good, outweighs losses in consumer surplus and firms profits. Condition for $\Delta SW_1^{A,T\theta} > \Delta SW_1^{A,L}$ is:

$$\alpha \in]0.4587, 1[; \qquad \beta \in]\frac{29 - 56\alpha + 16\alpha^2}{8(4\alpha - 1)}, 1[.$$

Chapter 3

Trade Costs, FDI Incentives, and the Intensity of Price Competition

3.1 Introduction

The standard theory of multinational enterprises suggests that a decrease in trade tariffs would reduce the amount of foreign direct investment (FDI).[1] Indeed, the adoption of FDIs has the aim to avoid tariffs by installing productive capacity in the country of the market where the firm operates (the so-called *tariff-jumping* argument). Nonetheless, stylized facts on FDIs show that the increase in trade liberalization has led in fact to an increase in the volume of FDIs.[2]

The developments in the literature on multinational enterprises focus on the relationship between the likelihood of FDI and distance, which depends crucially on the type of FDI considered. In particular horizontal FDIs are more likely the higher the transportation costs.[3] When FDI is vertical instead, the aim is to save on costs in a particular production stage (Helpman (1984)). In this case trade is more likely directed towards relatively close markets, and vertical FDI is a complement of trade rather than a substitute, since trade flows will occur intra-firm, and economic distance adds costs to the firm. In a recent contribution, Collie (2011) explains the paradox in a setting with two regions and two countries in each of them, Cournot competition and linear costs. He shows that multilateral trade liberalization may induce firms to shift from exporting to FDIs if the inter-regional transport cost is sufficiently high.[4]

We propose an alternative explanation in a setting where two Bertrand firms, supplying a homogeneous good with a convex cost function, enter the market of a foreign country. They choose between exporting, which involves a linear cost associated with either shipping or tariffs, or undertaking FDIs, involving a sunk cost. We model Bertrand competition as in Dastidar (1995), yielding a continuum of Nash equilibria, ranging also above marginal cost pricing.[5] Our results show that the paradox of an increase in FDI as trade liberalization increases can be explained on the basis of firms' ability to tune the intensity of price competition in the host market, provided the FDI sunk costs are sufficiently low for the FDI strategy to be viable. The result relies on the fact that softening competition raises firms' mark-up and this, in turn, may offset the cost of opening a new

[1] Some relevant contributions in this field are Horstmann and Markusen (1992), Motta (1992) and Rowthorn (1992) *inter alia*.

[2] See Markusen (2004) and Navaretti and Venables (2004).

[3] See, e.g., Horstmann and Markusen (1987); Brainard (1993); Markusen and Venables (1998); **?**.

[4] An alternative and solid explanation to this paradox can be found in the literature on tax competition and FDI, according to which trade libelisation can increase FDI if countries favour foreign investments through a low taxation. Some noteworthy contributions are Janeba (1995), Haufler and Wooton (1999, 2006), Raff (2004) and Davies, Egger, and Egger (2010), *inter alia*.

[5] Dastidar's (1995) result is further generalised in a repeated setting by Weibull (2006).

plant abroad.

3.2 The model

We consider a world with two countries, labelled 1 and 2. In country 1 there are two firms, labelled A and B. They produce the same homogeneous good, and have symmetric and convex production costs:

$$C = cq^2, \tag{B.1}$$

where q is the quantity produced by each firm and $c > 0$. Consider a scenario in which both firms can supply the market of country 2, hosting no home firms at all. Let the inverse demand expressed by consumers of country 2 be linear:

$$p = 1 - 2q. \tag{B.2}$$

Firms A and B can enter country 2 in two alternative ways, namely, by (i) exporting from country 1 or (ii) undertaking FDIs. In the first case, they bear a cost $t \in (0, 1)$ for each unit exported, which can be interpreted either as a transportation cost or a tariff, and thus obtaining profits:

$$\pi_{ex} = pq - cq^2 - tq, \tag{B.3}$$

while in the alternative case they incur the sunk costs $k > 0$, with profits:

$$\pi_{FDI} = pq - cq^2 - k. \tag{B.4}$$

3.3 Results

According to Dastidar (1995), if firms have symmetric convex costs and compete *à la* Bertrand, the Nash equilibrium is necessarily non-unique. In particular, a pure-strategy Nash equilibrium is characterized by both firms setting the same price p^*, which is bounded by two thresholds $p^{avc} \leq p^* \leq p^u$. The lower bound p^{avc} (the superscript *avc* stands for *average variable cost*) equals average variable costs, letting firms be indifferent between either producing at p^* or producing nothing at all. The upper bound p^u (with superscript u standing for *undercutting*) is the price at which firms are indifferent between choosing price p^u, and marginally undercutting it in order to capture the entire demand at p^u.

