Université de Montréal

Essais sur des questions internationales en économie des ressources naturelles

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Thèse présentée à la Faculté des arts et des sciences
en vue de l'obtention du grade de Philosophiæ Doctor (Ph.D.)
en sciences économiques

Juillet, 2011

Université de Montréal
Faculté des arts et des sciences

Cette thèse intitulée:

Essais sur des questions internationales en économie des ressources naturelles

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a été évaluée par un jury composé des personnes suivantes:

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Thèse acceptée le 12 octobre 2011

RÉSUMÉ

Cette thèse s'articule autour de trois essais portant sur des questions internationales en économie des ressources naturelles. Le premier essai examine la production et l'échange des ressources non-renouvelables dans un modèle spatial et souligne le rôle de la superficie des pays et du coût des transports dans la détermination du sens de l'échange. Le deuxième essai considère le tarif d'extraction de la rente de rareté liée aux ressources naturelles non-renouvelables avec le modèle spatial développé dans premier essai. Le cadre spatial (plus général) permet de représenter des pays qui sont à la fois importateurs et producteurs de la ressource, ce qui n'est pas possible dans les modèles traditionnels de commerce international où les pays sont traités comme des points (sans dimension). Le troisième essai aborde la question des droits de propriétés sur les zones maritimes et examine l'allocation d'une population de pêcheurs entre les activités productives et non-productives dans une communauté côtière.

Le premier chapitre propose un modèle spatial de commerce international des ressources non-renouvelables. Le cadre spatial considère explicitement la différence de taille géographique (superficie) entre les pays et permet ainsi de tenir compte du fait que les gisements naturels et leurs utilisateurs soient dispersés dans l'espace, même à l'intérieur d'un pays. En utilisant un modèle spatial à la Hotelling, nous examinons l'évolution dans le temps du sens de l'échange entre deux pays (ou régions) qui diffèrent du point de vue de leur technologie de production, de leur superficie et de leur dotation en gisement d'une ressource naturelle non-renouvelable. Le chapitre met en évidence le rôle de la taille géographique dans la détermination du sens de l'échange, à côté des explications traditionnelles que sont l'avantage comparatif et les dotations des facteurs. Notre analyse est fondamentalement différente des autres contributions dans la littérature sur le commerce international des ressources naturelles parce qu'elle souligne l'importance de la taille géographique et du coût de transport par rapport à d'autres facteurs dans la détermination des flux de ressource à l'équilibre. Le coût unitaire de transport joue un rôle capital pour déterminer si la différence de superficie entre les pays influence le sens de l'échange à l'équilibre plus que les autres facteurs. Le chapitre discute aussi du caractère

régional des échanges qui a été observé pour certaines ressources telles que le minerai de fer et la bauxite.

Le chapitre deux aborde la question de la répartition de la rente de rareté liée aux ressources naturelles non-renouvelables entre les pays producteurs et les pays consommateurs. Cette question a été abordée dans la littérature sous une hypothèse quelque peu restrictive. En effet, dans la plupart des travaux portant sur ce sujet le pays importateur est automatiquement considéré comme dépourvu de gisement et donc non producteur de la ressource. Pourtant la réalité est qu'il existe des ressources pour lesquelles un pays est à la fois producteur et importateur. Le cadre d'analyse de ce second essai est le modèle spatial développé dans le premier essai, qui permet justement qu'un pays puisse être à la fois importateur et producteur de la ressource. Le pays importateur détermine alors simultanément le tarif optimal et le taux d'extraction de son propre stock. Nous montrons que le tarif optimal croît au taux d'intérêt et de ce fait, ne crée aucune distorsion sur le sentier d'extraction de la ressource. Le tarif optimal permet de récupérer toute la rente lorsque le pays exportateur ne consomme pas la ressource. Néanmoins, la possibilité pour le pays exportateur de consommer une partie de son stock limite la capacité du pays importateur à récupérer la rente chez le pays exportateur. La présence de gisements de la ressource dans le pays importateur réduit la rente du pays exportateur et de ce fait renforce la capacité du pays importateur à récupérer la rente chez le pays exportateur. Le tarif initial est une fonction décroissante du stock de ressource dans le pays importateur. Cet essai aborde également la question de la cohérence dynamique du tarif obtenu avec la stratégie en boucle ouverte.

Le troisième chapitre examine un problème d'allocation de l'effort entre les activités productives (par exemple la pêche) et les activités non productives (par exemple la piraterie maritime) dans une population de pêcheurs. La répartition de la population entre les activités de pêche et la piraterie est déterminée de façon endogène comme une conséquence du choix d'occupation. Nous établissons l'existence d'une multiplicité d'équilibres et mettons en évidence la possibilité d'une trappe de piraterie, c'est-à-dire un équilibre stable où une partie de la population est engagée dans les actes de piraterie. Le modèle permet d'expliquer l'augmentation significative des attaques de piraterie dans

le Golfe d'Aden au cours des dernières années. Le chapitre discute aussi des différents mécanismes pour combattre la piraterie et souligne le rôle crucial des droits de propriété. (Classification JEL : F10 ; Q30 ; D41 ; F13 ; Q31 ; Q38 ; D23 ; D72 ; D74).

Mots clés : modèle spatial à la Hotelling, flux de commerce, ressources non-renouvelables, taille géographique, coûts de transport, rente pétrolière, tarif, jeu différentiel, équilibre de Stackelberg en boucle ouverte, droits de propriété, trappe à la piraterie, ressources à accès libre, recherche de la rente.

ABSTRACT

This thesis consists of three essays on international issues in natural resource economics. The first essay proposes a spatial model of trade in exhaustible resources and emphasizes the role of geographical size and transport costs in the determination of trade patterns. The second essay considers the rent-extracting tariff in a spatial (more general) framework in which the importing country can be simultaneously a producer and an importer of the resource, a feature which is not possible in the traditional trade model, where countries are assumed dimensionless. The third essay tackles the issue of property rights in maritime zones and examines the allocation of a population of fishermen between productive and unproductive activities in a coastal community.

The first chapter proposes a model of trade in exhaustible resources that explicitly accounts for the fact that countries have different geographical sizes while resource sites and their users are spatially distributed, even within a country. Using a spatial model à la Hotelling, we examine the evolution over time of the pattern of trade between two countries (or regions) which differ in terms of their technology, their geographical size, and their endowment of some nonrenewable natural resource. The model emphasizes the importance of geographical size in determining trade patterns besides the traditional explanations of comparative advantage and factor endowments. Indeed, three forces influence the direction of international trade in the presence of transport costs. The analysis fundamentally differs from other contributions in the natural resource literature because it emphasizes the importance of geographical size and of transport cost relative to other factors in the determination of the equilibrium resource flows. The unit cost of transport is shown to play a decisive role in determining whether the international asymmetry in terms of geographical sizes of countries has a greater influence than other factors on the equilibrium pattern of trade. The chapter also discusses the regional character of trade which has been observed for some resources such as iron ore and bauxite.

Most findings in the literature on tariff and exhaustible resources have been derived under a serious abstraction. Indeed, virtually all contributions on that issue have assumed that no stocks of the resource are available within the importing country's borders and therefore the importing country is not itself a producer. Reality is in fact quite different : there are many instances of countries that are simultaneously importers and producers of a natural resource. The second chapter makes use of the spatial trade model of chapter one to depart from the usual assumption and allow the importing country to have access to a stock of the resource of its own and to determine simultaneously the optimal tariff and the rate of depletion of its own stock. The optimal tariff is shown to increase at the rate of interest and is therefore nondistortionary. Moreover, the optimal tariff captures all the rent if the exporting country gets no utility from consuming the resource. Allowing the exporting country to consume the resource restricts the ability of the importer to capture all of the foreign rent. The presence of resource deposits in the importing country reduces the available rent to foreign producers and, in essence, reinforces the ability of the importer to capture the foreign rent. In effect, the initial tariff is shown to be a decreasing function of the initial resource stock in the importing country. The essay also discusses the time consistency of the open-loop tariff.

The third chapter examines how agents in a coastal community allocate effort between productive (fishing) and unproductive (piracy) activities. The allocation of population between fishing activity and piracy attacks is determined endogenously as a consequence of the occupation choice. We prove the existence of multiple equilibria and emphasize the possibility of a piracy trap, that is a steady state equilibrium where part of the population is engaged in piracy acts. The chapter offers an explanation for the significant increase in piracy attacks in the Gulf of Aden in the recent years. The chapter also discusses different schemes in combating piracy and highlights the crucial role of property rights.

(JEL Classification : F10 ; Q30 ; D41 ; F13 ; Q31 ; Q38 ; D23 ; D72 ; D74).

Keywords : Spatial model à la Hotelling ; Trade flows ; Nonrenewable resources ; Geographical size ; Transport costs, Oil rent ; Tariff ; Differential game ; Open-loop Stackelberg equilibrium ; Property rights ; Piracy trap ; Open access resources ; Rent-seeking.

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À mes parents, Njopmouo Zacharie et Tchuidjou Lydie,
À mes fils, Guiddel et Jeriel.

À la mémoire de :
mon grand-père, Ketimbeu Salomon,
mon oncle, Tchoutouo Jean,
mon beau-père, Kouakam Jean-Marie,
et ma petite-soeur, Ngopseu Sabine.

"Weeping may spend the night, but there is joy in the morning." **Psalm 30 :5**

REMERCIEMENTS

"*L'Homme n'est rien sans son bord*" avions nous coutume de dire ou d'entendre à Ngoa-Ékellé, colline du savoir à Yaoundé au Cameroun. Je me permets ici une paraphrase en disant : *le doctorant n'est rien sans son directeur, sa famille, ses amis*... Le cheminement de cette thèse m'a inspiré cette paraphrase et je voudrais de tout cœur exprimé ma gratitude et ma reconnaissance à toutes les personnes qui de près ou de loin ont contribué à sa réalisation.

La place d'honneur des remerciements revient à Gérard Gaudet, mon directeur de thèse, qui m'a fait confiance et qui n'a ménagé aucun effort pour m'encadrer pendant toutes ces années. La collaboration avec Gérard a été pour moi d'une valeur inestimable. J'ai beaucoup appris de sa longue expérience et ses multiples conseils ont été très enrichissants pour moi. Son exigence et sa rigueur au travail ont beaucoup contribué à mon apprentissage. Je tiens à remercier Gérard pour ses encouragements et sa très longue patience qui ont été indispensables à l'élaboration de cette thèse. Gérard a été pour moi l'encadreur parfait qui a su me motiver et qui a su me comprendre. ME LÈSSE TÉH !

Je remercie Pierre Lasserre, Ngo Van Long, Justin Leroux, William McCausland, ainsi que tous les participants à l'atelier d'économie des ressources naturelles et de l'environnement de Montréal pour les discussions et les commentaires qui ont été bénéfiques pour mes travaux de recherche. Mes remerciements vont également à tout le personnel administratif du département de sciences économiques de l'Université de Montréal dont le soutien logistique m'a permis d'avoir plus de temps pour la recherche. Je voudrais remercier aussi tous les professeurs que j'ai connus et dont les enseignements m'ont été bénéfiques.

Je suis très reconnaissant au département de sciences économiques de l'Université de Montréal, au Centre Interuniversitaire de Recherche en Économie Quantitative, à la Faculté des Études Supérieures et Postdoctorales de l'Université de Montréal et au Fonds Québécois de la Recherche sur la Société et la Culture pour le soutien financier qui a été essentiel à la réalisation de cette thèse.

J'ai une pensée spéciale pour tous mes collègues de promotion, en particulier Constant, Johnson, Barnabé et Rachidi. Je pense également à Roméo, Didier, Firmin, Samuel et Bertrand pour tout ce que nous avons partagé, sans oublier mes collègues de bureau Bruno, Éric et Maxime. J'adresse des remerciements particuliers à Évariste et à toutes les personnes qui ont contribué à la relecture de cette thèse. Que tous les amis et collègues étudiants que j'ai côtoyés trouvent en ce travail le fruit des échanges fructueux que nous avons eus pendant toutes ces années.

Florence était là au tout début de ce projet. Je voudrais lui exprimer, ainsi qu'à toute sa famille, ma profonde gratitude pour le soutien permanent. Je remercie également Cyriaque et Joseph pour leur soutien et leurs encouragements, et pour tout ce que nous avons vécu et partagé ensemble depuis nos débuts à Bafoussam.

Que mes parents voient en cette thèse l'aboutissement des sacrifices et des efforts qu'ils ont consentis pour assurer mon éducation. Je saisis cette opportunité pour leur renouveler ma profonde gratitude ainsi qu'à toute ma famille. Vous avez toujours été là, dans la félicité comme dans l'adversité, et vous m'avez toujours soutenu. Je vous suis infiniment reconnaissant.

Je ne saurais terminer sans une mention spéciale pour Sylvie Valter Ngueumbou, ma très chère épouse. Sa présence a été indispensable à l'accomplissement de ce travail. Je lui suis infiniment reconnaissant pour les efforts et les sacrifices consentis.

Que toute la gloire revienne au Dieu Tout-Puissant, l'Éternel des Armées.

INTRODUCTION GÉNÉRALE

Les ressources naturelles jouent un rôle essentiel dans la vie économique du monde moderne. La répartition inégale des ressources naturelles non-renouvelables dans le monde implique que certains pays ne peuvent satisfaire leurs contraintes de ressources que par le biais du commerce international. L'échange international des ressources non-renouvelables soulève deux questions fondamentales. Premièrement, qu'est ce qui détermine le sens du mouvement de ces ressources entre les pays ? Deuxièmement, comment la rente de rareté liée aux ressources non-renouvelables se répartit-elle entre les pays producteurs et les pays consommateurs ? Les deux premiers essais de cette thèse examinent ces questions dans un cadre spatial en tenant explicitement compte du fait que les gisements naturels ainsi que leurs utilisateurs sont dispersés dans l'espace. Par ailleurs, le troisième essai aborde la question des droits de propriétés sur les ressources renouvelables, plus précisément les ressources maritimes, et fait ressortir le lien avec la répartition de la population entre les activités productives et non-productives dans une communauté côtière de pêcheurs.

En dépit de la distribution spatiale des gisements naturels et de leurs utilisateurs, très peu de place a été accordée à des considérations spatiales dans l'analyse des ressources naturelles non-renouvelables. Quelques contributions théoriques ayant considéré la distribution spatiale des ressources et de leurs utilisateurs sont Laffont et Moreaux (1986), Kolstad (1994), Gaudet et al. (2001). Seulement, aucune de ces contributions ne s'est faite dans le cadre du commerce international, notamment pour ce qui est de la détermination du sens de l'échange. La littérature sur le commerce international des ressources non-renouvelables est abondante (voir par exemple Djadjic (1988) et les autres références qui y sont mentionnées). Cependant, la plupart des contributions à cette littérature considère les pays comme des points dans l'espace et les coûts de transport sont supposés nuls. Le premier chapitre de la thèse propose un modèle de flux international des ressources non-renouvelables qui considère la taille géographique (superficie) des pays et qui tient explicitement compte du fait que les gisements naturels et leurs utilisateurs sont dispersés dans l'espace, même à l'intérieur d'un pays. Plusieurs faits justifient la considération spatiale dans l'analyse des flux internationaux des ressources non-renouvelables.

Premièrement, pour certaines ressources comme le minerai de fer, le coût de transport représente une large proportion du prix de vente, comparée à la valeur même de la mine. Galdon-Sanchez et Schmitz (2002) rapporte que le fret pour une tonne de fer du Brésil (ayant le coût de production le plus bas au monde) vers l'Europe représente plus de 50% du prix de vente. De plus, l'étude relève que les frais liés au transport dépendent considérablement de la distance. Ainsi, transporter une tonne de minerai de fer de l'Australie vers Baltimore (États-Unis) coûte en moyenne deux fois plus cher que de la transporter au Japon ($\$11,55$ contre $\$5,5$). La différence des coûts de transport est aussi observée à l'intérieur d'un même pays, si bien qu'il coûte largement moins cher de transporter une tonne de fer de la côte est canadienne vers Baltimore (Maryland) que de la transporter vers Chicago. Les coûts de transport représentent une large proportion du prix de vente dans l'industrie du minerai de fer. Un producteur avec un coût de production élevé pourrait avoir un avantage compétitif à cause de sa proximité à un marché par rapport à un lointain concurrent ayant un coût de production plus bas. C'est par exemple le cas du producteur suédois LKAB qui, en dépit de ces coûts de production très élevés, est demeuré compétitif sur le marché international du fer à cause de sa proximité de son port d'expédition et de son marché européen.

Une deuxième raison de tenir compte de la distribution spatiale est que les modèles traditionnels (non spatial) de commerce international où les pays sont traités comme des points pourraient ne pas aider à expliquer les flux internationaux sur le marché du minerai de fer. En effet, comme conséquence des coûts de transport élevés, un pays ayant un avantage comparatif tant en termes de coût de production que de dotation relative en minerai de fer pourrait, dans un modèle spatial, être un importateur net de la ressource et non un exportateur net comme le prévoit les modèles traditionnels où les pays sont sans dimension. Cette situation est possible dans le cas spatial parce que les consommateurs ne sont pas tous situés au même endroit comme le suppose les modèles traditionnels. Certains consommateurs, notamment ceux qui sont éloignés du site de production de la mine, pourraient acheter la ressource à moindre prix dans un autre pays où ils sont plus rapprochés du site de production de la mine. Ceci serait certainement une des explications du sens de l'échange entre la Chine et l'Inde dans l'industrie du minerai de fer. En effet, la Chine est relativement plus riche en minerai de fer que l'Inde ; que ce soit en termes de réserves (16596 tonnes métrique pour la Chine contre 4298 tonnes métrique pour l'Inde) ou de production (198 tonnes métrique pour la Chine contre 124 tonnes métrique pour l'Inde) par habitant. Sans tenir compte de la superficie des pays et de la distribution spatiale des consommateurs, l'on s'attendrait à ce que l'Inde importe le fer de la Chine ; pourtant, c'est la Chine qui importe le fer de l'inde.

