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A Note on Trade Liberalization and Common Pool Resources

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Abstract: When countries share access to a common resource stock, optimal management is based on strategic considerations. We develop a simple general equilibrium model and show that regulatory policies are strategic substitutes under autarky. Trade liberalization not only changes relative prices, but may also change the qualitative nature of the game between jurisdictions. In the small country case with exogenous prices, regulatory policies become strategic complements. In the context of a two-country model, policies remain strategic substitutes but the factors that drive policy changes differ from those under autarky and the small country case. The implications in terms of conservation and resource management are discussed.

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1. Introduction

The literature on trade and resource management has evolved rapidly in the past decades. After an initial focus on the social planner's response to relative price changes in the 1970s and 1980s, attention has now shifted to the welfare implications of trade in a second-best world. Brander and Taylor (1997, 1998) were among the first to demonstrate that trade may reduce welfare if trading partners have an imperfect system of property rights to the traded resource (see also Chichilnisky 1994). When there is open access to the traded commodity, individuals enter until resource rents have dissipated. When the (relative) resource price increases after opening up for trade, additional labor flows into harvesting and the pre-existing market imperfection is exacerbated.[1]

But changes in relative price *levels* are not the only reason why trade might at times lower national welfare levels. Another important effect of trade is that in a small open economy the link between (local) supply and prices is removed, since price is exogenous. This in turn will influence the strategic harvesting decisions of governments. It is this problem that we investigate in this paper. We also consider the impact of trade when prices are endogenously determined (the two-country model). In this situation strategic interactions arise since the harvesting decisions of one nation affect the common price and the resource stock faced by all other rivals.

We set up a strategic management model, assuming that multiple countries interact via a common input market: a shared *in situ* resource stock. Unilateral management

[1] Of course there are other reasons why resource trade might be "immiserizing." For an argument based on endogenous enforcement of property rights, see Hotte *et al*. (2000). Emami and Johnston (2000) show that resource management may be immiserizing when resource prices are endogenous and only one of two trading partners shifts from open access to optimal management (and resource stocks are separate).

decisions may thus affect the profits from harvesting of all players, setting the stage for different types of strategic interactions under different trade regimes.[2]

The analysis is most closely related to the work of Copeland (1990) and Ruseski (1998) who applied strategic trade models to renewable resource management.[3] By strategically using investments in enhancement and destruction of a marine habitat (Copeland), or licensing of fleets and granting effort subsidies (Ruseski), resource rents may be shifted from foreigners to the domestic resource sector. Both analyses are based on partial equilibrium models where prices are given and where there is no movement of labor between sectors, and neither explicitly considers the role of trade.

We aim to construct a new model by bringing together two strands of literature. We combine elements of the decentralized general equilibrium trade models by Brander and Taylor (driven by myopic agents) with the strategic interaction models by Copeland and Ruseski (involving a forward-looking planner). We set up a simple general equilibrium model of two countries with two sectors (production of manufactures and resource extraction) that share access to the same renewable resource stock. Following Ruseski we consider the case of effort taxes and subsidies. The regulators, absent in the Brander and Taylor model, are assumed to be forward-looking and have a zero discount rate. In contrast, harvesters do not have well defined property rights and are assumed myopic, treating the resource stock as exogenous.

We use the model to show that opening up for trade may lead to fundamentally different strategic interactions between harvesting nations, depending upon how prices are determined. In an autarkic regime, the harvesting policies of countries sharing a common resource are strategic substitutes. However, in the small country case, opening up for trade

[2] For a non-cooperative model of two trading countries sharing a common resource stock, with an emphasis on market power and endogenous prices, see Markusen (1976). Our model extends Markusen's work by explicitly solving for equilibrium strategies (Markusen considers the national optimum for one country, assuming foreign taxes are fixed).

leads to a qualitative change in the strategic incentives of policy makers, and harvest policies become strategic complements instead. To our knowledge this finding is new to the literature. It has important policy implications for the control of common resources. For example, when harvest policies are strategic complements, a wasteful "race to the bottom" will be the result if one country unilaterally lowers its tax rate. However, the opposite may also occur – when one country decides to raise its tax rate, it is in the other country's interest to follow suit. Trade liberalization may thus foster outcomes closer to the cooperative equilibrium. On the other hand, in the context of a two-country model with endogenous prices, optimal polices are strategic substitutes. Intuitively, an increase in harvesting by one country influences the common price and resource stock faced by all other harvesting nations – a cross-border externality that individual harvesters fail to adequately internalize.