If both firms export from their respective home plants, the level of p^{avc} is given by equating the inverse demand function to the average variable cost (which includes the trading cost):

$$1 - 2q = cq + t, \tag{B.5}$$

then solving for q and substituting in the demand function we obtain:

$$p_{ex}^{avc} = \frac{c + 2t}{2 + c}. \tag{B.6}$$

The upper bound of the equilibrium price obtains by imposing indifference between duopoly profits (B.3) and the monopoly profits generated by undercutting:

$$pq - cq^2 - tq = 2pq - 4cq^2 - 2tq. \tag{B.7}$$

Solving for p, we obtain

$$p_{ex}^{uc} = \frac{3c + 2t}{2 + 3c}. \tag{B.8}$$

Finally, by equating the inverse demand function to the marginal cost, solving for q and substituting into p, we obtain the price equal to marginal cost:

$$p_{ex}^{mc} = \frac{c + t}{1 + c}, \tag{B.9}$$

where the superscript *mc* stands for *marginal cost pricing*.

The continuum of Nash equilibria can be represented by the following expression:[6]

$$p_{ex}^{*} = \frac{c + (2 - \alpha)\, t}{2 + c - \alpha}. \tag{B.10}$$

Parameter α represents the relative intensity of price competition between firms. Note that, when $\alpha = 0$, in equilibrium price equals average variable cost; $\alpha = 1$ corresponds to the Bertrand reference case in which price is equal to marginal cost, while at $\alpha = 4/3$ the price attains the highest level above which undercutting takes place. As a consequence, $\alpha \in [0, 4/3]$. Using (B.10), the individual profit function (B.3) writes:

$$\pi_{ex}^{*} = \frac{\alpha c\,(2 - \alpha)\,(1 - t)^2}{4\,(2 + c - \alpha)^2}. \tag{B.11}$$

The per-firm equilibrium profits obtained by undertaking FDI can be easily found by setting $t = 0$ in equation (B.11) and subtracting the FDI sunk cost k:

$$\pi_{FDI}^{*} = \frac{\alpha c\,(2 - \alpha)}{4\,(2 + c - \alpha)^2} - k. \tag{B.12}$$

[6] For an analogous application of Dastidar's (1995) approach, see André, Gonzlez, and Porteiro (2009).

Of course, in order for π^*_{FDI} to be positive, the following condition must hold:[7]

$$k < \widehat{k} = \frac{\alpha c\,(2-\alpha)}{4\,(2+c-\alpha)^2}. \tag{B.13}$$

the straightforward implication of (B.13) is that exporting is the only viable strategy for all $k > \widehat{k}$. By comparing π^*_{ex} with π^*_{FDI}, it emerges that $\pi^*_{FDI} - \pi^*_{ex} > 0$ for all

$$k < \widetilde{k} = \frac{\alpha c\,(2-\alpha)\,(2-t)\,t}{4\,(2+c-\alpha)^2}. \tag{B.14}$$

Finally, note that:

$$\widehat{k} - \widetilde{k} = \frac{\alpha c\,(2-\alpha)\,(1-t)^2}{4\,(2+c-\alpha)^2} > 0. \tag{B.15}$$

This leads to the following proposition:

Proposition 1 *For all $k \in \left[0, \widetilde{k}\right]$, both firms undertake FDIs to install capacity in the host country. For all $k > \widetilde{k}$, both firms choose to export from their home sites.*

We are now in a position to exploit this result in order to explain the puzzle by which trade liberalization leads to an increase in the volume of FDIs. This can be ascertained by evaluating the overall effect on $\widetilde{k}$, whose increase expands the space for FDIs, of variations in (i) t, whose decrease leads to an increase in trade liberalization, and (ii) α, which represents an inverse measures of the intensity of price competition.