Le premier chapitre de cette thèse adapte le cadre d'analyse de Kolstad (1994) pour tenir compte des implications du commerce international.[1] À la suite de Tharakan et Thisse (2002) nous considérons deux pays dont les consommateurs sont dispersés dans l'espace, chacun ayant une adresse spécifique. Le cadre spatial ainsi construit nous permet d'examiner l'évolution dans le temps du sens de l'échange entre deux pays (ou régions) qui diffèrent du point de vue de leur superficie, de la densité de distribution des consommateurs dans l'espace, de leur dotation en gisement d'une ressource non-renouvelable, et de leur technologie de production (coût d'extraction de la ressource). Notre analyse est fondamentalement différente des autres contributions à la littérature sur le commerce international des ressources non-renouvelables parce qu'elle souligne l'importance de la taille géographique et du coût de transport par rapport à d'autres facteurs dans la détermination des flux de ressource à l'équilibre. En effet, trois facteurs déterminent le sens des flux de l'échange dans un contexte spatial : l'avantage lié au coût de production, l'avantage lié à la dotation en ressource par habitant, et l'avantage lié à la taille géographique. Le coût unitaire de transport joue un rôle capital pour déterminer si la différence de superficie entre les pays influence le sens de l'échange à l'équilibre plus que les autres facteurs. Le cadre ainsi construit permet de comprendre les faits mentionnés plus haut et le caractère régional des échanges qui a été observé pour certaines ressources telles que le minerai de fer et la bauxite.

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[1] Kolstad (1994) utilise un modèle spatial *à la* Hotelling (Hotelling, 1929) pour examiner l'interrelation entre les rentes associées à différents sites de ressources non-renouvelables. L'analyse de Kolstad se fait dans le cas d'un monde global. Nous y introduisons deux pays et analysons les conséquences du commerce international entre les deux pays.

Une propriété essentielle des ressources naturelles non-renouvelables est que les réserves sont fixes si bien qu'une unité consommée aujourd'hui ne pourra plus être disponible pour un usage futur. De ce fait, les producteurs seraient disposés à vendre une unité de la ressource seulement à un prix incluant le coût d'opportunité d'avoir moins de ressource pour les ventes futures. Ainsi, il existe une *rente économique* associée à l'exploitation des ressources non-renouvelables.[2] Dans le cas du commerce international de la ressource, la totalité de cette rente reviendrait aux pays producteurs. Cependant, du fait de la fixité de l'offre de ressource disponible, les pays consommateurs seraient tenté de récupérer une partie de la rente en imposant une taxe sur l'importation de la ressource. Ainsi, il existe une bataille permanente entre les pays importateurs et les pays exportateurs sur la répartition de la rente de rareté associée aux ressources non-renouvelables.[3] La littérature traitant de l'interaction stratégique entre les vendeurs et les acheteurs sur le marché des ressources non-renouvelables est abondante. Dans le chapitre deux de la thèse, nous considérons la situation où l'acheteur a un pouvoir de marché et les vendeurs sont en concurrence parfaite.[4]

La considération du pouvoir de marché de la part des acheteurs a donné lieu à une littérature abondante traitant le tarif optimal sur les ressources non-renouvelables. Les principales contributions à cette littérature sont : Kemp et Long (1980), Bergstrom (1982), Brander et Djajic (1983), Karp (1984), Maskin et Newbery (1990), Karp et Newbery (1991, 1992). À l'exception de Bergstrom (1982), tous les autres auteurs ont supposé explicitement ou implicitement que le pays importateur était dépourvu de gisement et donc non producteur de la ressource. Une telle hypothèse est inappropriée pour certaines ressources non-renouvelables, notamment les ressources énergétiques. En effet, il existe des pays qui sont simultanément producteurs et importateurs des ressources éner-

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2. Cette rente, encore appelée rente de Hotelling, ou rente de rareté, représente la différence entre le coût marginal d'extraction de la ressource et son prix de marché.

3. Cette bataille est particulièrement observée sur le marché international du pétrole, avec d'un côté les pays de l'OCDE (qui représentent l'essentiel de la consommation mondiale) et de l'autre côté l'OPEP et la Russie (qui fournissent l'essentiel de la production mondiale).

4. Plusieurs contributions ont considéré la situation où les vendeurs ont un pouvoir de marché. Voir par exemple, Salant (1976), Dasgupta et Heal (1979), Lewis et Schmalensee (1980), Loury (1986), Salo et Tahvonen (2001), Groot et al. (2003). Nous supposons que les vendeurs prennent le prix comme donné pour simplifier les calculs et obtenir des résultats analytiques.

gétiques. C'est le cas par exemple des États-Unis qui sont troisième producteur mondial du pétrole avec 7,6% de la production mondiale et premier importateur mondial avec 27,4% des importations mondiales. En outre, les États-Unis sont deuxième producteur et importateur mondial de gaz naturel avec 18,5% de la production mondiale et 10,7% des importations mondiales. C'est aussi le cas de l'Inde, troisième producteur mondial de charbon avec 8,4% de la production mondiale et deuxième importateur mondial avec 7,5% des importations mondiales (Agence Internationale de l'Énergie, 2009).

Sous l'hypothèse des coûts d'extraction nuls (ou identiques), Bergstrom (1982) a implicitement analysé le cas où les pays importateurs possédaient des gisements de la ressource et étaient donc à la fois producteurs et importateurs. Cependant, l'auteur a lui-même relevé qu'une telle situation était impossible dans le cas plus proche de la réalité où différents gisements de ressources peuvent être exploités à des coûts distincts. En effet, un résultat fondamental en économie des ressources naturelles non-renouvelables est qu'il est optimal d'exploiter les gisements à bas coûts avant les gisements à coûts élevés.[5] Cependant, Kolstad (1994), puis Gaudet et al. (2001) ont montré dans un cadre spatial avec des coûts de transport, qu'il est possible que deux gisements de ressources, ayant des coûts de production distincts puissent être simultanément exploités. Ce qui signifie qu'une troisième justification du modèle spatial est qu'il permet de considérer la réalité de certaines ressources (le pétrole par exemple) pour lesquelles un pays peut être à la fois producteur et importateur. Le deuxième chapitre utilise ce fait pour examiner le tarif d'extraction de la rente de rareté liée aux ressources naturelles non-renouvelables dans le cas où le pays importateur est aussi producteur de la ressource.

L'interaction stratégique pour la répartition de la rente est modélisée sous la forme d'un jeu différentiel en deux étapes. Le gouvernement du pays importateur détermine d'abord le tarif optimal, suivi des producteurs situés dans les deux pays qui déterminent la quantité de ressource à vendre. Notre modèle est plus général dans la mesure où, en

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[5] Ce résultat, dû à Herfindahl (1967), a été obtenu dans un cadre non spatial et permet de comprendre pourquoi il est difficile de justifier dans un cadre non spatial qu'un pays puisse être simultanément importateur et producteur d'une ressource non-renouvelable, ce qui signifie s'approvisionner à des gisements ayant des coûts de production différents. La raison étant qu'elle devrait s'approvisionner à la source la moins chère aussi longtemps qu'elle soit disponible.

plus de considérer le cas où le pays importateur est aussi producteur de la ressource, il permet d'analyser tous les autres cas de figure qui ont été abordés dans la littérature liée au tarif optimal sur les ressources non-renouvelables. Ainsi, nous montrons que le tarif optimal croît au taux d'intérêt et de ce fait, ne crée aucune distorsion sur le sentier d'extraction de la ressource. Le tarif optimal permet de récupérer toute la rente lorsque le pays exportateur ne consomme pas la ressource. Néanmoins, la possibilité pour le pays exportateur de consommer une partie de son stock limite la capacité du pays importateur à récupérer la rente chez le pays exportateur. La présence de gisements de la ressource dans le pays importateur réduit la rente du pays exportateur et de ce fait renforce la capacité du pays importateur à récupérer la rente chez le pays exportateur. Le tarif initial est une fonction décroissante du stock de ressource dans le pays importateur. Ce dernier résultat signifie concrètement que le tarif optimal d'extraction de la rente pétrolière serait plus petit dans un pays riche en pétrole comme les États-Unis, comparé à ce qu'il serait dans des pays pauvres en pétrole comme l'Allemagne et le Japon. Nous examinons également la question de la cohérence dynamique du tarif obtenu avec la stratégie en boucle ouverte. Nous montrons, comme la plupart des précédentes contributions, que la stratégie en boucle ouverte est incohérente dans le temps. Cependant l'incohérence dynamique dans notre modèle provient essentiellement de la distribution spatiale des consommateurs qui fait que le prix de la ressource pour chaque consommateur dépende de son adresse personnelle.[6]

À la différence des deux premiers chapitres, le troisième chapitre de la thèse s'intéresse à la gestion internationale des ressources naturelles renouvelables, notamment la pêcherie. Deux problèmes majeurs se posent à l'économie de la gestion des pêcheries. Premièrement, les ressources maritimes sont des créatures vivantes dont l'habitat et les caractéristiques biologiques échappent le plus souvent au contrôle de l'être humain. Deuxièmement, il est difficile de créer et de faire respecter les droits de propriété sur les ressources maritimes. En effet, les ressources maritimes sont le plus souvent sous libre accès, ce qui favorise une exploitation excessive, tant du point de vue économique que

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[6] L'incohérence dynamique signifie que le pays importateur modifierait le tarif initialement annoncé si l'opportunité lui était donnée à une date ultérieure. Ce résultat a été obtenu sous d'autres hypothèses, par exemple dans le cas où le coût unitaire d'extraction augmente lorsque le stock diminue.

biologique. La surexploitation des pêcheries sous libre accès entraîne la dissipation de la rente et contribue à de faibles revenus aux pêcheurs qui demeurent alors pauvres. L'incapacité de protéger les droits de propriété est vraisemblable dans les zones maritimes des pays où l'État est faible et les institutions légales quasi inexistantes. Les pêcheurs dans de tels pays sont plus vulnérables à la pauvreté parce que les ressources maritimes y sont plus susceptibles d'être surexploitées. Dans ce type d'environnement où en plus il n'existe pas de filet de sécurité sociale, une baisse drastique du revenu des pêcheurs pourrait les inciter à s'adonner à des activités non productives telles que la piraterie maritime. Pour examiner ce fait, nous construisons un modèle qui permet de déterminer comment la population dans une communauté côtière de pêcheurs alloue son temps entre les activités productives (la pêche par exemple) et les activités non productives (la piraterie maritime par exemple).

Notre démarche s'appuie sur deux courants de littérature. Premièrement, nous considérons une pêcherie sous libre accès et examinons l'interaction non-coopérative entre les pêcheurs pour exploiter une biomasse commune. Chaque pêcheur décide alors unilatéralement de l'effort à fournir pour maximiser son profit de la pêche (voir par exemple Ruseski (1998)). Deuxièmement, nous nous inspirons de la littérature de recherche de la rente et d'allocation du talent (voir par exemple Acemoglu (1995)). La répartition de la population entre la pêche et la piraterie est alors déterminée de façon endogène comme une conséquence du choix d'occupation. Le modèle ainsi construit nous permet d'établir l'existence d'une multiplicité d'équilibres. Nous mettons notamment en évidence la possibilité d'une trappe de piraterie, c'est-à-dire l'existence d'un équilibre stable où une partie de la population est engagée dans l'activité de piraterie. Le chapitre discute aussi de différents mécanismes pour combattre la piraterie et souligne le rôle crucial des droits de propriété. En effet il pourrait être difficile de combattre la piraterie maritime dans une zone où les droits de propriétés sont faibles ou inexistants. C'est peut-être ce qui explique l'émergence et la persistance de la piraterie aux larges des côtes somaliennes, malgré la multiplication des actions militaires par la communauté internationale.

L'émergence de la piraterie aux larges des côtes somaliennes a coïncidé avec la chute du dernier gouvernement fonctionnel en Somalie en 1991. Depuis cette date, les eaux somaliennes (sans protection) sont devenues une zone de libre accès internationale où des bateaux étrangers pêchent illégalement ou déversent des déchets toxiques. La présence illégale de gros bateaux industriels dans les eaux somaliennes a favorisé la réduction du stock de ressources maritimes et contribué à la réduction du revenu des pêcheurs locaux. En l'absence d'un État formel pouvant défendre leurs droits, les pêcheurs se sont alors organisés pour protéger leurs eaux. Ainsi, les premières attaques pirates visaient uniquement les bateaux de pêche. Par la suite, la valeur élevée des rançons a fait de la piraterie une activité lucrative. Peu à peu la piraterie s'est accentuée et les attaques se sont étendues à tous les types de bateaux dans le Golfe d'Aden. Au cours des deux dernières décennies, le nombre d'attaques pirates y a considérablement augmenté, en dépit de la multiplication des patrouilles navales et des convois de bateaux escortés. L'étude menée dans ce dernier chapitre permet d'analyser et de comprendre ce phénomène et propose des mesures alternatives de lutte contre la piraterie maritime qui pourraient être complémentaires aux actions militaires actuellement utilisées.

CHAPITRE 1

A SPATIAL MODEL OF TRADE FLOWS IN EXHAUSTIBLE RESOURCES

Abstract

Using a spatial model à la Hotelling, this paper examines the evolution over time of the pattern of trade between two countries (or regions) which differ in terms of their technology, their geographical size, and their endowment of some nonrenewable natural resource. The model emphasizes the importance of geographical size in determining trade patterns besides the traditional explanations of comparative advantage and factor endowments. Indeed, three forces influence the direction of international trade in the spatial context. The analysis fundamentally differs from other contributions in the natural resource literature because it emphasizes the importance of geographical size and of transport cost relative to other factors in the determination of the equilibrium resource flows. The paper also discusses the regional pattern of trade flows which has been observed formerly for some resources such as iron ore and bauxite.

1.1 Introduction

Exhaustible resources, which are amongst the most tradable commodities worldwide,[1] are scattered around the globe, as are their users. Yet, the literature on nonrenewable resources has paid little attention to spatial issues.[2] Although the issue of depletable resources management in open economies has been widely addressed,[3] in virtually all papers in the literature on trade in exhaustible resources, countries are treated as dimensionless points in space (and zero transportation costs between and inside

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[1] In 2008 for example, fuels and mining products accounted for 22.5% of world merchandise exports and 72.5% of exports in primary products. Moreover, the annual average growth rate of exports was 33% for fuels and mining products, compared to 19% for agricultural products and 10% for manufactures (WTO, 2009).

[2] Exceptions are Laffont and Moreaux (1986), Kolstad (1994) and Gaudet et al. (2001).

[3] See for example Djajic (1988) and references therein. Brander and Taylor (1998) is also a valuable overview of trade and renewable resources, while Long (1999) provides a comprehensive review on trade and natural resources in general.

countries are frequently assumed as well).[4] The aim of this paper is to provide a model of trade flows in exhaustible resources that accounts for countries' (or regions') geographical sizes and the spatial distribution of resource sites and their users. There are many reasons to be interested in spatial and geographical aspects when analyzing trade flows in exhaustible resources.

For some resources, transportation costs per unit value are high and often amount to a large share of delivered prices. A typical example is the iron ore industry where the cost of transporting iron ore is very high relative to its mine value. Indeed, Galdon-Sanchez and Schmitz (2002) report the freight charges per ton of concentrates[5] from Brazil (the world's lowest cost producer) to Europe to be more than 50% of the delivered price. Moreover, the authors note that 'transport charges depend in an important way on the length of trip, so that transporting out of a local area adds significantly to transport charges'. For example, the average ocean charge per ton of iron ore from Australia to Baltimore (USA) is estimated to be more than twice the charge per ton to Japan ($11.55 versus $5.5).[6]

Given that the cost of transporting iron ore is very high relative to its mine value, a high cost mine may still have a competitive advantage in a nearby market over a distant rival site with lower mining costs. Hence, 'the Swedish iron ore producer, LKAB, in spite of mining its ore underground in an arctic climate at relatively high costs, has remained internationally competitive thanks to its . . . relatively short distance to both its shipping harbour and its international European markets' (Hellmer, 1996). Also, Canadian and U.S. iron ore producers had faced no competition from foreign iron ore in the Great Lakes steel market for nearly a century as they had significantly lower transport charges to these steel producers than mines outside the region (see Schmitz, 2005).

Finally, the introduction of spatial and geographical aspects makes it possible to ac-

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[4] It is worth mentioning here that, since Krugman (1991), spatial considerations have been introduced in several studies on trade in reproducible goods. Valuable overviews include Shachmurove and Spiegel (1995, 2005) and Rossi-Hansberg (2005).

[5] There are three major types of iron ore : lump ore, concentrates (or fines), and pellets.

[6] It is also important to stress that shipping costs also differ within a country. Thus, the ocean charge per ton of Canadian iron ore to Chicago is nearly 73% greater than the charge per ton to Baltimore (see Galdon-Sanchez and Schmitz, 2002).

count for the fact that countries can be simultaneously importers and producers of an exhaustible resource, such as coal or oil.[7] In traditional trade models, where countries are usually treated simply as points in space, this is difficult to justify, for the simple reason that a country would then always want to supply itself strictly from the cheapest source as long as it is available. That explains why all the papers in the resource economics literature dealing for instance with the capture of foreign resource rent through tariffs have neglected that case, which is nonetheless important in reality.[8] This paper gets around this by proposing a model in which countries have geographical size and consumers are distributed over space inside the country.

In this paper, I follow the framework of Kolstad (1994) and adapt it to investigate the implications of trade.[9] For this purpose, I build on Tharakan and Thisse (2002) and assume two countries with their respective population dispersed, each consumer (or each market) having a specific address. The two countries are assumed to be each endowed with a fixed stock of some nonrenewable resource, which we may call iron ore for convenience. With the help of this model I characterize the pattern of resource flows and its evolution over time between countries (or regions) that differ in terms of their geographical size, the density of the distribution of consumers over space, their resource endowment, and their extraction costs.