2. The model

Assume there are L identical households in the home country and L' households abroad. Both L and L' are exogenously determined and constant. In what follows we focus on the home country, but a similar analysis holds for foreigners. Throughout we use primes to denote foreign variables. We assume throughout that both countries are identical and use identical production technologies, and can only differ in the size of their population. Each household has a time endowment normalized at 1, and allocates its time to extraction effort (e) and manufacturing ($1-e$) to maximize income. Define $E=Le$. Of course the following holds: $(1-e)L + E \equiv L$.

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[3] For applications to pollution issues see, for example, Ulph (1998) and the references contained therein.

Following Hannesson (2000) we assume that there are diminishing returns to scale in manufacturing, defined by $M = L(1-e)^{1/2}$.[4] This output may be consumed domestically or exported to a third country for a price p^{M}. Following Brander and Taylor (1998) we choose p^{M} to be the numeraire and set it equal to 1 in what follows. Labor markets clear and labor flows freely from one activity to the other—there is free access to the resource good.[5] In the absence of government intervention, the allocation of labor will be inefficient as each harvester ignores the costs imposed upon rivals. Households take stocks as given and act as myopic optimizers.

Turning to the resource sector, we assume a logistic growth function for the common fish stock, $g(x)=rx[1-(x/k)]$, where r is the intrinsic growth rate and k is the carrying capacity. Household harvesting is described by a Schaefer harvest function, $h=qex$, with effort e and the fish stock x as arguments. The parameter q is a catchability coefficient. The steady state fish stock (growth equals aggregate harvest) can be described as a function of domestic and foreign effort levels:

$$(1) \qquad \frac{dx}{dt} = g(x) - H - H' = 0 \rightarrow x = \frac{k}{r}[r - q(E + E')],$$

where H is aggregate harvesting in the domestic country ($H=qLex$). We are primarily interested in the case of diversified production, such that labor is allocated between both sectors in both countries. This implies that $pqk>1$, where p denotes the price of the resource commodity, such that extracting a stock that is at its carrying capacity level (and

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[4] The purpose for including diminishing returns to manufacturing is to generate a non-linear production possibility frontier PPF. Other approaches, yielding qualitatively similar results, would be to assume decreasing returns to scale in harvesting (Clark 1990). Or, as in Ruseski, to add a non-linearity by assuming that households consider the effect of their own harvesting on steady state stocks (Ruseski's model adopts the somewhat unusual assumption that fishers, though lacking property rights, consider the effect of harvesting on the steady state fish stock and discount future benefits and costs at a zero discount rate). Alternatively, in an earlier version of this paper we show that all the results hold if there are convex harvesting costs. We also show that the results carry over to the case when there are per capita diminishing returns in manufacturing defined as: $[L(1-e)]^{1/2}/L$.

[5] An important issue that we neglect is the trade off between leisure and work (Bryant 1990). For comparison with the related literature we ignore this issue and instead retain the specification most commonly used in the literature (e.g. Brander and Taylor 1997, 1998; Hannesson 2000).

harvesting costs are at their lowest) must be more profitable than working in manufacturing. Otherwise, $E=E'=0$.

Households maximize a Cobb-Douglas utility function with consumption of the resource good *y* and a manufactured commodity *z* as arguments: $u = y^b z^{1-b}$. Defining household income as *I*, household demand for the resource good is given by $y = Ib/p$ and demand for the manufactured commodity is $z=I(1\text{-b})$. Total demand is $Y^d = IbL/p$ and $Z=I(1-b)L$. The definition of household income depends on assumptions with respect to prices and taxes. In the absence of government regulation and assuming diversified production, household income is non-linear in fishing effort and defined as:

(2) $I = pqex + (1-e)^{1/2}$.