Totally differentiating $\widetilde{k}$ yields:

$$d\widetilde{k} = \frac{\partial \widetilde{k}}{\partial t}dt + \frac{\partial \widetilde{k}}{\partial \alpha}d\alpha = \tag{B.16}$$

$$\frac{\alpha c\,(2-\alpha)\,(1-t)}{2\,(2+c-\alpha)^2}dt + \frac{c\,[2+c-\alpha\,(1+c)]\,(2-t)\,t}{2\,(2+c-\alpha)^3}d\alpha.$$

The existing literature on FDIs confines itself to the discussion of $\partial\widetilde{k}/\partial t$, which is usually positive and therefore delivers the clearcut message that trade liberalization jeopardizes FDI incentives. In the present model, this effect can be (more than) counterbalanced by the price behaviour of firms, provided $\partial\widetilde{k}/\partial\alpha > 0$, in such a way that a decrease in t may indeed be accompanied by a constant or even increasing level of $\widetilde{k}$, in accordance with empirical observation.

Examining (B.16), one observes that the coefficient of $\partial\widetilde{k}/\partial t$ is unambiguously positive for all admissible values of parameters. This feature is fully in line with the established

[7] This must be imposed as we are not imposing the price to cover average total costs.

theoretical wisdom dating back to Horstmann and Markusen (1992), Motta (1992) and Rowthorn (1992). Instead, the partial derivative $\partial\widetilde{k}/\partial\alpha$ is positive for all

$$\alpha \in \left[0, \max\left\{\frac{2+c}{1+c}, \frac{4}{3}\right\}\right), \tag{B.17}$$

with

$$\lim_{c\to 0}\frac{2+c}{1+c} = 2 \quad \text{and} \quad \lim_{c\to\infty}\frac{2+c}{1+c} = 1. \tag{B.18}$$

Now note that

$$\max\left\{\frac{2+c}{1+c}, \frac{4}{3}\right\} = \frac{4}{3}\,\forall\, c > 2, \tag{B.19}$$

so that for $c \leq 2$, the sign of $\partial\widetilde{k}/\partial\alpha$ is unambiguously positive and may be large enough to compensate the effect generated by a decrease in trade barriers so as to restore or enhanced FDIs. For all $c > 2$, the sign of $\partial\widetilde{k}/\partial\alpha$ depends instead on the level of α: in particular, it becomes negative for all $\alpha \in ((2+c)/(1+c), 4/3]$. A portray of this result is offered in Figure 3.1, where the region $\alpha \in [0, \max\{(2+c)/(1+c), 4/3\})$ is one in which raising prices (i.e., increasing α) may in fact lead to a reversal of the traditional tariff-jumping argument. Intuitively, the region in which this happens shrinks as marginal cost c becomes higher, but never disappears, as (B.18) proves.

Therefore firms starting, say, from the point $(2, 1)$, and facing a decrease in trade barriers, might restore their own FDI incentives by moving vertically in the direction of a more remunerative mark-up.

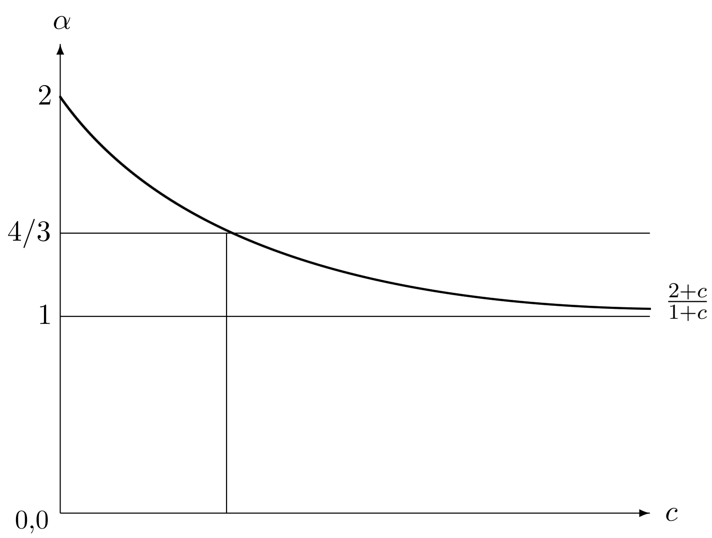

Figure 3.1: Pricing behaviour and FDI incentives

The foregoing discussion can be summarised in

Proposition 2 *In the parameter region identified by* $\alpha \in \left[0, \max\left\{\frac{2+c}{1+c}, \frac{4}{3}\right\}\right)$*, an appropriate increase in the mark-up may offset the negative effect of trade liberalization on FDI incentives.*