The analysis fundamentally differs from other contributions in the literature on trade and exhaustible resources because it emphasizes the importance of geographical size and of transport costs relative to other factors in the determination of the equilibrium resource flows. Indeed, three forces influence the direction of trade flows in the spatial context : the production cost advantage, the geographical size advantage and the per-capita resource endowment advantage. The unit cost of transport is shown to play a decisive role in determining whether the international asymmetry in terms of geographical sizes of

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[7] While the United States is the third largest oil producer in the world, with 7.6% of the world oil production, it is also the largest oil importer, with 27.4% of world oil imports. Similarly India ranked third in the world with 8.4% of the world coal production, while being the second largest importer of coal with 7.5% of the world imports (International Energy Agency, 2009).

[8] See for example, Karp (1984).

[9] Kolstad (1994) uses a spatial model *à la* Hotelling (Hotelling, 1929) to examine the interrelationship between resource rents in related exhaustible resource markets.

countries has a greater influence than other factors on the equilibrium pattern of trade flows. An interesting contribution of this paper is that it can provide an explanation for a situation where a relatively resource rich country, even with the lowest mining costs, is a net exporter of the resource, contrary to what is to be expected in a spaceless trade model. Such a situation is more likely in a country with a large geographical size, because, if shipping costs are high, domestic consumers located far from the domestic mine site may be able to supply themselves at a cheaper price from a nearer foreign mine, that may even have higher mining costs. This is certainly an important explanation of the trade patterns between China and India in the iron ore industry.

In fact, China is relatively richly endowed in iron ore than India, whether in terms of reserves or output flow. In 2008, per capita iron ore reserves were almost 4 times larger in China than in India (16596 Mt vs 4298 Mt) and per capita iron ore production was more than 1.5 times larger (198 Mt versus 124 Mt). Without accounting for the geographical size, one would have expected India to import iron ore from China. Yet, the opposite pattern of trade is actually observed with China importing iron ore from India. The relatively larger geographical size of China (almost 3 times larger than India), coupled with high transport costs, allows Chinese consumers located close to the Indian border the possibility of buying iron ore at a lower delivered price from Indian mines. [10]

The remainder of the paper is organized as follows. Section 1.2 presents the basic model. Section 1.3 characterizes the autarky equilibrium in terms of the fundamental parameters of the economy. The model is extended in Section 1.4 to allow free trade in the exhaustible resource. After first focusing on the forces which interact to determine the direction of trade, equilibrium resource flows are analyzed. Section 1.5 proposes concluding remarks.

1.2 The Model

The model is framed around two countries, a domestic (or home) country and a foreign country. There is an international iron ore industry with firms located in both

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[10] Mt stands for metric ton. Estimates are obtained using data from U.S. Geological Survey (Various years).

countries. These firms extract ore from deposits of fixed size and can sell it in both the domestic and foreign markets, which I consider to be adjacent and non-overlapping linear segments. Let $L_i > 0$ denote the length, or geographical size, of country $i = h, f$; the two countries have a common border and are collinear as depicted in Figure 1.1. Therefore, residents of our global economy are located along a straight line of finite length $L = L_h + L_f$. Contrary to the traditional location models *à la* Hotelling (1929), in which firms choose where to locate, the location of the ore deposits is given by Nature. Placing the origin to the left-most end of the line, ore reserves are assumed to be located at 0 (the domestic firms' production site) and L (the foreign firms' production site). I assume that consumers of country $i = h, f$ are uniformly distributed with density ρ_i along its segment, so that the population size of country i is $\rho_i L_i$.

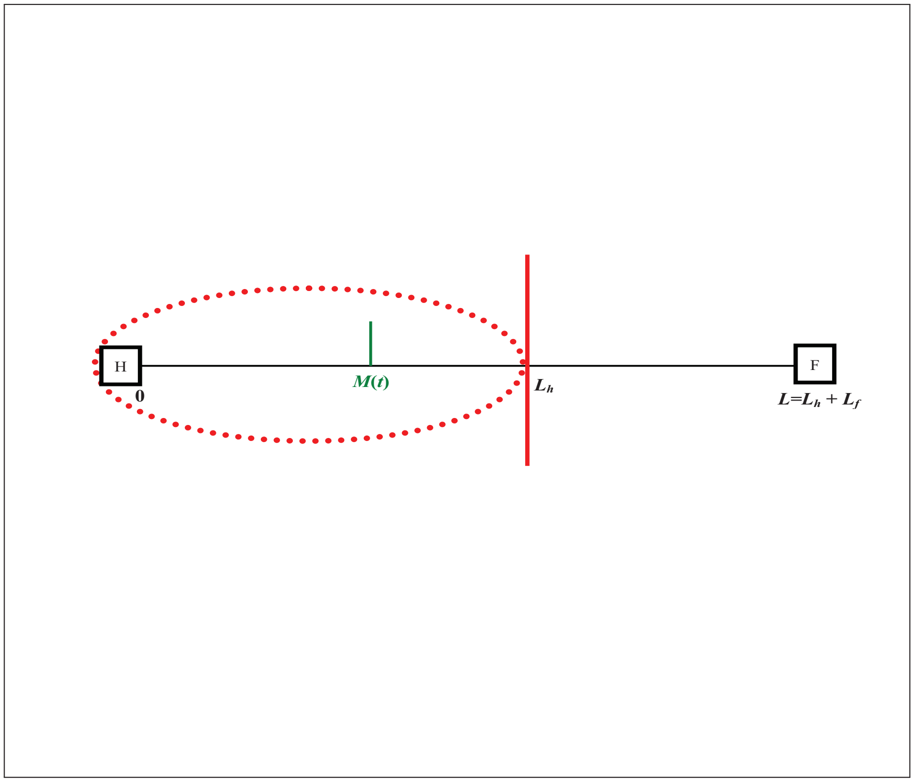

Figure 1.1 – The model-graphical illustration

Consumers at each location have an identical demand function $q(p)$ with $q(\bar{p}) = 0$, where $\bar{p}$ is the choke price. It should be noted that analysis of spatial model is sensitive to the specification of individual consumer's demand functions.[11] Hotelling's original spatial model (Hotelling, 1929) assumed totally inelastic demand. Of course this is not possible with an exhaustible resource, for rents will be bid infinitely high due to the resource's finite supply. For simplicity, I will assume a rectangular demand ; i.e. inelastic demand up to a "choke" price at which point demand drops to zero.

Let $\tau(.)$ be the unit transport cost for the resource as a function of distance. A common convention in spatial models is to assume linear or quadratic unit transport cost. For simplicity and without loss of generality, I will assume that unit transport cost is a linear function of distance ; i.e., $\tau(u) = \alpha u$, where α is the transport cost per unit of distance, and u the distance.[12] Hence, a consumer located at distance u from firm $i = h, f$ pays the full delivered price $p_i^m + \alpha u \leq \bar{p}$, where p_i^m is the mill price at firm i's location. Each consumer is assumed to always buy from the seller who quotes the lowest delivered price.

For a representative seller in country $i = h, f$, let c_i be the constant marginal cost of extracting the resource. I will assume that neither set of producers can undercut the other (in costs) at their location ; i.e., $|c_h - c_f| < \alpha L$. The remaining resource stock of producer $i = h, f$ at time t is $S_i(t)$ and S_i^0 denotes its initial stock. The quantity of resource sold by seller $i = h, f$ at date t is $q_i(t)$ is depending on the market boundary $M(t)$ shared commonly by the mining firms in both countries at date t. For instance, if both resource sites are being depleted and the domestic country is an importer, we would have $q_h(t) = \rho_h M(t)$. While the natural boundary is fixed, being determined by L_h, the market boundary $M(t)$ changes over time, subject to $0 \leq M(t) \leq L$, as resource stocks get depleted. $M(t) = 0$ means that the whole market is supplied by the producer at location L (the foreign firm), while $M(t) = L$ means that it is supplied by the producer at 0 (the domestic firm). At the market boundary, consumers are indifferent between buying from the domestic or the foreign sellers. Thus, the market boundary is implicitly given by :

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[11] More details on that can be found in Graitson (1982).

[12] The specification of the transport cost function usually matters when the location of firms is an issue, which is not the case with resource firms (See d'Aspremont et al., 1979, for more details). Of course, different cost functions may lead to different quantitative implications. However, the paper focuses mainly on equilibrium patterns of resource flows and linear cost specification is assumed to ease the derivation of analytical results.

$$p_h^m(t) + \alpha M(t) = p_f^m(t) + \alpha(L - M(t)) \tag{1.1}$$

As a consequence of the spatial separation of producers, equation (1.1) implies that it may be possible to simultaneously exploit resources from two sites with different constant marginal costs. In effect, if $0 < M < L_h$, the home country uses resources from domestic and foreign deposits with different marginal costs ($c_h \neq c_f$). Hence, the Herfindahl rule (Herfindahl, 1967) is not valid in the spatial context. Kolstad (1994) and Gaudet et al. (2001) reached the same conclusion in a single world economy. However, a direct consequence of this result specific to our model is that a country can be simultaneously an importer and a producer of an exhaustible resource, a pattern actually observed in real world.

I assume that producers in both country are price-takers.[13] Thus, the mill price of the resource for producer $i = h, f$ is given by $p_i^m(t) = c_i + \lambda_i e^{rt}$, where λ_i is the initial resource rent for producer i and $r > 0$ is the interest rate, assumed equal to the discount rate. Implicit in this equation is the well known Hotelling's rule (Hotelling, 1931) which states that the scarcity resource rent at each production site must rise at the rate of interest along any positive extraction path.

1.3 Autarky equilibrium

Let us first assume that firms operate in autarky. In this case, the equilibrium outcome depends only upon the parameter values of the country each firm belongs to ; they are independent of the behavior of the firm in the other country. Hence, in autarky the market boundary at each moment in time is given by the smaller of the natural boundary of the country and the location of the consumer for whom the full price is equal to her reservation price (the choke price, given the assumptions on demand). The results are similar for the home and the foreign countries. Therefore, I state the results below for a

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[13] Assuming price taking firms may be restrictive for some resources such as oil. But, extraction sites for some resources such as iron ore seem to have many firms more or less competitive. I assume many identical competitive firms in each country and I consider a representative firm in each country to carry the analysis.

country of size l, keeping in mind that $l \in \{L_h, L_f\}$.

Given that the quantity demanded is determined by the market boundary $M(t)$ and $0 \leq M(t) \leq l$, the optimal extraction path is to keep $M(t) = l$ from date 0 until date T_1 at which the delivered price at location l reaches the choke price $\bar{p}$. After this date only a part of the market is covered and the price path is determined so that the delivered price at the producer's location hits the choke price at the date T_2 at which the stock is depleted. Therefore, the market boundary at each date is given by :

$$M(t) = \begin{cases} l & \text{if} \quad 0 \leq t < T_1, \\ \frac{\bar{p} - \lambda e^{rt} - c}{\alpha} & \text{if} \quad T_1 \leq t \leq T_2, \\ 0 & \text{if} \quad t > T_2. \end{cases} \tag{1.2}$$

From equation (1.2), T_1 and T_2 can be derived by setting $M(T_1) = l$ and $M(T_2) = 0$. It follows that

$$T_1 = \frac{1}{r} \ln \frac{\bar{p} - c - \alpha l}{\lambda} \tag{1.3a}$$

$$T_2 = \frac{1}{r} \ln \frac{\bar{p} - c}{\lambda}. \tag{1.3b}$$

The initial resource rent λ must be such that market clears, that is, it must generate a price path that equates total quantity demanded to total quantity supplied. Formally, this can be expressed as $\int_0^{T_2} \rho M(t) dt = S^0$. Upon integration, we get

$$\frac{l}{r} \ln \frac{\bar{p} - c - \alpha l}{\lambda} + \frac{1}{\alpha} \frac{\bar{p} - c}{r} \ln \frac{\bar{p} - c}{\bar{p} - c - \alpha l} - \frac{l}{r} = \frac{S^0}{\rho}.$$

which implies :

$$\ln \lambda = -\frac{rS^0}{\rho l} - 1 + \frac{1}{\alpha l} \big[(\bar{p} - c) \ln(\bar{p} - c) - (\bar{p} - c - \alpha l) \ln(\bar{p} - c - \alpha l) \big]. \tag{1.4}$$

It is worth emphasizing that the three market phases described in equations (1.2) and (1.3) will occur under autarky (i.e., the market is fully covered at $t = 0$) only if $T_1 \geq 0$.

From equation (1.3a), it must be the case that $\bar{p}-c-\alpha l \geq \lambda$. Using equation (1.4) and after some manipulations, we can obtain the condition for the market to be totally served at the initial date as :

$$\begin{aligned}\frac{S^0}{\rho l} &\geq \frac{1}{r}\Big[-1-\ln(\bar{p}-c-\alpha l)\Big] \\ &\quad + \frac{1}{\alpha l r}\Big[(\bar{p}-c)\ln(\bar{p}-c)-(\bar{p}-c-\alpha l)\ln(\bar{p}-c-\alpha l)\Big] \\ &\equiv \Phi(l,c).\end{aligned} \tag{1.5}$$

If $\frac{S^0}{\rho l} < \Phi(l,c)$, only two market phases will emerge, described by :

$$M(t) = \begin{cases} \frac{\bar{p}-\lambda e^{rt}-c}{\alpha} & \text{if} \quad 0 \leq t \leq T_2, \\ 0 & \text{if} \quad t > T_2. \end{cases}$$

In that case, the market clearing condition $\int_0^{T_2} \rho M(t)dt = S^0$ leads to the determination of the initial resource rent λ, given implicitly by :

$$\lambda - (\bar{p}-c)\ln\lambda = \frac{\alpha r S^0}{\rho} + (\bar{p}-c) - (\bar{p}-c)\ln(\bar{p}-c).$$

Putting all together, the initial resource rent in the autarky equilibrium (λ^a) is determined as follows :

$$\lambda^a = \begin{cases} \exp(-\frac{rS^0}{\rho l} - 1 + \frac{A(l,c;\alpha,\bar{p})}{l}) & \text{if} \quad \frac{S^0}{\rho l} \geq \Phi(l,c), \\ F^{-1}[\frac{\alpha r S^0}{\rho} + F(\bar{p}-c)] & \text{if} \quad \frac{S^0}{\rho l} < \Phi(l,c), \end{cases}$$

where

$$\begin{cases} A(l,c) = \frac{1}{\alpha}\Big[(\bar{p}-c)\ln(\bar{p}-c)-(\bar{p}-c-\alpha l)\ln(\bar{p}-c-\alpha l)\Big], \\ \Phi(l,c) = \frac{1}{r}[-1-\ln(\bar{p}-c-\alpha l)] + \frac{A(l,c)}{lr}, \\ F(x) = x - (\bar{p}-c)\ln x \quad \text{with} \quad F'(x) < 0 \quad \text{for} \quad x < \bar{p}-c. \end{cases} \tag{1.6}$$

$A(l,c)$ can be labeled the “as-if social surplus” from consuming one unit of the resource.

Indeed, if we assume the social surplus function (the net utility) from consuming one unit of the resource at any address x to be given by :[14]

$$u(x) = \ln(\bar{p} - c - \alpha x) + 1, \text{ with } u'(x) < 0,\ u''(x) < 0,$$

then, the total surplus on the whole segment l is given by $\int_0^l u(x)dx$, which is $A(l,c)$. Thus, $\frac{A(l,c)}{l}$ is the average (per-capita) social surplus from the consumption of one unit of the resource.

Both markets may or may not be totally served in autarky at the beginning. Condition (1.5) guarantees initial full coverage for a market with demand $\rho\, l$ supplied by firms with initial stock S^0 and unit cost of extraction c. This constraint may be more stringent for a country, depending on production technology (c), per-capita resource endowment ($\frac{S^0}{\rho l}$) and geographical size (l). Since $\Phi(l,c)$ is an increasing function of both l and c, this constraint will be more stringent for the country with the largest geographical size and/or the less efficient technology in production. However, I will assume that under autarky, the market in each country is entirely served. More precisely, I assume that parameter values are such that :[15]

$$\frac{S_h^0}{\rho_h L_h} \geq \Phi(L_h, c_h) \text{ and } \frac{S_f^0}{\rho_f L_f} \geq \Phi(L_f, c_f). \tag{1.7}$$

Under conditions (1.7), the initial resource rent in the autarky equilibrium for foreign and home producers are determined as follows :

$$\begin{cases} \lambda_f^a = \exp\left[-\frac{rS_f^0}{\rho_f L_f} - 1 + \frac{A(L_f,c_f)}{L_f}\right] \\ \lambda_h^a = \exp\left[-\frac{rS_h^0}{\rho_h L_h} - 1 + \frac{A(L_h,c_h)}{L_h}\right] \end{cases} \tag{1.8}$$

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[14] Observe that $u(x)$ is simply a monotone increasing transformation of the true social surplus, which is $\bar{p} - c - \alpha x$. Also note that the functions A and Φ depend on α and $\bar{p}$ as well. Only country-specific dependent variables are maintained to economize in notation.

[15] Note that $\frac{d\Phi}{d\alpha} > 0$, which implies that the condition for initial full coverage is more stringent when the unit cost of transport, α, is high. This is because with higher transportation costs, more resource are needed in order to serve consumers farther from the resource site. Furthermore, $\frac{d\Phi}{d\bar{p}} < 0$, which means that the condition for initial full coverage is less stringent when the reservation price of consumers, $\bar{p}$, is high. The intuition is that wealthier consumers are more willing to buy the resource at a higher price, which arises notably when the resource is scarce.

Once λ is determined we can solve for the market boundary path, the extraction path, the mill price and the delivered price paths, under autarky equilibrium.

The solution for the autarky equilibrium indicates that the initial resource rent in either country depends on two opposing forces : the per-capita resource endowment and the per-capita surplus from the consumption of one unit of the resource. Clearly, the larger the per-capita benefit a country gets from one unit of its resource, the larger the resource rent accruing to producers in that country. Our aim is now to determine what happens when borders are opened and trade is allowed between the two countries.