The government aims to maximize aggregate domestic welfare, and may influence the allocation of labor by taxing (or subsidizing) an activity. Taxes are returned to households in a lump-sum fashion and subsidies will be financed through lump-sum taxation, τ. We assume the government has a single instrument at its disposal, which is the subsidy (tax) rate for extraction effort of the resource *s*.[6] With intervention, household income is defined as:

(3) $I = pqex + (1-e)^{1/2} + es - \tau$,

where balancing of the government's budget implies $\tau = Es/L$. Hence in a symmetric equilibrium when $e=E/L$, the subsidy (tax) rate cancels in (3). Of course intervention affects the outcome through its effect on the allocation of labor over sectors.

For our modelling purpose we distinguish between two stages. In the first stage, governments decide about taxes and subsidies, taking into account the effects of regulation

[6] While there are cases where trade measures may be preferable from the national government's viewpoint, such policies may conflict with WTO regulation. Resource management can then act as a second-best form of intervention (Ulph 1998).

on domestic and foreign harvesting effort. In the second phase, households decide about the allocation of labor. The model is solved by backward induction.

3. The autarky case

3.1 Second phase: allocation of labor

We start with the autarky case, where prices of the resource and manufactured good are determined domestically. Assuming Cobb-Douglas utility, both goods are essential and therefore produced. Since aggregate demand for the resource good is given by $Y^d = \frac{bIL}{p}$ and aggregate supply equals $H = qEx$, the equilibrium price of the resource good is:

$$(4) \qquad p = \frac{bIL}{qEx}.$$

Substituting (4) into (3), and using $E=Le$ we obtain an expression for household income:

$$(5) \qquad I = \frac{(1-e)^{1/2} + es - \tau}{(1-b)}.$$

We solve for the optimal allocation of labor between the two activities for each household. First, assuming households take prices as given when deciding about the allocation of labor, differentiate (3) with respect to e:

$$(6) \qquad \frac{dI}{de} = pq\frac{k(r - q(E + E'))}{r} - \frac{1}{2(1-e)^{1/2}} + s = 0.$$

Next, eliminate p using (4), and substitute $e=E/L$, in this expression:

$$(7) \qquad \frac{dI}{de} = \frac{bI}{e} - \frac{1}{2(1-e)^{1/2}} + s = 0.$$

This expression may be solved for the equilibrium level of effort $e^*=e(b,s,I)$, and all the comparative statics follow immediately. It is of interest to note that *ceteris paribus* effort is not affected by the size of the stock, x, nor by the size of the foreign fishing fleet, E'. While changes in the stock will directly affect harvested output ($H=qEx$), it leaves effort unaffected. The reason is that fishers are exactly compensated for any change in harvest by an offsetting adjustment in prices. The revenue effects of variations in domestic harvesting are sterilised by domestic price changes—a consequence of the unit elastic specification of demand that follows from Cobb-Douglas preferences. This leads us to our first observation; under autarky, expansion or contraction of the fishery sector at home (abroad) does not affect harvesting effort abroad (at home). In other words, for given policy parameters the harvesters' reaction curves are orthogonal.[7]

Furthermore, for future use we note that by total differentiation of (7) it follows that: $\frac{de}{ds} = -\frac{1}{d^2 I / de^2} > 0$. Thus, as expected, a higher subsidy (lower tax) raises domestic effort and vice-versa.

3.2 First stage: regulating a fishery under autarky

The government chooses the optimal subsidy (tax) to maximize aggregate welfare. The government cares about future benefits and costs and considers the effect of harvesting on the stock. For a stark comparison between myopic households and the 'relatively patient' government, we follow Ruseski's assumption that the government applies a zero discount rate and considers steady state rent. Total welfare is simply:

$$(8) \qquad W = \int_0^H p dv + L(1-e)^{1/2}.$$

The optimal choice of tax rate *s* is now given by the first-order-condition:

[7] The Cobb Douglas utility specification highlights this more general price sterilising effect under autarky. Our qualitative conclusions do not hinge on this assumption and would apply to any demand specification that was not too elastic. The CD assumption allows us to draw a sharp distinction between the strategic effects of trade and harvesting incentives under autarky. When using a more general CES utility function where the elasticity of substitution σ between goods is allowed to take on values other than unity, even starker results can be obtained. For example, when the resource good and manufactures are net complements (i.e., σ<1, such that the cross price effect dominates the income effect) then governments can affect harvesting effort abroad, but the optimal response is *opposite* to that derived by Ruseski. Specifically, the government should confront domestic households with a *higher* tax than would be optimal in the absence of strategic interaction. The reason is that the increment in the wild stock will induce foreign households to allocate labor away from harvesting the common stock (because the price of the resource falls more than proportionally). This will benefit domestic households by lowering harvesting costs.