That is, the standard effect associated with a decrease in trade barriers (i.e., a monotone positive relationship between trade costs and FDIs) can indeed flip over if accompanied by a higher mark-up, sufficient to make it easier (and indeed attractive) for firms to bear the sunk cost of a new plant abroad. An alternative way of reading Proposition 1 is that $\widetilde{k}$ defines a map of negatively sloped isoquants in the space (α, t) for all $c \leq 2$; in this range, α and t behave as substitutes and therefore any decrease in trade barriers may be exactly counterbalanced and even more than offset by an increase in α. Otherwise, if $c > 2$, these isoquants become positively sloped for all $\alpha \in ((2+c)/(1+c), 4/3]$ while remaining negatively sloped anywhere else. Accordingly, one could reformulate Proposition 1 by saying that in the parameter range in which α and t behave as substitutes, FDI incentives jeopardized by trade liberalization may be fully restored by exploiting the continuum of Bertrand-Nash equilibria to fine tuning the firms' profit margin.

To complete the picture, we briefly discuss the different implications on the social welfare of the host country in the two alternative situations. In the case of export, one can consider t, alternatively, as (i) a transportation cost or (ii) a tariff. If t represents a transportation cost, the host country's social welfare trivially coincides with its own consumer surplus, i.e.:

$$W_{ex}^{tc} = \frac{(2-\alpha)^2 (1-t)^2}{2(2+c-\alpha)^2}, \tag{B.20}$$

where superscript tc stands for *transportation cost*. Obviously, any increase in transportation costs hinders consumer surplus. Instead, if t is a tariff, then the related revenue contributes to the host country's social welfare, together with consumer surplus:

$$W_{ex}^{ta} = \frac{(2-\alpha)(1-t)[2-\alpha+t(2(1+c)-\alpha)]}{2(2+c-\alpha)^2}, \tag{B.21}$$

where the superscript ta stands for *tariff*. Clearly, $W_{ex}^{ta} > W_{ex}^{tc}$. Moreover, as t here becomes a policy instrument in the hands of the host country's government, is can be easily established that

$$\frac{\partial W_{ex}^{ta}}{\partial t} \propto c - t[2(1+c)-\alpha] = 0 \tag{B.22}$$

in

$$t^{*} = \frac{c}{2(1+c)-\alpha} \tag{B.23}$$

Finally, in the case of FDI, again the host country's social welfare is given by its consumer surplus (the same as (B.20), with $t = 0$):

$$W_{FDI} = \frac{(2-\alpha)^2}{2(2+c-\alpha)^2}. \tag{B.24}$$

We now compare the three alternatives. First note that $W_{FDI} > W_{ex}^{tc}$ for all $t > 0$, while $W_{FDI} < W_{ex}^{ta}$ for all:

$$t < \frac{2c}{2(1+c)-\alpha}, \tag{B.25}$$

leading to

Corollary 1 *The host country's social welfare ranking is* $W_{ex}^{ta} > W_{FDI} > W_{ex}^{tc}$.

This amounts to saying that imports are preferred to FDIs if and only if t can be controlled by the host country to generate revenues more than offsetting the negative effect on consumer surplus.

3.4 Concluding remarks

In a Bertrand setting generating a continuum of price equilibria, we have revisited the puzzle concerning the relationship between trade liberalization and FDIs, to illustrate the theoretical possibility that the apparent *hiatus* between theory and observation may indeed be traced back to the role of strategic pricing, so far overlooked in the discussion on this issue. Our analysis, based on Dastidar (1995), has shown that the traditional negative effect caused by lowering trade barriers on FDIs may in fact be neutralized by increasing the mark-up appropriately. This delivers a hint for empirical research, as one could test the prediction of the present model by checking whether the observed increase in FDIs going along with trade liberalization is also accompanied by higher prices.

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