1.4 A model of trade

This section primarily describes a model of free trade between two countries. [16] Once borders are opened, consumers are free to purchase from either firm at the same mill price, regardless of their locations, but must bear the corresponding transport costs. This implies that under free trade some consumers may purchase the resource good abroad. Hence, there is crosscountry competition among firms. The *marginal consumer* located at the market boundary $M(t)$ is indifferent between the home and foreign sellers. Therefore, $M(t)$ [cf. equation (1.1)] is implicitly defined by :

$$c_h + \lambda_h e^{rt} + \alpha M(t) = c_f + \lambda_f e^{rt} + \alpha (L - M(t)). \tag{1.9}$$

1.4.1 The pattern of trade

The trade pattern at each date t depends on the location of the common border at L_h relative to the address $M(t)$ of the marginal consumer. If $M(t) > L_h$, the home country exports the resource, while the foreign country exports if $M(t) < L_h$. Suppose that prior to free trade, prices in each country are such that $M(0) = L_h$. When the two countries

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[16] Unless otherwise specified, I will focus mainly on trade between two countries. However, the model presented may also be suitable to analyze trade flows between two regions, either at a country level (say, East and West) or at the international level (say, Atlantic basin and Pacific basin). Meanwhile, the model can also help to describe the situation where two firms located in two different countries are competing to supply consumers in a third country. The prevailing case will be made clear throughout the following sections.

are opened to trade, the foreign country will import the resource (i.e. $M(0) > L_h$) if the delivered price of the domestic producer at address L_h is less than that of the foreign producer. In comparing delivered prices at the common border under autarky at $t = 0$, we find that :

$$p_h(0) \gtreqless p_f(0) \quad \text{iff} \quad c_h + \lambda_h^a + \alpha L_h \gtreqless c_f + \lambda_f^a + \alpha L_f. \tag{1.10}$$

Hence, if delivered prices at the common border at $t = 0$ are equal, the marginal consumer is located at L_h and the free trade regime is characterized by the absence of trade. In inspecting equations (1.8) and (1.10), one can observe that this situation occurs if the two countries are identical with respect to production efficiency, geographical size and per-capita resource endowment (i.e., if $c_h = c_f$, $L_h = L_f$ and $S_h^0/\rho_h L_h = S_f^0/\rho_f L_f$). For given values of c_h, L_h and $S_h^0/\rho_h L_h$, there are other possible combinations of c_f, L_f and $S_f^0/\rho_f L_f$ such that no trade emerges.

Starting from a situation of no trade, a relatively larger per-capita resource endowment in the foreign country will make the foreign economy an exporter of the resource, as the initial resource rent in the foreign country will be smaller. On the other hand, relatively high values of c_f and/or L_f will increase the delivered price from foreign firms, making the foreign country an importer of the resource. Thus, various combinations of c_f, L_f and $S_f^0/\rho_f L_f$ which keep the volume of trade equal to zero at $t = 0$ (for given values of c_h, L_h and $S_h^0/\rho_h L_h$) must lie along a positively sloped curve in the plane $(S_f^0/\rho_f L_f, c_f)$ or $(S_f^0/\rho_f L_f, L_f)$. Let c_f be fixed and consider the zero trade curve in the plane $(S_f^0/\rho_f L_f,\ L_f)$. This curve, labeled $X_f = 0$ in Figure 1.2, describes combinations of L_f and $S_f^0/\rho_f L_f$ such that $M(0) = L_h$ (i.e., there is no trade). At any point above this locus, we have $X_f < 0$, meaning that the foreign country imports the resource. At any point below it, $X_f > 0$ and the foreign country exports the resource.

Hence, three forces influence the direction of trade : the production cost advantage (c_h relative to c_f), the geographical size advantage (L_h relative to L_f) and the per-capita resource endowment advantage ($S_h^0/\rho_h L_h$ relative to $S_f^0/\rho_f L_f$). Either of the three forces may dominate, depending on parameter values. If countries are identical with respect to their production costs and their per-capita resource endowments, the pattern of trade is predicted by the geographical size. Accordingly, the geographically smaller country exports the resource. This finding is similar to that of Tharakan and Thisse (2002), who stress the geographical disadvantage of large countries.[17] Alternatively, if countries are symmetric only with respect to their per-capita resource endowments, the production cost advantage of the large country may dominate its geographical size disadvantage, implying that the large country exports the resource.[18] Finally, if countries differ only in their per-capita resource endowments, the direction of trade is exclusively determined by the difference in per-capita resource endowments. Of course, the relatively resource poor country imports the resource.

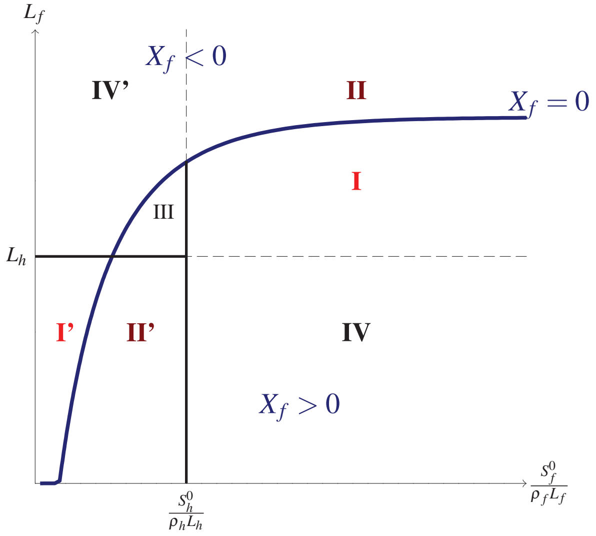

Figure 1.2 – Zero trade curve.

In general, the dominant force that occurs depends on the parameter values. Figure 1.2 helps to identify several parameter domains, each associated to forces that govern the pattern of trade. Regions I and I' correspond to the parameter values for which

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[17] Tharakan and Thisse (2002) consider trade in the case of reproducible goods' firms with identical production costs and prove that it is the small country that exports towards the large country due to lower transport costs for serving consumers at the common border.

[18] Egger and Egger (2007) achieve an analogous result in their analysis of outsourcing and trade for reproducible goods in a Hotelling-like spatial model.

the direction of trade is predicted by the per-capita resource endowment. In that case, the relatively resource rich country exports the resource regardless of its relative geographical size or its relative production cost. Regions II and II' are the parameter domains for which the geographical size has the greater influence on the equilibrium pattern of trade. In that case, the large country imports the resource regardless of whether it is relatively resource rich or relatively efficient in resource production. Region III is the parameter domain where the efficiency in production is the dominant force that determines the direction of trade. Then, the country with the lower unit cost of production exports the resource, even though it has disadvantage in geographical size and in per-capita resource endowment. Regions IV and IV' correspond to parameter domains where the geographical size and the per-capita resource endowment act in the same direction and dominate the production cost parameter. For that reason, the exporting country is the one with a small size and a greater per-capita resource endowment.

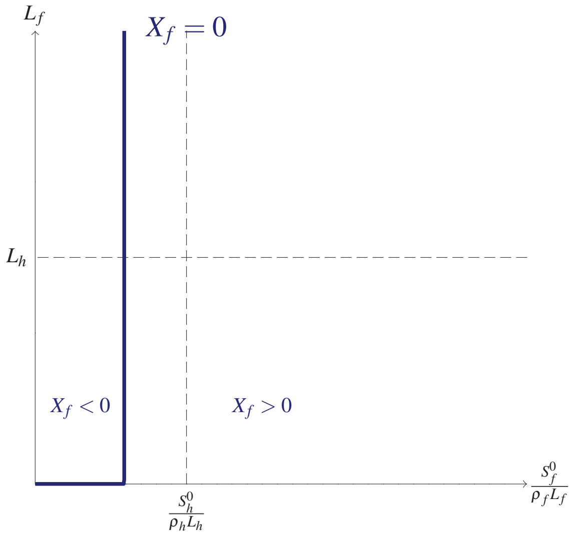

Figure 1.3 – Zero trade curve when α is too small.

In addition to the traditional comparative advantage and factor endowments explanations of the pattern of trade, this model emphasizes the importance of geographical size in the determination of trade patterns. Indeed, if the unit transport cost, α, is relatively high, the geographical size is likely to emerge as the driving force of trade patterns. In that case, the small country must export the resource regardless of whether it has comparative advantage in technology (the unit cost of production) or per-capita resource endowment. For relatively high values of α, regions I and I' shrink and those labeled II and II' expand. Alternatively, as $\alpha \to 0$, regions I and I' expand and those labeled II and II' disappear such that the zero trade curve becomes vertical as shown in Figure 1.3. Then, the geographical size has no influence on the trade pattern which is determined solely on the basis of relative production costs and relative factor endowments. Therefore, the unit transport cost, α, is seen to be crucial in determining whether the relationship between the relative geographical sizes of the two countries is dominant in predicting the equilibrium pattern of resource flows.

1.4.2 Equilibrium under free trade

It is important to note that two types of regimes are likely during the time that both home and foreign firms operate. It may be the case that all consumers are supplied the whole time period, or that the delivered price for some consumers (those farther from producing sites) are prohibitive. Either case can happen depending on parameters.[19] Following Kolstad (1994), I will focus on the case where the market is totally served. Thus, I assume that reserves, costs and other parameters of the model are such that the market is entirely supplied while home and foreign producers are in the market; i.e., we do not have the situation where both resource sites are being depleted with a gap in the middle of the line segment where neither site is able to deliver at a lower price than the backstop.

In order to determine the equilibrium outcome of the trading economy, I will now assume that the parameter values are such that the home country imports the resource

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[19] For example, if we take $\bar{p} = 5$; $r = 0.1$; $\alpha = 0.5$; $c_f = 0$; $c_h = 1$; $L_f = 1$; $L_h = 2$, we obtain $\Phi(L_h, c_h) = 3.01$; $\Phi(L_f, c_f) = 0.54$ and $\Phi(L, c_f) = 5.67$. So with $S_h^0 = 2$; $S_f^0 = 6$ and $\rho_h = 1 > \rho_f$, conditions (1.7) are satisfied. Instead, if we take $S_h^0 = 1$ and $S_f^0 = 1.5$, the maximum market length attainable by home and foreign producers are 1.2 and 1.64 respectively. This means that a portion of the market segment of length 0.16 is uncovered. Under the latter conditions, there will be a 'hole' in the middle of the line segment.

from the foreign country. It should be noticed that there is no loss of generality associated with this assumption. Consequently, it must be the case that $M(t) < L_h$, as long as domestic reserves are not depleted. I will also assume that reserves in the home country are exhausted first. Denoting by $T_i, i = h, f$ the time of resource exhaustion for producers $i = h, f$, we thus have $T_h \leq T_f$.

Given those assumptions, I will consider resource extraction schedules with a sequence of three phases as shown in Figure 1.4. In the first phase which lasts until T_h, foreign and home firms produce *simultaneously* and the whole market is covered. At time T_h, the domestic resource stock is exhausted, although the domestic mill price at T_h need not have reached the choke price. Actually, T_h is the date at which foreign firms can supply location 0 at the domestic producers' mill price. The second phase begins at T_h and corresponds to the interval of time during which the foreign firm is producing alone and *covers the entire market*. The third phase begins at some date $T \geq T_h$. It corresponds to the phase where foreign firms supply only a fraction of the market and just deplete their reserves at T_f.

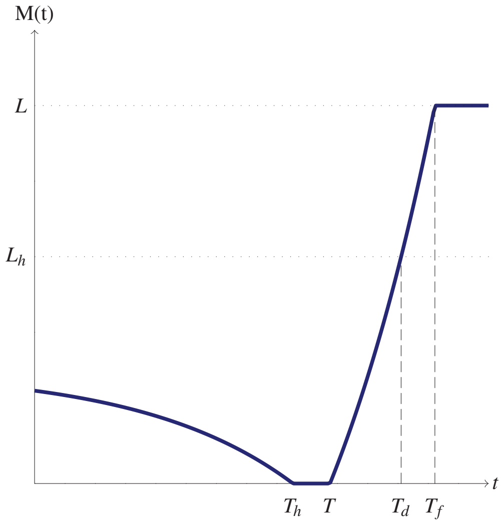

Figure 1.4 – Market boundary over time.

From equation (1.9), we can define the market boundary as follows :

$$M(t) = \begin{cases} \frac{(\lambda_f - \lambda_h)e^{rt} + c_f - c_h + \alpha L}{2\alpha} & \text{if} \quad 0 \leq t \leq T_h, \\ 0 & \text{if} \quad T_h < t < T, \\ \frac{c_f + \lambda_f e^{rt} - \bar{p} + \alpha L}{\alpha} & \text{if} \quad T \leq t \leq T_f, \\ L & \text{if} \quad t > T_f. \end{cases} \tag{1.11}$$

By setting $M(T_h) = 0$, we obtain $\lambda_h - \lambda_f = [\alpha L + c_f - c_h]e^{-rT_h}$, which is the rent premium accruing to the domestic producer. This rent premium is equal to the cost differential between the two mining sites, measured at the domestic site and discounted back to the present from the domestic exhaustion date, T_h. Since we have assumed that the foreign producing area cannot initially undercut in costs the domestic producers at their site, we have $\lambda_h > \lambda_f$. This arises because, for a given location, delivered prices from the home producer are rising faster than those from the foreign producer. Thus, as reserves at home get depleted, M moves towards 0 and the home firm loses customers to the foreign firm. Intuitively, home producers increase their rents because they are willing to lose customers such that their last unit is produced at time T_h when foreign producers can deliver location 0 at the domestic producers' mill price. Also, T_h, T and T_f are obtained from equation (1.11) by setting $M(T_h) = 0$, $M(T) = 0$ and $M(T_f) = L$. This gives

$$T_h = \frac{1}{r} \ln \frac{\alpha L + c_f - c_h}{\lambda_h - \lambda_f}, \tag{1.12a}$$

$$T = \frac{1}{r} \ln \frac{\bar{p} - c_f - \alpha L}{\lambda_f}, \tag{1.12b}$$

$$T_f = \frac{1}{r} \ln \frac{\bar{p} - c_f}{\lambda_f}. \tag{1.12c}$$

It is worth stressing that some of the phases described by equations (1.11) and (1.12) may not occur, depending on parameter values. For example, parameter values may be such that $T_h < 0$, meaning that there is no resource deposit in the domestic country, a case I do not consider in this paper. Moreover, if $T < T_h$, there will be a gap in the middle of the line segment, meaning that the market is not totally covered while both resource sites are depleting, a situation I also exclude. Hence, for the four phases to occur, we must have $T > T_h > 0$, which by equations (1.12a) and (1.12b) can be written as conditions (1.13) and will be assumed to hold in what follows.

$$\frac{\bar{p} - c_f - \alpha L}{\lambda_f} \geq \frac{\alpha L + c_f - c_h}{\lambda_h - \lambda_f} > 1. \tag{1.13}$$

Since the initial resource stocks, S_h^0 and S_f^0, will be exhausted and total quantity demanded will equal total quantity supplied, the following must hold :

$$\int_0^{T_h} \rho_h M(t)\, dt = S_h^0. \tag{1.14a}$$

$$\int_0^{T_d} \left[\rho_h \big(L_h - M(t)\big) + \rho_f L_f\right] dt + \int_{T_d}^{T_f} \rho_f \left[L - M(t)\right] dt = S_f^0. \tag{1.14b}$$

The date $T_d > T$ is the moment of import interruption and it corresponds to the time at which the delivered price at the common border reaches the choke price $\bar{p}$. Thus, $M(T_d) = L_h$; which gives $T_d = \frac{1}{r} \ln \frac{\bar{p} - c_f - \alpha L_f}{\lambda_f}$. Substituting this, equations (1.11) and (1.12) into equations (1.14) and integrating yield

$$(\alpha L + c_f - c_h) \ln \frac{\alpha L + c_f - c_h}{\lambda_h - \lambda_f} - (\alpha L + c_f - c_h) + (\lambda_h - \lambda_f) = \frac{2\alpha r S_h^0}{\rho_h}.$$

$$\begin{aligned} &\frac{\rho_h L_h + \rho_f L_f}{r} \ln \frac{\bar{p} - c_f - \alpha L_f}{\lambda_f} - S_h^0 - \frac{\rho_h L_h + \rho_f L_f}{r} \\ &\quad + \frac{1}{\alpha r} \left[\rho_h (\bar{p} - c_f - \alpha L) \ln \frac{\bar{p} - c_f - \alpha L_f}{\bar{p} - c_f - \alpha L} + \rho_f (\bar{p} - c_f) \ln \frac{\bar{p} - c_f}{\bar{p} - c_f - \alpha L_f}\right] = S_f^0. \end{aligned}$$

Then, in the free trade regime, the initial resource rents for foreign and home producers are obtained as

$$\begin{cases} \lambda_f = \exp\Big[-\frac{r(S_h^0+S_f^0)}{\rho_h L_h+\rho_f L_f} - 1 + \frac{\rho_h[A(L,c_f)-A(L_f,c_f)]+\rho_f A(L_f,c_f)}{\rho_h L_h+\rho_f L_f}\Big], \\ \lambda_h = \lambda_f + G^{-1}\big(2\alpha r S_h^0/\rho_h\big) \quad \text{with } G>0 \text{ and } G'<0. \end{cases} \tag{1.15}$$

where G is the function defined by $G(x) = (\alpha L + c_f - c_h)\ln\frac{\alpha L+c_f-c_h}{x} - (\alpha L + c_f - c_h) + x$ and A is the function defined in equation (2.8). Using (1.15), one can easily prove that $\frac{d\lambda_f}{d\alpha} < 0$ and $\frac{d\lambda_h}{d\alpha} < 0$. This shows that increases in transportation costs lead to reductions in resource rents.

Likewise, with the calculation of the initial resource rent at each production site, we can derive solutions for market boundary, prices and extraction trajectories in the free trade equilibrium. But instead, let us examine some of the implications of our solutions for resource rents.