(9) $$\frac{dW}{ds} = \frac{\partial W}{\partial H}\frac{\partial H}{\partial E}\frac{dE}{ds} + \frac{\partial W}{\partial E}\frac{dE}{ds} = \left(p\frac{dH}{dE} - \frac{L}{2(1-e)^{1/2}} \right)\frac{dE}{ds} = 0\,,$$

where in a steady state: $H = qE\frac{k}{r}(r - q(E+E'))$, and hence $\frac{dH}{dE} = qk(r - 2qE - qE')/r$.

Substituting in (9) and simplifying, the optimal level of regulation is defined by:

(10) $$\frac{dW}{ds} = \left(\frac{bI}{e}(1 - \frac{qE}{r - q(E+E')}) - \frac{L}{2(1-e)^{1/2}} \right)\frac{dE}{ds} = 0$$

This outcome may be compared to the decentralized outcome in (7). To get the optimal value of regulation, a tax s^a must be set such that decentralized effort is reduced by $-\frac{bI}{e}(\frac{qE}{r - q(E+E')}) < 0$. This amounts to internalizing the dynamic externality of harvesting.[8]

Failure to efficiently regulate the fishery (i.e., choosing a sub-optimally low tax rate) implies that steady state income of households declines. Harvesters treat the stock x as exogenous, and in the absence of a sufficiently high tax will choose harvest levels that are too high in the short run and which cannot be supported by replenishment. As the stock falls, so does real income (as the resource price increases) and eventually all households are worse off.

How are domestic policies affected by policy decisions in the rival country? Result 1 below summarises the outcome.

Result 1: *Under autarky harvesting policies are strategic substitutes. That is* $\frac{ds}{ds'} = -\frac{(d^2W/dsdE')(dE'/ds')}{d^2W/ds^2} < 0$.

Proof: See Appendix 1.

[8] This contrasts with Ruseski, who finds that under some conditions the government should subsidize fishing effort. The difference is explained by the fact that myopic fishers in the current model act competitively and not strategically, as in Ruseski's model.

Thus a laxer policy in the rival country induces more stringent controls by the domestic government. The intuition for this result is the following. Weaker controls in the competing jurisdiction lead to higher levels of foreign harvesting and a lower common stock. As a consequence, harvest in the domestic fishery declines *ceteris paribus*. However, since higher domestic prices sterilize the revenue effects of a lower domestic catch, local fishers have no incentive to shift effort into manufacturing (for Cobb Douglas utility). A new equilibrium materializes where fewer fish are caught but where manufactured output is unaffected. If prior to the foreign country lowering its tax, the domestic economy was at an optimum (such that the marginal rate of substitution MRS equaled the marginal rate of transformation MRT), then the new equilibrium cannot be optimal. A fall in the common stock shifts the vertical intercept of the concave production possibility frontier down, affecting the MRT. The new tax is necessary to restore MRS = MRT. The domestic economy again achieves an optimal allocation of labor (albeit at a lower level of equilibrium utility).

With autarky, a strategic game exists between jurisdictions sharing access to a common pool. The nature of this game is consistent with earlier work by Copeland and Ruseski – the domestic policy maker has an incentive to 'undercut' the other because it knows it is in the foreign country's best interest to respond to an expansion of domestic effort by 'accommodating' and restricting foreign effort. In a simultaneous move policy game, each policy maker takes the actions of its rival as given. Each policy maker has an incentive to capture a greater share of the harvest by setting less stringent controls. Since both are identical, a standard Prisoners Dilemma problem arises with a sub-optimal equilibrium – too low taxes and too much effort in the fishery.

How does opening up for trade affect this result?

4. The small open economy case

Next, assume that the countries open up for trade. In this Section we explore the 'small country case' where countries participate in world markets at exogenously given prices. The two countries share access to a common stock, but there are other stocks of the same species (or a perfect substitute) available elsewhere in the world, and the two countries have no influence on market prices.[9] When prices are fixed, the consumer side of the problem (maximizing utility by allocating the budget to consumer goods) is trivial, and we can instead focus on maximizing income.