The foreign resource rent, λ_f, depends on the world per-capita resource endowment, $\frac{S_h^0+S_f^0}{\rho_h L_h+\rho_f L_f}$, and on the world per-capita surplus from consuming one unit of the foreign resource. In fact, $A(L,c_f)$ is the total surplus from consuming one unit of the foreign resource over the integrated line L and $A(L_f,c_f)$ is the total surplus from one unit of the foreign resource over the segment L_f. Thus, the surplus from one unit of the foreign resource over the segment L_h is the differential

$$A(L,c_f) - A(L_f,c_f) = \int_0^{L_h} \big(\ln[\bar{p} - c_f - \alpha(L-x)] + 1\big)dx.$$

Therefore, the total surplus from consuming one unit of the foreign resource is $\rho_h[A(L,c_f)-A(L_f,c_f)]$ in the home country and $\rho_f A(L_f,c_f)$ in the foreign country. The world per-capita surplus from one unit of the foreign resource is derived accordingly as the ratio between the world total surplus and the world total population, that is, $\frac{\rho_h[A(L,c_f)-A(L_f,c_f)]+\rho_f A(L_f,c_f)}{\rho_h L_h+\rho_f L_f}$.

A noteworthy point to emphasize on is that λ_f is independent of c_h, the marginal extraction cost of the domestic resource. Therefore, a resource discovery in the home country will be beneficial for citizens in both countries.[20] It is also interesting to note that the rent differential between the two countries has an upper bound, the maximum value being the cost margin between the two mining sites, $\alpha L + c_f - c_h$. Of course, when transport cost approaches zero (a spaceless market), the rent differential between the two deposits reduces to the difference in production technology $c_f - c_h$.

Also notice that post-trade resource rents lie between the autarky rents. More specifically, resource rents satisfy the following inequalities :

$$\lambda_f^a < \lambda_f < \lambda_h < \lambda_h^a \tag{1.16}$$

The middle inequality in (1.16) follows from the second line of (1.15). The left and the right inequalities arise because increased (or reduced) demand for a fixed stock of resource implies an increase (or a decrease) in its rent. When trade opens, demand for the foreign deposit increases while that for the domestic deposit decreases. Consequently the opening of trade leads to increases in foreign rents and to reductions in domestic rents. Therefore, autarky prices in the foreign country are smaller than post trade prices whereas autarky prices in the home country are larger than equilibrium prices under free trade.

1.5 Conclusion

Most findings in the economics of exhaustible resources and trade have been derived in a spaceless context. Yet, spatial consideration may lead to results somewhat different from those derived in a non-spatial context. For example, it is possible to simultaneously extract different grades of resource when transportation costs are taken into account. This may explain why, empirically, many resource deposits with widely different extraction costs are extracted simultaneously (Adelman, 1986). Also, this helps to understand why it may be efficient for a country to simultaneously produce and import an exhaustible resource.

This paper has essentially focused on the role of asymmetries between countries in

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[20] This fact was also highlighted by Kolstad (1994).

terms of technologies, resource endowments, and geographical sizes in determining the pattern of trade flows. If countries have the same technology and resource-endowment ratios, trade is based exclusively on the relationship between geographical sizes. As a consequence, the small country exports the resource towards the large country. When countries differ in terms of technologies, resource endowments, and geographical sizes, the magnitude of the unit cost of transport was shown to be decisive in determining whether the relationship between geographical sizes of countries has a greater influence on the pattern of trade. The relative importance of geographical size is an increasing function of transport cost. Interestingly, when transport cost approaches zero, the trade pattern is based exclusively on comparative advantage in terms of production technology and per-capita resource endowments.

CHAPITRE 2

ON CAPTURING FOREIGN OIL RENTS

Abstract

A common assumption in the literature on tariff and exhaustible resources is that no stocks of the resource are available within the importing country's borders and therefore the importing country is not itself a producer. Reality is in fact quite different : there are many instances of countries that are simultaneously importers and producers of a natural resource. This paper makes use of a spatial trade model to depart from this limitation and examines the rent-extracting tariff in a more general framework where the importing country is allowed to have access to a stock of the resource of its own and to determine simultaneously the optimal tariff and the rate of depletion of its own stock. The presence of resource deposits in the importing country reinforces the ability of the importer to capture the foreign rent. In effect, the optimal tariff is a decreasing function of the initial resource stock in the importing country. The paper also addresses the issue of dynamic consistency.

2.1 Introduction

A special feature of nonrenewable resources is that they are in fixed supply and any unit consumed today will not be available in the future. So, suppliers will be willing to sell the resource only at a price that includes the opportunity cost associated with having less of the resource available for later sale. Therefore, there is some *economic rent* associated to the exploitation of nonrenewable resources. [1] In an international trading economy, all of the resource rent will accrue to countries that produce the resource. However, due to the fixed nature of total supply, consuming countries may have an incentive to capture some of the available rent by using a tariff. Hence, there is an ongoing

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[1] This rent, also known as Hotelling rent, or scarcity rent, is the difference between the marginal cost of producing (extracting) a nonrenewable resource and the market price charged.

battle for resource rents between exporting countries and importing countries. There is an abundant literature dealing with the strategic interaction among buyers and sellers in exhaustible resources market. This paper considers market power on the demand side (under the assumption of competitive sellers) and examines the optimal tariff when the importing country is also endowed with some resource deposits.[2]

The consideration of market power on the buyers' side has given rise to the literature on optimal tariff on exhaustible resources. Bergstrom (1982) shows that if resource extraction is costless, and consumer countries are constrained to choose only time-invariant tax rates, they can choose a tax rate sufficiently high to capture most of the rents. This result holds whether the resource is supplied competitively or by a monopoly that cannot discriminate. Brander and Djajic (1983) discuss the case where the exporting country diverts supply to its own domestic use and observe that rent extraction is limited by the exporter's ability to use the resource domestically. Kemp and Long (1980), Karp (1984), Maskin and Newbery (1990), Karp and Newbery (1991, 1992) address the issue of dynamic inconsistency and point out that open-loop tariffs are in general dynamically inconsistent ; that is, the importing country would wish to change the originally announced tariff rate at some later time.[3]

Apart from Bergstrom (1982), all of the above-mentioned contributions feature an important restriction. All of them assume either explicitly or implicitly that no stocks of the resource are available within the importing country's borders and therefore the importing country is not itself a producer.[4] For many exhaustible resources, and in particular energy resources such as oil and natural gas, such an assumption is inappropriate. Indeed, there are many instances of countries that are simultaneously importers and pro-

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[2] Many contributions to the theoretical analysis of nonrenewable resources have been devoted to the supply-side market structure and the issue of market power on the sellers' side has been widely addressed. See, for example, Salant (1976), Dasgupta and Heal (1979), Lewis and Schmalensee (1980), Loury (1986), Salo and Tahvonen (2001), Groot et al. (2003). I assume price-taking suppliers for simplicity.

[3] A detailed analysis of intertemporal consistency issues in exhaustible resources can be found in Karp and Newbery (1993). Other papers that consider tariff on exhaustible resources include Tahvonen (1996), Liski and Tahvonen (2004), Rubio (2011).

[4] Karp (1984) notes (p.77) that a serious abstraction in this literature is the assumption that the importer does not own any of the resource. He states that : "The most important generalization, however, would be to allow the buyers to own a stock of the resource, and to determine simultaneously the optimal tariff and consumption rate from his own stocks" (p.93).

ducers of energy resources : while the United States is the third largest oil producer in the world, with 7.6% of the world oil production, it is also the largest oil importer, with 27.4% of world oil imports. Similarly India ranked third in the world with 8.4% of the world coal production, while being the second largest importer of coal with 7.5% of the world imports (International Energy Agency, 2009).

This paper makes use of the spatial trade model developed in Keutiben (2009) to depart from the usual assumption and allow the importing country to have access to a stock of the resource of its own and to determine simultaneously the optimal tariff and the rate of depletion of its own stock. The purpose of the paper is then to investigate how a resource-importing country, endowed with some resource deposits, may capture foreign resource rents using a tariff. In other words, how does allowing the resource importing country to hold some resource deposits alter the rent-extracting tariff ?

Under the restriction of zero (or constant and identical) extraction costs, Bergstrom (1982) implicitly allows importing countries to also have their own resource stocks and accounts for the fact that countries can be simultaneously importers and producers of oil. As noted by Bergstrom, this is not possible in a more realistic situation with oil deposits which can be extracted at different costs. [5] Indeed, the fact that countries can be simultaneously importers and producers is difficult to justify in a spaceless model of oil deposits with different extraction costs. The reason is that a country would always want to supply itself strictly from the cheapest source of oil as long as it is available. This paper gets around this limitation by proposing a model in which countries have geographical size and consumers are distributed over space inside the country.

The strategic interaction among buyers and sellers for oil rent is modeled as a two stage differential game in which the government of the importing country leads. I begin with the characterization of the competitive *laissez-faire* equilibrium when there is no tariff. Then I analyze the open-loop tariff under various scenarios. Firstly, I characterize the equilibrium when production and consumption is possible in both countries. In that case, the importing country holds a stock of the resource and simultaneously determines

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[5] "A more realistic model, however, would have an array of oil deposits which can be extracted at differing costs. Analysis of tax incidence in such a model differs from the constant extraction model..." Bergstrom (1982) p. 200.

the optimal tariff and the optimal rate of depletion from its stock. Secondly, I examine the situation when the importing country has no resource and the exporting country does not consume the resource.

The optimal tariff is shown to increase at the rate of interest and is therefore nondistortionary. Moreover, the optimal tariff captures all the rent if the exporting country gets no utility from consuming the resource. Allowing the exporting country to consume the resource restricts the ability of the importer to capture all of the foreign rent. The presence of resource deposits in the importing country reduces the available rent to foreign producers and, in essence, reinforces the ability of the importer to capture the foreign rent. In effect, the initial tariff is shown to be a decreasing function of the initial oil stock in the importing country.

The next Section describes the general problem when production and consumption of the resource is possible in both the importing and the exporting countries. The competitive *laissez-faire* equilibrium is derived in Section 2.3. Section 2.4 considers and analyzes the open-loop tariff. Section 2.5 offers concluding remarks.

2.2 The model

The model is framed around two countries, a domestic resource-importing country and a foreign resource-exporting country. There is an international oil industry with firms located in both countries. These firms simultaneously extract oil from deposits of fixed size and can sell it in both the domestic and foreign markets, which I consider to be adjacent and non-overlapping linear segments.

Let $L_i > 0$ denote the length, or geographical size, of country $i = h, f$; the two countries have a common border and are collinear as depicted in Figure 1.1. Therefore, residents of our global economy are located along a straight line of finite length $L = L_h + L_f$. Contrary to the traditional location models *à la* Hotelling (1929), in which firms choose where to locate, the location of the oil deposits is given by Nature. Placing the origin to the left-most end of the line, oil reserves are assumed to be located at 0 (the domestic firms' production site) and L (the foreign firms' production site).[6]

I assume that consumers of country $i = h, f$ are uniformly distributed with density $\rho_i \geq 0$ along its segment, so that the population size of country i is $\rho_i L_i$. Consumers at each location have an identical demand function $q(p)$ with $q(\bar{p}) = 0$, where $\bar{p}$ is the "choke" price. For simplicity, I will assume a rectangular demand ; i.e. inelastic demand up to a "choke" price at which point demand drops to zero. For each seller $i = h, f$, let c_i be the constant marginal cost of extracting oil. I will assume that neither set of producers can undercut the other (in costs) at their location ; i.e., $|c_h - c_f| < \alpha L$. The remaining resource stock of producer $i = h, f$ at time t is $S_i(t)$ and S_i^0 denotes its initial stock.

A consumer located at distance u from firm $i = h, f$ pays the full delivered price $p_i^m + \alpha u \leq \bar{p}$, where p_i^m is the mill price at firm i's location, and α is the transport cost per unit of distance.[7] I assume that producers in each country are price-takers. Thus, the mill price of the resource for producer $i = h, f$ is given by

$$p_i^m(t) = c_i + \lambda_i e^{rt}, \tag{2.1}$$

where λ_i is the initial resource rent for producer i and $r > 0$ is the interest rate, assumed equal to the discount rate. Implicit in this equation is the well known Hotelling's rule (Hotelling, 1931) which states that the scarcity rent of oil at each production site must rise at the interest rate r along the equilibrium extraction path.

The quantity of oil supplied by home and foreign producers at each date t is completely determined by the market boundary $M(t)$. It is worth emphasizing that the natural boundary is fixed, being determined by L_h, while the market boundary $M(t)$ changes over time, subject to $0 \leq M(t) \leq L$, as resource stocks get depleted. $M(t) = 0$ means that the whole market is supplied by the producer at location L (the foreign firm), while $M(t) = L$ means that it is supplied by the producer at 0 (the domestic firm). At the market boundary, consumers are indifferent between buying from the domestic or the foreign

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[6] This assumption is without loss of generality, since only the market area between firms is relevant for the analysis.

[7] For simplicity and without loss of generality, I will assume that unit transport cost is a linear function of distance. Indeed, the specification of the transport cost function matters only when the location of firms is an issue, which is not the case with resource firms.

sellers. Thus, the market boundary can be explicitly derived from

$$p_h^m(t)+\alpha M(t)=p_f^m(t)+\alpha\big(L-M(t)\big). \tag{2.2}$$

In the case the government of the importing country imposes a specific tariff $\tau(t)$, the market boundary is determined from

$$p_h^m(t)+\alpha M(t)=p_f^m(t)+\theta(t)+\alpha\big(L-M(t)\big). \tag{2.3}$$

2.3 Laissez-faire Equilibrium

Let us first assume that producers are competitive and that the government of the oil-importing country is passive, i.e., sets $\tau(t)=0$ for all t. I will begin with the more general case where consumption and production are possible in both countries.

General situation : $S_h^0, S_f^0>0$ and $\rho_h, \rho_f>0$

In this case, production and consumption of oil are possible in both the importing and the exporting countries. The market boundary is then determined by :

$$M(t)=\begin{cases}\frac{(\lambda_f-\lambda_h)e^{rt}+c_f-c_h+\alpha L}{2\alpha} & \text{if} \quad 0\le t\le T_h,\\ 0 & \text{if} \quad T_h<t<T,\\ \frac{c_f+\lambda_f e^{rt}-\bar{p}+\alpha L}{\alpha} & \text{if} \quad T\le t\le T_f,\\ L & \text{if} \quad t>T_f.\end{cases} \tag{2.4}$$

where T_h is the date at which the domestic stock is exhausted, T is the date at which the foreign producer is no longer able to supply consumers at address 0 below the choke price $\bar{p}$, and T_f is the exhaustion date for foreign stock. T_h, T and T_f are obtained from equation (2.4) by setting $M(T_h)=0$, $M(T)=0$ and $M(T_f)=L$:

$$T_h=\frac{1}{r}\ln\frac{\alpha L+c_f-c_h}{\lambda_h-\lambda_f}, \tag{2.5a}$$

$$T=\frac{1}{r}\ln\frac{\bar{p}-c_f-\alpha L}{\lambda_f}, \tag{2.5b}$$

$$T_f = \frac{1}{r} \ln \frac{\bar{p} - c_f}{\lambda_f}. \tag{2.5c}$$

The initial resource stocks, S_h^0 and S_f^0, will be exhausted and total quantity demanded will equal total quantity supplied. [8] Therefore, the following conditions must hold :

$$\int_0^{T_h} \rho_h M(t)\, dt = S_h^0. \tag{2.6a}$$

$$\int_0^{T_d} \big[\rho_h \big(L_h - M(t)\big) + \rho_f L_f\big]\, dt + \int_{T_d}^{T_f} \rho_f \big[L - M(t)\big]\, dt = S_f^0. \tag{2.6b}$$

The date $T_d > T$ is the moment of import interruption and it corresponds to the time at which the delivered price at the common border reaches the choke price $\bar{p}$. Also, $M(T_d) = L_h$; which gives $T_d = \frac{1}{r} \ln \frac{\bar{p} - c_f - \alpha L_f}{\lambda_f}$.
Substituting the latter expression, (2.4) and (2.5) into (2.6) and integrating yield the initial resource rent at each production site which completely characterizes equilibrium paths. The initial rent from the foreign deposit is then obtained as

$$\lambda_f = \exp\Big[-\frac{r(S_h^0 + S_f^0)}{\rho_h L_h + \rho_f L_f} - 1 + \frac{\rho_h [A(L, c_f) - A(L_f, c_f)] + \rho_f A(L_f, c_f)}{\rho_h L_h + \rho_f L_f} \Big], \tag{2.7}$$

where

$$A(l, c) = \frac{1}{\alpha} \Big[(\bar{p} - c) \ln(\bar{p} - c) - (\bar{p} - c - \alpha l) \ln(\bar{p} - c - \alpha l) \Big]. \tag{2.8}$$

$A(l, c)$ can be labeled the "as-if-social surplus" from consuming one unit of the resource. Indeed, if we assume the social surplus function (the net utility) from consuming one unit of the resource at any address x to be given by : [9]

$$u(x) = \ln(\bar{p} - c - \alpha x) + 1, \text{ with } u'(x) < 0,\ u''(x) < 0,$$

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[8] It is worth emphasizing that the four market phases described in equations (2.4) and (2.5) will occur (i.e., the market is fully covered at $t = 0$) only if the initial resource stock in the foreign country is large enough, which is assumed throughout the paper. More details on that issue can be found in Keutiben (2009).

[9] Note the $u(x)$ is simply a monotone increasing transformation of the true social surplus, which is $\bar{p} - c - \alpha x$.

then, the total surplus on a segment of length l is given by $\int_0^l u(x)dx$, which is $A(l,c)$. It is worth noting that

$$A(L,c_f)-A(L_f,c_f)=\int_0^{L_h}\big(\ln[\bar{p}-c_f-\alpha(L-x)]+1\big)dx.$$

The determination of λ_f completely characterizes the equilibrium outcome.