4.1 Non-cooperative effort in second stage

Households again maximize (3), yielding (6) as the first order condition for harvesting effort. However, now the resource price *p* is a parameter. As noted earlier, the government sets the regulatory parameter, *s*, such that resource stocks are in a steady state *x* $\equiv \frac{k}{r}(r - q(E + E'))$. Thus the first-order-condition for the optimum choice of effort is given by:

$$(11) \qquad \frac{dI}{de} = pq\frac{k(r - q(E + E'))}{r} - \frac{1}{2(1-e)^{1/2}} + s = 0\,.$$

From (11) it follows that effort levels are strategic substitutes with trade: an increase in foreign harvesting effort "drives out" domestic effort, and *vice versa*. To see why note that $\frac{dE}{dE'} = -\frac{dI/dE'}{d^2I/dE^2} = \frac{pq^2k/r}{d^2I/dE^2} < 0$, where by the second-order conditions the denominator is negative. Thus, the harvest reaction functions are downward sloping, and the

[9] An example of a fishing fleet which faces an exogenously determined price is the Southern Blue Fin Tuna which is harvested in the S Pacific by Australian and New Zealand fleets and sold mainly to Japan in competition with tuna harvested from other wild fisheries and farmed tuna from the aquaculture industry (http://www.maff.gov.au/releases/).

equilibrium is unique. The equilibrium is stable because the slopes of the reaction curves are smaller than unity.

This brings us to our next result, akin to findings by Ruseski; with trade (given prices), expansion or contraction of the fishery sector at home (abroad) affects harvesting effort abroad (at home). Foreign effort drives out domestic effort through the effect on the common stock. Harvesting reduces the stock and thereby the catch per unit of effort for all fishermen (or, alternatively, raises the marginal harvesting costs). At the margin, extraction becomes less attractive than manufacturing and some effort will be re-allocated to manufacturing. It is again immediate that higher subsidies (taxes) raise (lower) harvesting effort:

(12) $$\frac{de}{ds} = -\frac{I_{es}}{I_{ee}} = -\frac{1}{I_{ee}} > 0 .$$

Equilibrium effort is also positively affected by higher prices (p) or faster resource growth (k,r), and negatively affected by higher returns to manufacturing. Next, turn to the first stage of the game, where the regulator decides about management.

4.2 First Stage: Government regulation

The government aims to maximize $I = pqex + (1\text{-}e)^{1/2} + se - sE/L$ by choosing s.[10]

(13) $$\frac{dI}{ds} = \frac{\partial I}{\partial e}\frac{de}{ds} + \frac{\partial I}{\partial x}\frac{dx}{ds} - s\frac{de}{ds} = 0$$, or:

(13') $$\frac{dI}{ds} = \left(pqx - \frac{1}{2(1-e)^{1/2}} + s \right)\frac{de}{ds} + pqe\frac{dx}{ds} - s\frac{de}{ds} = 0 .$$

From (11) the term in brackets is zero. Moreover, $\frac{\partial x}{\partial s} = \left(\frac{\partial x}{\partial E} + \frac{\partial x}{\partial E'}\frac{\partial E'}{\partial E} \right)\frac{dE}{ds}$ $= \frac{kq}{r}\left(-1 - \frac{\partial E'}{\partial E} \right)\frac{dE}{ds}$, hence (13') can be expressed as:

[10] In strategic situations like this, price and quantity instruments are non-equivalent as they generate different incentives for fishers (e.g., Laffont and Tirole 2000). The results in this paper will therefore spill over to a case where, say, harvest effort quota are auctioned off to fishers, but not to the case where individual harvest quotas are set by the planner. Exploring such models is left for future work.

$$(14) \qquad \frac{dI}{ds} = (-pq\frac{Ekq}{Lr}(1+\frac{\partial E'}{\partial E}) - \frac{s}{L})\frac{dE}{ds} = 0 .$$

Equation (14) reveals that under free trade the optimal policy always takes the form of a tax on harvesters (as in the autarky case above, subsidizing fishers is never optimal). To see this, note that in (14) for a stable equilibrium we require that $\left|\frac{\partial E'}{\partial E}\right| < |1|$. Therefore $-pq\frac{Ekq}{Lr}(1+\frac{\partial E'}{\partial E})$ < 0. It follows that (14) can only be satisfied (as an equality) if $s < 0$ which implies that a tax is imposed on harvesters.