Special cases

In order to make my results comparable with those from previous contributions, where it is assumed that there is no stock of the resource available in the importing country, I will now consider this restriction in the current setup. Interestingly, the framework of previous studies can be obtained as special cases of the general model outlined in this paper just by changing some of the parameter values. For example, when there is no stock of the resource in the importing country and the exporting country is allowed to consume some of the resource domestically as in Brander and Djajic (1983), the resource rent in the foreign exporting country is given by

$$\lambda_f=\exp\Big[-\frac{rS_f^0}{\rho_h L_h+\rho_f L_f}-1+\frac{\rho_h[A(L,c_f)-A(L_f,c_f)]+\rho_f A(L_f,c_f)}{\rho_h L_h+\rho_f L_f}\Big]. \tag{2.9}$$

which can be derived from equation (2.7) by setting $S_h^0=0$. Also, the rent extracting tariff has been commonly analyze in the situation where importers do not produce and exporters do not consume as in Karp (1984) and subsequent related literature. In that case, the resource rent in the foreign exporting country is derived as

$$\lambda_f=\exp\Big[-\frac{rS_f^0}{\rho_h L_h}-1+\frac{A(L,c_f)-A(L_f,c_f)}{L_h}\Big]. \tag{2.10}$$

which can be obtained from (2.7) by setting $S_h^0=0$ and $\rho_f=0$.

Discussion

The equilibrium outcome indicates that the initial resource rent from the foreign stock depends on two opposing forces : the per-capita resource endowment in the global economy and the per-capita surplus from the consumption of one unit of the foreign resource. Clearly, the larger the per-capita surplus from one unit of the foreign resource, the larger the resource rent accruing to foreign producers. Also, the larger the total resource endowment, the smaller the foreign resource rent. Moreover, increases in transportation costs lead to reductions in foreign rent since $d\lambda_f/d\alpha < 0$. Accordingly, maximum rent is obtained when $\alpha = 0$. Notice from (2.7) that the foreign rent decreases as resource endowment in the importing country increases. Therefore, the availability of resource deposit in the home importing country reduces the resource rent accruing to foreign producers. I will now examine the optimal tariff.

2.4 Optimal tariffs

The battle for the foreign oil rent is modeled as a Stackelberg differential game, in which the government of the importing country leads. In the first stage, the domestic government sets a specific tariff $\theta(t)$ on oil imports. In the second stage, producers in the domestic and foreign countries simultaneously compete to supply both the home and foreign markets whenever possible. [10] As usual, the game will be solved backward beginning with the behavior of sellers while determining the rate of extraction. Since producers are price-takers, the resource supply is described by the Hotelling arbitrage condition which is written as

$$\dot{p}_i^m = r(p_i^m - c_i) \qquad i = f, h. \tag{2.11}$$

where r is the rate of interest and a dot signifies the derivative with respect to time, d/dt. Recall that p_i^m and c_i are respectively the mill price and the unit cost of extraction at production site i.

The government of the domestic importing country chooses the tariff to maximize the discounted present value of the domestic social welfare. This social welfare includes the domestic consumer surplus, the domestic firms' profits, and the tariff revenue. Hence,

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[10] In the case there is a stock of oil in the home country, the government also determines the domestic supply from that stock because domestic producers' surplus is considered in its optimization problem. Actually, the follower in our game is only the foreign supplier.

the home payoff when there is no deposit at home is given by

$$\begin{aligned} W_h &= \int_0^\infty \rho_h e^{-rt} \left[\int_{M(t)}^{L_h} \Big[\bar{p} - p_f^m(t) - \theta(t) - \alpha(L-u)\Big] du + \theta(t)[L_h - M(t)] \right] dt \\ &= \int_0^\infty \rho_h e^{-rt} \Big[\bar{p} - p_f^m(t) - \alpha L_f - \frac{\alpha}{2}[L_h - M(t)]\Big][L_h - M(t)] dt, \end{aligned} \tag{2.12a}$$

while with reserve at home it is given by

$$\begin{aligned} W_h &= \int_0^\infty \rho_h e^{-rt} \left[\int_0^{M(t)} \Big[\bar{p} - p_h^m(t) - \alpha u\Big] du + \int_{M(t)}^{L_h} \Big[\bar{p} - p_f^m(t) - \theta(t) - \alpha(L-u)\Big] du \right. \\ &\qquad \left. + (p_h^m - c_h)M(t) + \theta[L_h - M(t)] \right] dt \\ &= \int_0^\infty \rho_h e^{-rt} \Big[\bar{p}L_h - c_h M(t) - p_f^m(t)[L_h - M(t)] \\ &\qquad - \alpha\frac{M(t)^2}{2} - \alpha\frac{[L_h - M(t)]^2}{2} - \alpha L_f[L_h - M(t)]\Big] dt. \end{aligned} \tag{2.12b}$$

In determining the intertemporal import tariff the government of the importing country takes into account the reaction of producers. Thus he treats (2.11) as an additional state constraint. The differential game is then solved as a standard control problem where the importer's control variable is the time path of the tariff or equivalently the time path of imports. Therefore the government of the importing country chooses the time profile of imports to maximize (2.12a) or (2.12b) subject to (2.11), the resource constraints and suitable boundary conditions to be specified under each scenario.

General situation : *consumption and production in both countries*

When consumption and production are possible in both the importing and the exporting countries, we have the following resource constraints :

$$\dot{S}_f(t) = -q_f(t), \quad S_f(0) = S_f^0 \text{ given}, \quad S_f(t) \geq 0 \text{ for all } t \tag{2.13}$$

$$\dot{S}_h(t) = -q_h(t), \quad S_h(0) = S_h^0 \text{ given}, \quad S_h(t) \geq 0 \text{ for all } t, \tag{2.14}$$

where $q_f(t)$ is the total supply of oil by foreign producers and $q_h(t)$ is the total supply by home producers. [11]

Let $D_f(\lambda_{\theta f})$ denote the total accumulated oil consumption in the foreign exporting country, where $\lambda_{\theta f}$ is the initial rent from foreign deposit in the presence of tariff. [12] Since total demand must equal total supply, the implied total accumulated consumption of foreign oil by domestic consumers is then $\int_0^{T_d} \rho_h \big(L_h - M(t)\big)\, dt = S_f^0 - D_f(\lambda_{\theta f})$.

Recalling from (2.11) that $p_f^m(t) = \lambda_{\theta f} e^{rt} + c_f$ and substituting this in (2.12b), the social surplus in the home country can be rewritten as

$$W_h = \int_0^{\infty} \rho_h e^{-rt} \Big[\bar{p}L_h - c_h M(t) - (c_f + \alpha L_f)[L_h - M(t)] - \alpha \frac{M(t)^2}{2} - \alpha \frac{[L_h - M(t)]^2}{2}\Big] dt \\ - \lambda_{\theta f}\big[S_f^0 - D_f(\lambda_{\theta f})\big].$$

The government of the importing country has to maximize this integral with respect to the market boundary path $M(t)$ and the initial foreign oil rent $\lambda_{\theta f}$, subject to (2.14) and $\int_0^{T_d} \rho_h \big(L_h - M(t)\big)\, dt = S_f^0 - D_f(\lambda_{\theta f})$. Define the state variable $Z(t)$ as the home country's cumulative consumption of foreign oil from time t onwards. It follows that $Z(0) = S_f^0 - D_f(\lambda_{\theta f})$ and $\dot{Z}(t) = -\rho_h\big(L_h - M(t)\big)$. The current value Hamiltonian of this problem is

$$H = \rho_h \Big[\bar{p}L_h - c_h M(t) - (c_f + \alpha L_f)[L_h - M(t)] - \alpha \frac{M(t)^2}{2} - \alpha \frac{[L_h - M(t)]^2}{2}\Big] \\ - \mu \rho_h [L_h - M(t)] - \nu \rho_h M(t).$$

The necessary first-order conditions are

$$\frac{\partial H}{\partial M} = -c_h + c_f + \alpha L_f - \alpha M + \alpha [L_h - M] + \mu - \nu = 0. \qquad (2.15a)$$

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[11] It should be noted that $q_f(t) = \rho_h\big(L_h - M(t)\big) + \rho_f L_f$ if $M(t) \leq L_h$ and $q_f(t) = \rho_f\big(L - M(t)\big)$ if $M(t) > L_h$, i.e., when imports become zero. Also, $q_h(t) = \rho_h M(t)$ if $M(t) \leq L_h$ and $q_h(t) = 0$ if $M(t) > L_h$.

[12] $D_f(\lambda_{\theta f}) = \int_0^{T_d} \rho_f L_f\, dt + \int_{T_d}^{T_f} \rho_f \big[L - M(t)\big]\, dt$. Clearly, $dD_f/d\lambda_{\theta f} < 0$.

$$-\frac{\partial H}{\partial Z} = \dot{\mu} - r\mu. \tag{2.15b}$$

$$-\frac{\partial H}{\partial S_h} = \dot{\nu} - r\nu. \tag{2.15c}$$

$$-\mu(0)\frac{d\big[S_f^0 - D_f(\lambda_{\theta f})\big]}{d\lambda_{\theta f}} = -\frac{d\big[\lambda_{\theta f}\big(S_f^0 - D_f(\lambda_{\theta f})\big)\big]}{d\lambda_{\theta f}}. \tag{2.15d}$$

Equation (2.15d) follows from the transversality condition which determines the optimal value for the initial foreign rent $\lambda_{\theta f}$.[13] This equation can be rewritten as $\big(\mu(0) - \lambda_{\theta f}\big)\big(dD_f/d\lambda_{\theta f}\big) = -\big(S_f^0 - D_f(\lambda_{\theta f})\big)$. Since $S_f^0 > D_f(\lambda_{\theta f})$ and $dD_f/d\lambda_{\theta f} < 0$, we conclude that $\mu(0) > \lambda_{\theta f}$. Integrating (2.15b) and (2.15c) and inserting into (2.15a) yields

$$c_h + \nu(0)e^{rt} + \alpha M(t) = c_f + (\mu(0) - \lambda_{\theta f})e^{rt} + \lambda_{\theta f}e^{rt} + \alpha\big(L - M(t)\big). \tag{2.16}$$

In comparing (2.16) and (2.3) we can obtain the unit tariff at each date t as $\theta(t) = (\mu(0) - \lambda_{\theta f})e^{rt}$. Thus, the tariff rises at the rate of interest until imports fall to zero ; that is, when $M(t) = L_h$. Furthermore, the use of the tariff introduces no modification in the extraction profile, since the market boundary schedule is unchanged.[14] This reflects the general view that an import tariff rising at the rate of interest acts as lump sum tax and is then a means by which a government can capture foreign oil rents without causing any distortion in extraction (see Dasgupta and Heal, 1979).

However, it should be stressed that the ability of the importing country to extract foreign rent is limited because of the possibility of oil consumption in the foreign country. Clearly, the importing country would have wished to keep $\lambda_{\theta f}$ as low as possible. But the government must find an optimal tradeoff because the gain from capturing foreign rent is achieved at the cost of restricting oil consumption to domestic consumers. Indeed, total oil consumption in the importing country is lower with tariff compared to the case when the importing country adopts a passive behavior.

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[13] This kind of transversality condition is obtained by applying Hestenes's theorem, treating $\lambda_{\theta f}$ as a "control parameter". This theorem is stated and discussed in Łéonard and Long (1992). Interested readers may also find Dockner et al. (2000) helpful.

[14] Only the initial value will adjust such that $\mu(0) = \lambda_f$, the initial rent without tariff.

To better see this, observe that the initial rent without tariff coincides with $\mu(0)$, which by (2.15d) is greater than the initial rent with tariff. Since the total oil consumed in the foreign exporting country is a decreasing function of the initial foreign rent, it follows that total oil consumed in the foreign exporting country is greater under tariff than under laissez-faire, which means that total oil consumption in the importing country under the tariff is less than what would occur with passive behaviour. Let us now focus on the case where there is no resource deposit in the importing country.

Special cases

Let us now assume that there is no stock of the resource available in the importing country. Therefore, there is only one resource constraint for the depletion of the foreign stock which is given by (2.13). The objective of the importer is now to maximize (2.12a) over $M(t)$, subject to (2.11) and (2.13). Following the same technique used for the general case above, the home welfare can be rewritten as

$$W_h = \int_0^{\infty} \rho_h e^{-rt} \Big[\bar{p} - c_f - \alpha L_f - \frac{\alpha}{2}[L_h - M(t)]\Big][L_h - M(t)]dt - \lambda_{\theta f}\big[S_f^0 - D_f(\lambda_{\theta f})\big].$$

This integral has to be maximized with respect to the market boundary path $M(t)$ and the initial foreign oil rent $\lambda_{\theta f}$, subject to $\int_0^{T_{2d}} \rho_h \big(L_h - M(t)\big)\,dt = S_f^0 - D_f(\lambda_{\theta f})$. Again, let us define the state variable $Z(t)$ as the home country's cumulative consumption of oil from time t onwards. It follows that $Z(0) = S_f^0 - D_f(\lambda_{\theta f})$ and $\dot{Z}(t) = -\rho_h\big(L_h - M(t)\big)$. The current value Hamiltonian for the importer's problem is now written as

$$H = \rho_h \Big[\bar{p} - c_f - \alpha L_f - \frac{\alpha}{2}[L_h - M]\Big][L_h - M] - \mu\rho_h[L_h - M].$$

Necessary conditions for optimality are

$$\frac{\partial H}{\partial M} = -(\bar{p} - c_f - \alpha L_f) + \alpha(L_h - M) + \mu = 0. \tag{2.17a}$$

$$-\frac{\partial H}{\partial Z} = \dot{\mu} - r\mu = 0. \tag{2.17b}$$

$$-\mu(0)\frac{d\big[S_f^0-D_f(\lambda_{\theta f})\big]}{d\lambda_{\theta f}}=-\frac{d\big[\lambda_{\theta f}\big(S_f^0-D_f(\lambda_{\theta f})\big)\big]}{d\lambda_{\theta f}}. \tag{2.17c}$$

Equation (2.17c) is the transversality condition which determines the optimal value for the initial rent $\lambda_{\theta f}$. From this, we obtain that $\mu(0)>\lambda_{\theta f}$. Integrating (2.17b) and substituting into (2.17a), we can derive the market boundary path from

$$\bar{p}=c_f+\lambda_{\theta f}e^{rt}+(\mu(0)-\lambda_{\theta f})e^{rt}+\alpha\big(L-M(t)\big). \tag{2.18}$$

Again, in comparing the right hand side of (2.18) with the right hand side of (2.3), one can derive the time profile of the specific open-loop tariff as $\theta(t)=\big(\mu(0)-\lambda_{\theta f}\big)e^{rt}$. So, the open-loop tariff rises at the rate of interest until imports become zero as in the previous case. Therefore, the availability of oil stock in the importing country does not change the tariff schedule.

However, it is worth emphasizing that the initial tariff is lower when the importing country is itself a producer of the resource. To better see this, notice that $\mu(0)=\lambda_f$ and that $d\lambda_f/dS_h^0<0$ from (2.7), which shows that the initial tariff is decreasing with respect to the initial oil stock in the importing country. This suggests that when holding some resource stock at home, the importing country need not be too aggressive in order to capture foreign rent. In essence, the ability of the importing government to capture foreign rent is reinforced when there is some resource deposit in the importing country.

I will now examine the optimal tariff in the common framework where importers do not produce and exporters do not consume. In that case, the resource constraint is described by

$$\dot{S}_f(t)=-\rho_h\big(L_h-M(t)\big),\quad S_f(0)=S_f^0\text{ given},\quad S_f(t)\geq 0\text{ for all }t, \tag{2.19}$$

where $\rho_h\big(L_h-M(t)\big)$ is the time path of imports which is completely identified once the market boundary $M(t)$ is determined. Therefore, the importer's problem is to maximize (2.12a) over $M(t)$, subject to (2.11) and (2.19). Let μ and η be the costate variables associated with the stock and the price. The current value Hamiltonian of this problem is

$$H=\rho_h\Big[\bar{p}-p_f^m-\alpha L_f-\frac{\alpha}{2}[L_h-M]\Big][L_h-M]-\mu\rho_h[L_h-M(t)]+\eta r(p_f^m-c),$$

from which we derive the first-order conditions that characterize the optimal path

$$\frac{\partial H}{\partial M}=-(\bar{p}-p_f^m-\alpha L_f)+\alpha[L_h-M]+\mu=0 \tag{2.20a}$$

$$-\frac{\partial H}{\partial S_f}=\dot{\mu}-r\mu=0 \tag{2.20b}$$

$$-\frac{\partial H}{\partial p_f^m}=\dot{\eta}-r\eta=\rho_h(L_h-M)-r\eta \tag{2.20c}$$

Integrating (2.11) and using (2.1), we obtain $p_f^m(t)=\lambda_f e^{rt}+c_f$. By (2.20b) we have $\mu(t)=\mu(0)e^{rt}$. Substituting these into (2.20a) implies

$$\bar{p}=c_f+\lambda_{\theta f}e^{rt}+\mu(0)e^{rt}+\alpha\big(L-M(t)\big). \tag{2.21}$$

In comparing the right hand side of (2.21) and the right hand side of (2.3), we can derive the unit tariff at date t as $\theta(t)=\mu(0)e^{rt}$. Again, the tariff rises at the rate of interest until imports fall to zero. Also, the use of the tariff introduces no modification in the extraction profile, since the market boundary schedule is unchanged.[15] Notice that the higher is $\mu(0)$ the lower is the initial rent and consequently the value of the stock. It follows that the domestic government can extract all of the foreign resource rent by a convenient adjustment of the initial tariff. This result is similar to Bergstrom's major conclusion (Bergstrom, 1982) that if resource extraction is costless, and consumer countries (holding no deposit) are constrained to choose only time-invariant tax rates, they can choose a tax rate sufficiently high to capture most of the rents.

An important question to consider is whether or not the optimal tariff is time consistent. To address that, let us examine the costate variable associated to the state variable $p_f^m(t)$.

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[15] Only the initial rent will adjust such that $\lambda_{\theta f}+\mu(0)=\lambda_f$ where $\lambda_{\theta f}$ is the initial rent when the tariff is introduced.

Because $p_f^m(0)$ is free, the transversality condition for $\eta(t)$ is $\eta(0) = 0$. [16] This condition with (2.20c) and (2.19) implies

$$\eta(t) = S_f^0 - S_f(t). \tag{2.22}$$

η is the marginal benefit to the importer of an increase in the foreign supplier's rent, $p_f^m - c_f$. From (2.22), we have $\eta(t) > 0$ for $t > 0$. Therefore, after the initial date, the importer will have an incentive to increase the exporter's rent. This is the consequence of the time inconsistency of the open-loop strategy. This is shows up in the term S_f^0, the initial condition on stock, which appears in equation (2.22). Clearly, if the importer is allowed to renege at any later time, he will find it in his interest to change the original announced tariff.

It is worth noting that the issue of time consistency of the open-loop solution has been widely addressed in previous studies on tariff and exhaustible resources. However, our spatial approach fundamentally differs from the analysis in the previous literature. The inconsistency of the open-loop tariff in our model is primarily due to the spatial distribution of consumers which makes the resource price for any individual consumer dependent on his personal address. Indeed, at the time when the price of oil attains its choke value at any location in the importing country, the world stock of oil is still available at a lower price. Then, the importer has an incentive to revise his earlier announcement and import more oil at an advantageous price. [17]

2.5 Conclusion

Most findings in the literature on tariff and exhaustible resources have been derived under a serious abstraction. Indeed, virtually all contributions on that issue have assumed that the importing country owns no deposit. This paper departs from this assumption by

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[16] In fact, $p_f^m(0)$ is determined by the total stock of oil and the demand made by the importer. Thus, the importer can freely manipulate $p_f^m(0)$ by its imports.

[17] In Kemp and Long (1980) the inconsistency arises because of the possibility for the exporting country to use the resource domestically ; In Karp (1984), it is the stock-dependence of costs that causes the inconsistency of the open-loop tariff. The inconsistency arises in Karp and Newbery (1992), and Maskin and Newbery (1990) because they consider importing countries that differ in market power.

allowing the importing country to own a stock of the depletable resource. The rent-extracting tariff is then reconsidered in a framework which rationalizes the fact that a country can simultaneously produce and import an exhaustible resource. The open-loop equilibrium is characterized when a single importer uses a specific tariff to capture foreign rent from competitive oil producers. The analysis conducted here generalizes previous studies, in the sense that most of their results can be derived as special cases in the present model.

The open-loop tariff is shown to increase at the rate of interest and is therefore non-distortionary. When the exporting country obtains no utility from oil consumption, the open-loop tariff is confiscatory, in the sense that it is as if the importer were able to expropriate the stock from the exporter. In that case, the use of the open-loop tariff results in the same total oil consumption as without tariff. Allowing the exporting country to consume oil restricts the ability of the importer to capture all of the foreign rent. In that case, total oil consumption in the importing country under the tariff is less than what would occur with passive behaviour.

The innovation of the paper is to allow the importer to own a stock of oil and to determine simultaneously the optimal tariff and extraction rate from his own deposit. The presence of oil deposit in the importing country reduces the available rent to foreign producers, and in essence reinforces the ability of the importer to capture the foreign rent. In effect, the optimal tariff is lowered when a reserve of oil is available in the importing country. This suggests that the importer need not be too aggressive in capturing foreign rent when he also holds deposit at home.

This paper also corroborates the time inconsistency of the open-loop tariff. Clearly, if the importer is allowed to renege at any later time, he will find it in his interest to change the originally announced tariff. This situation arises here because the resource price for any individual consumer depends on his address. Indeed, at the time when the price of oil attains its choke value at any location in the importing country, the world stock of oil is still available at a lower price. Then, the importer would has an incentive to revise his earlier announcement and import more oil at an advantageous price. Therefore, our spatial approach fundamentally differs from previous studies on tariff on exhaustible resources.

By focusing on the possibility for the importing country to also hold oil deposit, this work has ignored the evident market power of oil producers. In further research, it would be worth analyzing the conflict over resource rent when there is market power on both the buyer and the seller side. It would also be worth attempting to characterize the time-consistent tariff in the model outlined here. This will be considered in future work.

CHAPITRE 3

OPEN ACCESS FISHERIES, PROPERTY RIGHTS, AND PIRACY IN THE GULF OF ADEN

Abstract

This paper examines how agents in a coastal community allocate effort between productive (fishing) and unproductive (piracy) activities. The allocation of population between fishing activity and piracy attacks is determined endogenously as a consequence of the occupation choice. The paper offers an explanation for the significant increase in piracy attacks in the Gulf of Aden in the recent years. The paper also discusses different schemes in combating piracy and highlights the crucial role of property rights.

3.1 Introduction

Since the collapse of Somalia's last functional government in 1991, Somali waters have become the site of an international 'free for all' with fishing fleets from around the world illegally plundering Somali stocks and freezing out the country's own rudimentarily equipped fishermen. Also, piracy began to grow off the Somali coast in the early 1990s with most of the pirates being former fishermen. Somali pirates have intensified their attacks in the Gulf of Aden, carrying out attacks on over 111 commercial ships, and successfully hijacking an estimated 40 ships in 2008. In 2009 there were 217 incidents, with 47 vessels hijacked.

The responses to piracy off the Horn of Africa include multinational naval patrols, the establishment of a Maritime Security Patrol Area in the Gulf of Aden with an Internationally Recommended Transit Corridor protected by warships, the option of escorted convoys, improved arrangements for surveillance and information sharing among participating navies, and a series of the International Maritime Organization (IMO) meetings that have promoted cooperation and developed a Code of Conduct among littoral countries covering matters such as the prosecution of offences. The UN Security Council has adopted several resolutions relating to Somalia and these have helped facilitate cooperation to suppress piracy in the area, for example the deployment of naval forces and the investigation, trial and punishment components of repression efforts "unprecedented in scope and authority for the international community to counter a threat in the maritime domain."

Despite all these measures, attacks in the waters off the Horn of Africa continue. The naval operations have several limitations. Most warships have restrictive rules of engagement and they lack the national legal authority to arrest pirates and bring them to trial. The most serious limitation, however, is the lack of resources in terms of the number of ships and surveillance aircraft covering the piracy-prone waters off the Horn of Africa that now include large areas of the north-west Indian Ocean around the Seychelles. Comprehensive air surveillance is a basic requirement but there are insufficient military patrol aircraft. The United States has deployed surveillance drones to the Seychelles but these do not provide a visible deterrent to pirates. However, modern warships and military aircraft with their sophisticated military equipment are in many ways an 'overkill' for anti-piracy operations. Cheaper and less well-armed coast guard vessels and aircraft would be quite sufficient for the task. A cheaper option would be to use civilian aircraft under charter perhaps to the United Nations. Bateman (2010) provides more details on sea piracy.

This paper attempts to explain those facts by examining how agents in a coastal community allocate effort between productive (fishing) and unproductive (piracy) activities. Our approach is built on two streams of literature. First, we borrow from the literature on open access to natural resources and build on Ruseski (1998) to model the noncooperative interaction among agents to exploit a common fish stock. Second, our model is in line with the rent-seeking literature as the allocation of agents between productive and unproductive activities is determined endogenously as a consequence of the occupation choice. However, our approach is different from previous contributions because unproductive agents do not prey on productive agents.

An essential feature of our model is the possible existence of a piracy trap. Indeed, there may exist a locally stable equilibrium with piracy. The results in this paper have many implications in terms of policy to combat policy. The paper emphasizes the crucial role of the protection of property rights as an alternative anti-piracy measure, beside the current multinational naval patrols or escorted convoys. In fact piracy attacks may be difficult to overcome in an environment where property rights are weak or lacking.

The paper proceeds as follows. Section 3.2 describes fundamental model. Section 3.3 derives and characterizes the equilibrium. Some comparative statics are carried out in Section 3.4, leading to the discussion of policy implications in Section 3.5. Section 3.6 provides some concluding remarks.

3.2 The model

Consider a coastal community populated by a continuum of agents (fishermen) of measure 1, who can engage in one of two activities. Each agent can harvest fish from a common pool fishing ground. A typical fisherman undertakes an artisan fishing activity, from which he can earn rent just enough to ensure him a subsistence level of consumption. However, a lack of regulation or a mismanagement of the fishery may lead to a gradual decline in the fish stock with the dissipation of the rent. Therefore, with a significant drop in their income from fishing, some fishermen may find unproductive (‘*bad*’) activities such as piracy or drugs trafficking attractive. Piracy is thus the second activity that each agent can pursue.

Agents who opt for the fishing activity compete with each other for the exploitation of a common fish stock. Each fisherman then chooses his effort to maximize his individual steady-state rent from the fishery, taking as given the effort levels chosen by rival harvesters.[1] We denote by $\pi(\alpha;\gamma)$ the rent accruing to an individual agent engaged in the fishery, where α is the fraction of agents undertaking piracy and $\gamma > 0$ is the agent's index of efficiency in the fishery. $\pi(\cdot)$ is an increasing function of α and γ. Furthermore, $\pi(\cdot)$ is convex in α.[2] A typical rent function, which we shall use for illustration and

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[1] The dynamic resource problem is ignored here in order to focus on the strategic activity choice of agents.

[2] We know from the literature on noncooperation between agents allocating effort to exploit a fish stock, that the maximized rent accruing to an individual agent is decreasing and convex in the total number of harvesters. If there are α fishermen engaged in pirating, there will be $1-\alpha$ agents active in the fishery

analytical tractability is the following :[3]

$$\pi(\alpha;\gamma) = \frac{\gamma}{(2-\alpha)^2}. \tag{3.1}$$

The coastal community is assumed to lack strong legal institutions, so that it is difficult or impossible for it to enforce property rights over its waters. Hence, the fishing ground is a global ‘free for all’ with outsiders’ fishing fleets competing with local fishermen. The payoff for an individual fisherman from the fishing activity is therefore given by

$$V_F(\alpha) = (1-\tau)\pi(\alpha;\gamma), \tag{3.2}$$

where τ is the part of resource rent captured by outside competitors, possibly foreign vessels with higher efficiency in fishing.

The parameter τ, which we assume exogenous, can be seen as an ‘inverse degree of property rights’ or the extortion intensity. In effect, if $\tau = 0$, each local fisherman will keep his entire rent, meaning that the community is able to enforce complete property rights over the fish stock. If $\tau > 0$, we have a situation where the local community is unable to enforce complete property rights and to protect its fishing areas from outsiders. In that case tougher competition from foreign vessels induces a significant decrease in the rent accruing to local fishermen. In the extreme case where $\tau = 1$, the fish stock is expropriated from the coastal community. Thus, a feature of our model is that profits to fishing activity go to zero when the enforcement of property rights is very weak.

Acts of piracy are illegal. Each fisherman who commits to join a piracy network can expect to earn a ransom. The ransom an individual pirate can expect is uncertain and depends on the likelihood (probability) $\Phi(\cdot)$ of being successful in a piracy venture. The probability of succeeding in a pirate attack depends on the effort $e \in [0,1]$ an agent allocates to pirating and the size (or the power) of the network he belongs to. Let $\alpha \in$

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and a decreasing and convex function of $1-\alpha$ is an increasing and convex function of α.

[3] This function can be derived from a traditional Schaefer model of fishery. Then, $\gamma = rpK(1-\frac{c}{pqK})^2$, where r is the intrinsic rate of growth and K is the carrying capacity of the fishing ground, q is the catchability coefficient, p is the price and c is the cost per unit of effort (see for example Ruseski, 1998).

$[0,1]$ denote the proportion of fishermen who are connected with one another to operate a piracy network. We will assume $\Phi(\cdot)$ to take the following functional form :

$$\Phi(e,\alpha) = \frac{\alpha e}{\phi(\alpha)^a}, \tag{3.3}$$

where $\phi(\alpha) \geq 1$ is the monitoring effort to deter or to fight against piracy and $a \geq 0$ is a parameter characterizing the intensity of the monitoring effort.

The function $\phi(\cdot)$ is convex, differentiable, and strictly increasing in the proportion α of fishermen engaged in pirating. We also assume that $\lim_{\alpha \to 1} \phi(\alpha) = +\infty$, meaning that the monitoring effort is very high when all fishermen are engaged in piracy.[4] It is worth noting that $\Phi(e,0) = 0$, $\lim_{\alpha \to 1} \Phi(e,\alpha) = 0$ and $\Phi(e,\alpha) > 0$ for $\alpha \in (0.1)$. Therefore, for any given effort e, there exists $\hat{\alpha} \in (0,1)$ such that $\Phi(e,\alpha) \leq \Phi(e,\hat{\alpha})$, for all $\alpha \in [0,1]$. This $\hat{\alpha}$ is implicitly given by $\phi(\hat{\alpha}) - a\hat{\alpha}\phi'(\hat{\alpha}) = 0$

That $\Phi(e,\alpha)$ is inverted U-shaped means that pirate attacks are likely to fail if either a small fraction or a large fraction of fishermen turn into piracy venture. In effect, it is hard for a network to succeed in a pirate attack if it contains a small number of fishermen. Accordingly, it is impossible for a typical fisherman to be successful in a pirate assault if privately acting alone. Likewise, if a significant proportion of fishermen turn out to be pirates, piracy will become less successful because more effort will be allocated for monitoring and deterrence. Correspondingly, there is no chance to succeed in a piracy venture if all fishermen are involved.

An individual fisherman can claim a ransom $\bar{R} > 0$ from a successful piracy venture, whereas if he fails, he will get $\underline{R} < \bar{R}$. Agents are risk neutral such that what matters is the expected payoff. The expected net return from piracy for a single fisherman is equal to :

$$\Phi(e,\alpha)\bar{R} + \big(1 - \Phi(e,\alpha)\big)\underline{R} - c(e) = \Phi(e,\alpha)(\bar{R} - \underline{R}) - c(e) + \underline{R}, \tag{3.4}$$

where $c(e)$ is the cost of effort with $c'(e) > 0$ and $c''(e) > 0$, $\lim_{e \to 0} c'(e) = 0$ and $c(0) =$

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[4] A typical function with the underlined properties is $\phi(\alpha) = \frac{1}{1-\alpha}$. We shall use this specific functional assumption for illustration and analytical tractability.

0. Each agent chooses the effort level to maximize his expected net return which implies

$$e(\alpha) = c'^{-1}\Big(\frac{\alpha}{\phi(\alpha)^a}\big(\bar{R} - \underline{R}\big)\Big). \tag{3.5}$$

where $c'^{-1}(e)$ is the inverse function of $c'(e)$. Since $c''(e) > 0$, $e(\alpha)$ behaves in a similar way as the function $\frac{\alpha}{\phi(\alpha)^a}$, which is inverted U-shaped. Therefore, the effort level first increases when there are few agents engaged in pirating activities and then declines as many fishermen undertake pirates attack. This is because monitoring becomes more intensive when a large number of fishermen decide to operate in pirate activities.[5] Notice that the optimal level of effort depends only on the difference $\bar{R} - \underline{R} > 0$ of the ransoms.

Inserting (3.5) in (3.4) yields the individual maximized expected return from piracy as

$$V_P(\alpha) = \frac{\alpha e(\alpha)}{\phi(\alpha)^a}(\bar{R} - \underline{R}) - c\big(e(\alpha)\big) + \underline{R}. \tag{3.6}$$

Differentiating (3.6) using the envelope theorem, we can see that

$$V_P^{'}(\alpha) = \frac{\phi(\alpha) - a\alpha\phi^{'}(\alpha)}{\phi(\alpha)^{a+1}} e(\alpha)\big(\bar{R} - \underline{R}\big). \tag{3.7}$$

It follows that V_P is inverted U-shaped with a maximum at $\hat{\alpha}$ such that $\phi(\hat{\alpha}) - a\hat{\alpha}\phi'(\hat{\alpha}) = 0$. We also know that $V_F(\cdot)$ is an increasing and convex function of α. Observe also that $V_P(0) = V_P(1) = \underline{R}$, while $V_F(1) > V_F(0) > 0$, for $\tau < 1$.[6]

Define by $\underline{\widetilde{R}}$ the value of $\underline{R}$ such that $V_P(\hat{\alpha}) = 0$ and by $\underline{\widehat{R}}$ the value of $\underline{R}$ such that $V_F(1) = \underline{\widehat{R}}$. Obviously, $\underline{\widehat{R}} > 0 > \underline{\widetilde{R}}$. If $\underline{R} \leq \underline{\widetilde{R}}$, then $\underline{R}$ is so highly negative that piracy is ruled out altogether.[7] On the other hand, if $\underline{R} \geq \underline{\widehat{R}}$, then $\underline{R}$ is so highly positive that the fishing activity is ruled out, being dominated by piracy no matter what. Neither of those

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[5] That the individual effort level decreases when the network size is large may also be explained by the free riding effect which is more likely in large size groups than in small size groups (see Olson, 1965).

[6] Recall that $V_F(\alpha) = (1-\tau)\pi(\alpha)$ and $\pi(\alpha) > 0$. Therefore, $V_F(\alpha)$ can be zero only if $\tau = 1$, that is complete expropriation of the fish stock. In that case, fishing activity will not occur as unproductive (piracy) activity will turn out to be, for any α, more profitable.

[7] It is worth emphasizing that if $V_P(\hat{\alpha}) \leq 0$, then $V_P(\alpha) \leq 0$ for all α, and the return to piracy is always negative and hence smaller than the return to fishing. In that case, piracy is also ruled out altogether.

situations is of interest for our purpose. We will therefore assume in what follows that

$$\underline{\widehat{R}} > \underline{R} > \underline{\widetilde{R}}. \tag{3.8}$$

That the return to fishing (productive activity) increases with the number of agents involved in piracy (unproductive activity) is a result of the negative externality of crowding effort in the fishery. However, it is the opposite which is generally observed in contributions analyzing the allocation of talent between productive and unproductive activities.[8] Also, $V_P(\alpha)$, the return to piracy (unproductive activity), is non-monotonic in α which is uncommon in the rent-seeking literature as well. An exception to the latter feature is Baland and François (2000) who show that the profit from rent-seeking is non-monotonic in the number of rent-seekers. Contrary to our approach, those papers deal with the case where returns to rent-seeking depend directly on returns from productive activity, as rent-seekers essentially prey on productive agents. The payoff from productive activities in our analysis does not affect the reward from unproductive activities, even though it may change the incentive to engage in them.