Turning next to the strategic interaction between policy makers in the two countries, the following result demonstrates that policies are strategic complements with trade.

Result 2: *Under free trade in a small open economy harvesting policies are strategic complements. That is* $\frac{ds}{ds'} = -\frac{(d^2I/dsdE')(dE'/ds')}{d^2I/ds^2} > 0$.

Proof: See Appendix 1.

Opening up for trade therefore changes the qualitative nature of the harvesting game in a small open economy with given prices – the government instruments have switched from being strategic substitutes to strategic complements. The intuition for this result is the following. When the foreign government lowers the effort tax, foreign fishers will respond by increasing harvesting – depleting the common stock. In contrast to the autarky case above this now triggers an outflow of domestic fishing effort because there is no higher price to compensate for the fall in quantities. Labor will spill into manufacturing, where it will lower the marginal (and average) return to labor – a negative externality. To mitigate this effect, the domestic government responds by also lowering the effort tax. The objective is to retain some of the labor in the common pool.

However, such a 'race-to-the-bottom', is but one possible outcome. The reverse may also happen – when one country raises its tax, this good example will be followed by the other. If the initial non-cooperative tax is too low, relative to the global optimum, such a transition implies a move towards the true cooperative optimum.

5. The two-country case

Consider next the two-country model where price is endogenously determined by aggregate demand and harvest. Aggregate demand is the sum of demand in the two countries: $Y^a = \frac{bIL}{p} + \frac{bI'L'}{p}$ and aggregate harvest is: $H^a = xq(E+E')$. Equating these gives an expression for the equilibrium price: $p = \frac{b(IL + I'L')}{xq(E+E')}$. Again we choose the manufacturing price, p^M, to be the numeraire. Households maximise (3), taking price and fish stocks as given, yielding the following first order condition:

(15) $$\frac{dI}{de} = pqx - \frac{1}{(1-e)^{1/2}} + s = 0$$

Consider next the strategic interaction between harvesters. Totally differentiating (15) it follows that $\frac{de}{de'} = -\frac{\partial^2 I/\partial e \partial e'}{\partial^2 I/\partial e^2} < 0$, where $\frac{\partial^2 I}{\partial e \partial e'} < 0$ and the denominator is negative by the second order conditions. In a two-country model the reaction functions are downward sloping.

The strategic interaction amongst harvesters observed in the small country case therefore reappears, but it does so for a different reason than before. An expansion of foreign effort has two distinct effects: a stock effect and a supply effect. First, a higher foreign harvest lowers fish stocks and thereby the harvest per unit of effort. This leads to a compensating increase in prices, such that the total revenue from harvesting is unaffected and fishers are no worse off.[11] In addition, an increase in the foreign harvest raises aggregate supply, which lowers the price of the resource (and thus payoffs of domestic harvesters). Labor is therefore reallocated to manufacturing. Unlike the small country case examined above, strategic interaction arises because of interaction on the output market and not because of interaction through the common resource stock.

First Stage: Government regulation

The government sets regulations to maximize aggregate domestic welfare (the sum of consumers and producers surplus). Define domestic demand as: $R^d = \frac{bIL}{p}$. Welfare in the resource sector is $W^R = \int_0^{R^d} p dv - pR^d + pqeLx$, where the first two terms define domestic consumers' surplus and the final term is sales revenue from harvesting. Welfare in manufacturing is simply: $W^M = L(1-e)^{1/2}$. Total welfare is $W = W^R + W^M$.

The optimal level of regulation is given by the first order condition:

$$\text{(16)} \qquad \frac{dW}{ds} = \frac{\partial W}{\partial E}\frac{dE}{ds} = \left(\frac{\partial W^R}{\partial E} + \frac{\partial W^R}{\partial E'}\frac{dE'}{dE} + \frac{\partial W^M}{\partial E}\right)\frac{dE}{ds} = 0.$$

The following result summarizes the impact on domestic policies of changes in policies in the foreign country.

Result 3: *In a two-country model with a common resource stock harvesting policies are strategic substitutes. That is* $\frac{ds}{ds'} < 0$.

Proof: See Appendix 1.