3.3 Equilibrium in the activity choice

An equilibrium in our economy is the allocation of population between productive (fishing) and unproductive (piracy) activities. In equilibrium, agents must be indifferent between the two activities. Therefore, their expected return from both activities must be the same : $V_P = V_F$. Taking $\underline{R}$ to satisfy (3.8), it is useful to distinguish two cases : $V_F(0) > \underline{R}$ and $V_F(0) < \underline{R}$.

Consider first the case where $V_F(0) > \underline{R}$. The relevant profit curves V_P and V_F are depicted in Figures 3.1 and 3.2. The two figures are drawn with $\underline{R} = 0$ for illustrative purposes.[9] They may intersect twice, once (as a tangency), or not at all. The two latter

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[8] In those analysis, essentially the rent-seeking literature, an increase in the number of rent-seekers lowers returns to both rent-seeking and productive activity as rent-seekers prey on productive agents. See, for example, Murphy et al. (1993) ; Acemoglu (1995) ; Baland and François (2000) ; Torvik (2002) ; Mehlum et al. (2003), and Mariani (2007).

[9] If $0 > \underline{R} > \underline{\widetilde{R}}$, then $V_P(0) = V_P(1) = \underline{R} < 0$ and $V_P(\alpha)$ will both times cut the horizontal axis at some

cases can arise if and only if $V_P(\alpha) \leq V_F(\alpha)$, for all α. Under this condition, the return to fishing activity is always greater than the return to piracy. Consequently, there exists a unique equilibrium in which no agent chooses to become a pirate. The equilibrium without piracy, denoted as point E_0 in Figure 3.1 is a stable corner equilibrium. When it is more gainful to engage in fishing even when the rents from the fishery have to be shared among many, piracy acts will not occur.

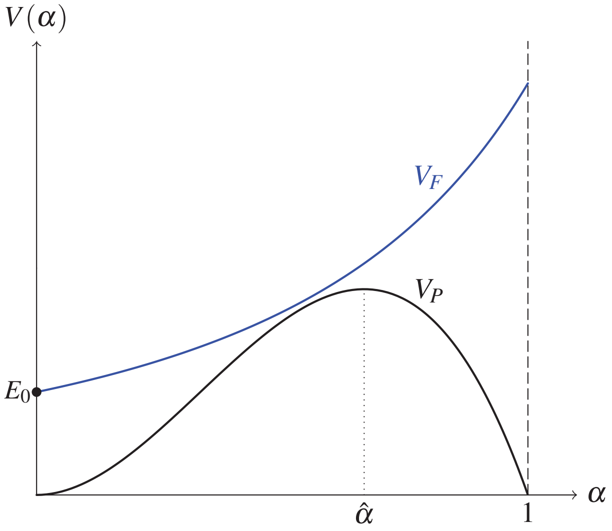

Figure 3.1 – Activity choice : unique corner equilibrium.

Figure 3.2 illustrates the case where the two profit curves cross twice. There will then exist three equilibria : one without piracy (point E_0) and the others with piracy (points E_1 and E_2). This will occur when condition (3.9) is satisfied :

$$\exists\alpha^* \text{ such that } V_P(\alpha^*) > V_F(\alpha^*). \tag{3.9}$$

As discussed in Mehlum et al. (2003) and many other papers dealing with rent-seeking and multiple equilibria, E_0 and E_2 in Figure 3.2 are locally stable equilibrium points while E_1 is an unstable equilibrium point. Indeed, starting at any point on the left

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$\alpha \in (0,1)$. If $V_F(0) > \underline{R} > 0$, then $V_F(0) > V_P(0) = V_P(1) = \underline{R} > 0$. Hence in both cases the equilibrium will have the same configuration as is depicted in Figures 3.1 and 3.2 with $\underline{R} = 0$.

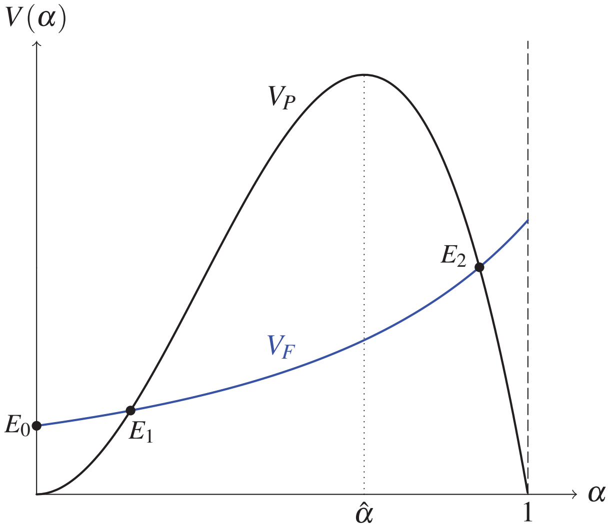

Figure 3.2 – Activity choice : multiple equilibria.

of E_1, the economy will end up at the equilibrium point E_0 with no piracy at all ($\alpha = 0$). Similarly, if the economy starts out either to the right of E_1 or to the right of E_2, it ends up at the equilibrium point E_2.

The above discussion has assumed $V_F(0) > \underline{R}$. Consider now the case of $\widehat{R} > \underline{R} > V_F(0)$. In that case we will have $V_P(0) > V_F(0)$. The resulting profit curves are depicted as in Figure 3.3. There will then be a unique interior stable equilibrium with a high rate of pirates (point E_2).

The preceding discussion has therefore shown that the situation where all agents are engaged in piracy is never an equilibrium. The situation where no agent is engaged in piracy is always an equilibrium, unless it is the case (as in 3.3) that, when evaluated at zero piracy the return to piracy is greater than that to fishing. In that case, there is only one locally stable equilibrium with piracy. Also, if and only if at some level of pirating activity, piracy is more rewarding than fishing, there is a locally stable equilibrium with piracy in addition to the stable equilibrium with no piracy. In what follows, our analysis will focus on interior stable equilibria like E_2, characterized by a high proportion of pirates.

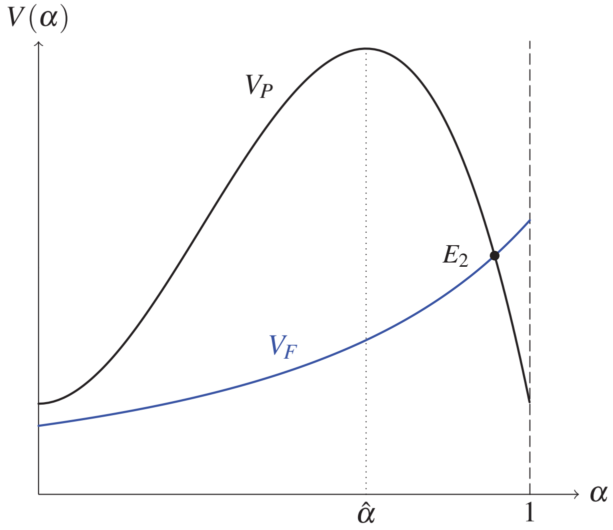

Figure 3.3 – Activity choice : unique interior equilibrium.

3.4 Comparative Statics

Let us now examine how changes in parameter values affect the equilibrium outcome. From equations (3.2) and (3.6), it is straightforward to verify that $\frac{dV_F}{d\gamma} > 0\,;\ \frac{dV_F}{d\tau} < 0\,;\ \frac{dV_P}{d\bar{R}} > 0\,;\ \frac{dV_P}{da} < 0$. Thus, improved efficiency in the fishery (increase in γ) and/or lower extortion intensity (decrease in τ) increase the returns from fishing. An increase in the intensity of monitoring effort (increase in a) and/or a lower ransom (decrease in $\bar{R}$) decrease the profitability of pirating activities.

The profit curve for piracy is unchanged by an improved efficiency in the fishery or a lower extortion intensity, whereas a higher γ or a lower τ mean higher returns from the fishing activity at all levels of piracy. The profit curve for fishing therefore shifts to the left, to the dotted curve in Figure 3.4. The new equilibrium is at point A, entailing fewer pirates and more fishermen. An increase in the intensity of monitoring effort does not affect the profit curve for fishing activity, while with a higher a, it becomes less profitable to engage in pirating activities at all levels of piracy. The profit curve for piracy thus moves down to the dotted (inverted U-shaped) curve in Figure 3.4. The new equilibrium at point B also involves fewer pirates and more fishermen. Of course an increase in a, combined with an increase in γ or a decrease in τ will affect both the profits curve for fishing and pirating activities, and the new equilibrium at point C in Figure 3.4 will involve further fewer pirates and more fishermen.

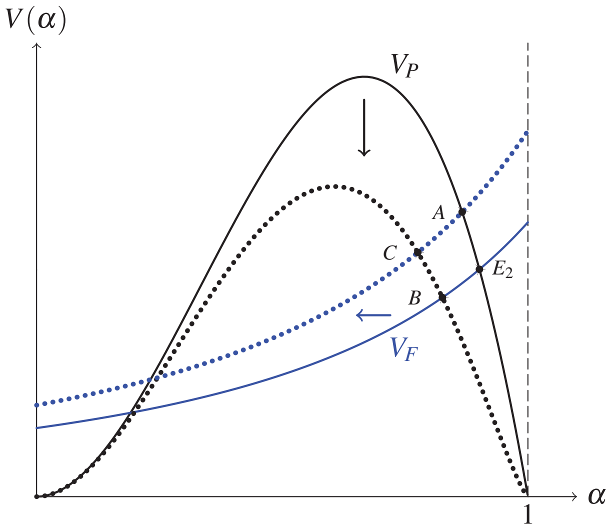

Figure 3.4 – Activity choice : Comparative Statics.

As discussed above, the equilibrium with piracy may not exist. If $V_F(\alpha) \geq V_P(\alpha)$ for all α, there will be no agents engaged in pirating activities as fishing will always be more rewarding than piracy. A necessary condition for no equilibrium with piracy is that $V_F(\hat{\alpha}) \geq V_P(\hat{\alpha})$. Using (3.2) and (3.6) and substituting for $\alpha = \hat{\alpha}$, it follows that there is no equilibrium with piracy only if[10]

$$\tau \leq \bar{\tau} \equiv 1 - \frac{V_P(\hat{\alpha})}{\pi(\hat{\alpha};\gamma)} \qquad \text{or} \quad a \geq \underline{a}. \tag{3.10}$$

Therefore, if the enforcement of property rights is weak ($\tau > \bar{\tau}$) or the intensity of monitoring effort is low ($a < \underline{a}$), there is always a stable equilibrium with piracy.

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[10] Note that $\bar{\tau}$ and $\underline{a}$ satisfy $V_F(\hat{\alpha}) = V_P(\hat{\alpha})$.

3.5 Policy Analysis

The results derived above have implications in terms of policy to combat piracy. First, an increased rent in the fishery increases returns from fishing thereby reducing the incentive for agents to engage in pirating activities. An improved efficiency for any agent in the fishery is likely to increase its returns from fishing. However, without a good protection of property rights (low value of τ, any rent from the fishery may be extorted from the coastal community, so that its members will face the temptation to undertake unproductive activities such as piracy.

Another means of fighting piracy is monitoring through naval patrols or escorted convoys. As our model indicated above, this measure is helpful in reducing piracy. Indeed, a high intensity in monitoring effort lessens the chance to succeed in a piracy venture thereby reducing agents' incentives to engage in pirating activities. It is difficult to know which anti-piracy measure, protection of property rights and monitoring, is more effective. But our model suggest that both approaches could be combined in fighting against piracy, with a larger effect in the reduction of piracy.

An important feature of our model is that a stable equilibrium with piracy exists. Therefore, the economy may be caught in a piracy trap. If this was to happen, effective anti-piracy measures would be essential to overcome piracy. Monitoring effort through naval patrols or escorted convoys may not be sufficient or effective. This would certainly be the case if the protection of property rights is very low, as shown above. Hence piracy will be difficult to eliminate, unless some improvements of property rights are made.

3.6 Conclusion

This paper has developed an activity choice where agents allocate effort between productive and unproductive activities. As in many other studies addressing the issue, the allocation of agents between the two activities is determined endogenously as a consequence of the occupation choice, and there are multiple equilibria. However, our approach is different from previous contributions because unproductive agents do not prey on productive agents. The results in this paper have some implications in terms of policy to combat piracy. The paper emphasizes the crucial role of the protection of property rights as an alternative anti-piracy measure, besides the current multinational naval patrols or escorted convoys. In fact piracy attacks may be difficult to overcome in an environment where property rights are weak or lacking. This may be one of the reason for the persistence piracy attacks in the Gulf of Aden.

CONCLUSION

Cette thèse a examiné des questions internationales en économie des ressources naturelles. Les deux premiers chapitres ont utilisé un cadre spatial pour examiner deux questions fondamentales pour l'analyse du commerce international des ressources non-renouvelables. Nous avons d'abord analysé les facteurs déterminant le sens des flux de ressources non-renouvelables. Ensuite, nous avons examiné la question de la répartition de la rente de rareté associée aux ressources non-renouvelables dans un contexte où le pays importateur est aussi producteur de la ressource. Le troisième chapitre a abordé le problème des droits de propriété sur les ressources renouvelables, notamment les ressources maritimes. Nous avons proposé un modèle qui permet de comprendre la piraterie maritime, notamment sa persistance dans certaines zones comme dans le Golfe d'Aden.

La plupart des études sur le commerce international des ressources non-renouvelables a été faite dans un cadre non spatial où les pays sont considérés comme des points dans l'espace, les gisements et leurs utilisateurs étant situés au même endroit. La réalité est pourtant très différente ; les gisements naturels et leurs utilisateurs sont disséminés dans l'espace, même à l'intérieur d'un pays. Le premier chapitre de cette thèse a proposé un modèle qui tient compte de cette distribution spatiale. Utilisant un modèle spatial à la Hotelling, nous avons examiné les facteurs déterminant le flux des ressources non-renouvelables entre deux pays. Nous avons montré qu'en présence des coûts de transport, la taille géographique joue un rôle important dans la détermination du sens de l'échange entre les pays, en plus des déterminants traditionnels que sont l'avantage comparatif en technologie (coût d'extraction de la ressource) et en dotation de ressource par tête. Un pays relativement pauvre en ressource et ayant des coûts d'extraction élevés peut avoir un avantage compétitif tout simplement à cause de sa proximité à un marché. Le coût unitaire de transport joue un rôle crucial pour déterminer lequel des facteurs influence le plus le sens de l'échange. Nous avons montré que le sens de l'échange est déterminé par la différence de taille géographique entre les pays lorsque le coût de transport est élevé, alors qu'il est influencé par les différences de technologie et de dotation en ressource lorsque le coût de transport est quasi nul.

Le cadre d'analyse spatial développé dans le chapitre un a aussi permis de montrer que différents gisements de ressource, ayant des coûts d'extraction distincts, peuvent être simultanément exploités. Ce résultat permet ainsi de comprendre pourquoi un pays peut être à la fois importateur et producteur d'une ressource non-renouvelable. Le deuxième chapitre de la thèse a utilisé ce fait pour examiner le tarif d'extraction de la rente de rareté associée aux ressources naturelles non-renouvelables dans le cas où le pays importateur est aussi producteur de la ressource. Nous avons introduit un jeu différentiel en deux étapes dans lequel le gouvernement du pays importateur détermine d'abord le tarif optimal et les producteurs déterminent ensuite la quantité de ressource qu'ils doivent vendre. Nous avons montré que le tarif optimal permet de récupérer seulement une partie de la rente lorsque le pays exportateur consomme lui-même une partie de stock. En revanche, toute la rente est récupérée par le pays importateur lorsque le pays exportateur vend toute sa production à l'étranger. Nous avons aussi montré que le pays importateur récupère plus facilement la rente lorsqu'il possède un stock de la ressource et est aussi producteur. Ainsi le tarif d'extraction de la rente sera plus petit dans un pays riche en ressource, comparé à celui d'un pays pauvre en ressource. Enfin, nous avons montré, comme la plupart des études avant nous, que la stratégie en boucle ouverte est incohérente dans le temps. Toutefois, l'incohérence dynamique dans notre analyse découle de la distribution spatiale des consommateurs alors qu'elle est justifiée par des raisons différentes dans les précédentes contributions. Notre analyse a ignoré la structure oligopolistique de l'offre évidente sur le marché international de la plupart des ressources non-renouvelables. Il serait donc intéressant de tenir compte de cette réalité dans une recherche future. Il serait aussi intéressant d'examiner le problème dans le cas de plusieurs pays importateurs.

Dans le troisième chapitre de la thèse, nous avons abordé le problème des droits de propriété sur les ressources maritimes et nous avons fait un lien avec la piraterie maritime. En empruntant d'une part à la littérature de recherche de la rente et d'allocation du talent, et d'autre part à la littérature sur la gestion des pêcheries sous libre accès, nous avons examiné comment une population de pêcheurs alloue l'effort entre les activités productives (pêche par exemple) et les activités non productives (piraterie par exemple).

Nous avons ainsi construit un modèle de choix d'occupation et nous avons établi l'existence d'une multiplicité d'équilibres. Notre modèle a mis en évidence l'éventualité d'une trappe à la piraterie, c'est-à dire l'existence d'un équilibre stable où une partie de la population est engagée dans l'activité de piraterie. Nous avons aussi montré que la piraterie est très vraisemblable dans un environnement où les droits de propriété sont faibles ou quasi inexistants. Ceci pourrait être le cas actuel de la Somalie, pays pauvre et sans institutions légales. En effet, la piraterie maritime a émergé aux larges des côtes somaliennes au lendemain de la chute du dernier gouvernement fonctionnel en 1991. Depuis lors, les actes de piraterie s'y multiplient, en dépit de nombreuses actions militaires pour la combattre. Dans ce travail nous avons expliqué ce phénomène et avons relevé la protection des droits de propriété comme une mesure alternative pour lutter contre la piraterie maritime.

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