The two-country model represents an intermediate case between autarky and the small open economy. As with the small open economy case, domestic and foreign fishing effort are strategic substitutes, and expansion of foreign effort drives some of the domestic

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[11] Formally, substitute $p=b(IL+I'L')[xq(E+E')]^{-1}$ into (15). Terms with q and x cancel, such that resource

effort from harvesting to manufacturing. However, the magnitude of this outflow is not sufficiently large compared to the socially optimal outcome. Domestic fishers suffer from a fall in prices triggered by an expansion of foreign effort, but are fully compensated for their fall in productivity by an offsetting increase in prices (as under autarky). With the incentive to lower domestic effort in response to lower fish stocks negated by a price increase, more stringent government controls on harvesting are required to correct for the stock externality. Hence, as with the autarky case, in a two-country model regulatory policies are strategic substitutes.

5. Conclusion and discussion

We have developed a model that combines a simple general equilibrium model with a strategic trade model. Domestic and foreign households have free access to a common resource stock and maximize short-term payoffs, but are regulated by patient and forward-looking planners. Our foremost result is that the potential impact of trade on welfare goes beyond simply changing the relative price *level* – the nature of strategic interaction also depends on how prices are determined.

Countries may potentially interact through a common input (the shared resource stock) and the output market for commodities. Various combinations are possible. While countries will always affect each other's welfare through the common stock, private parties will ignore these interactions if quantity effects are compensated by price adjustments (this happens under autarky and in the two-country model). In contrast, interactions through the output market are ruled out under autarky (by definition) and for small open economies (where prices are fixed). The nature of interaction determines the nature of the strategic game that unfolds between policy makers.

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stocks and harvesting productivity have no impact on effort, since they lead to offsetting price changes.

When small countries move from autarky to trade, taking prices as given, the slopes of the reaction curves change: (*i*) from orthogonal to downward sloping for harvesting effort; and (*ii*) from downward sloping to upward sloping for regulatory policies. By 'fixing' prices, trade changes the rules of the game. In contrast, in a two-country model the slope of the harvesting effort reaction curve changes (from orthogonal to downward sloping due to a direct price effect), but the nature of the game between policy makers is unaffected, compared to autarky, as the sterilizing impact of price adjustments in response to productivity shocks remains. These results are summarized in Table 1.

Table 1: Overview of the main results

	Autarky	**Small open economies**	**Two country model**
Fishers' response	No interaction	Strategic substitutes (through stock)	Strategic substitutes (through price)
Planners' response	Strategic substitutes	Strategic complements	Strategic substitutes

One observation relevant for policy-making stands out: Controlling over-extraction of shared resources may be easier under trade with exogenous prices than under autarky (or under conditions where prices are endogenous under trade). Temporary intervention by an external agency such as the World Bank or FAO could change the nature of the game between competing jurisdictions, and trigger permanent gains in welfare. With small open economies it only takes one country to trigger a race to the top with trade, whereas conservationist efforts by one jurisdiction are penalized by extra harvesting in the other country under autarky (or in a two-country model).

An important question concerns the impact of trade liberalization on welfare. In a second best context this impact is generally ambiguous. Removing barriers to trade can exacerbate the pre-existing distortion (over-extraction due to open access) and make countries worse off. Using a model with linear technologies, Brander and Taylor (1997) demonstrate that trade lowers steady state welfare for “resource abundant” countries.[12] Countries are defined as “resource-abundant” when the resource price rises after opening up for trade. Resource scarce countries (where resource prices fall after opening up for trade), in contrast, experience a gain in utility – the pre-existing distortion in such economies is mitigated rather than enhanced. Hannesson (2000) extended the Brander and Taylor model by allowing for decreasing returns to scale in manufacturing. Then trade might *raise* steady state welfare in *resource abundant* countries. The expansion of effort in the common pool increases the return to labor in manufacturing which constitutes an offsetting external effect. The shared common pool model developed above further extends the welfare results by Brander and Taylor. Specifically, it suggests that opening up for trade can *lower* welfare in *resource scarce* countries.

Consider the case of small open economies. If trade results in a regulatory race to the bottom such that the effort tax is lower than the autarky effort tax (which varies with preference parameter *b*), then opening up for trade implies a move away further from the cooperative outcome (as non-cooperative autarky taxes are set at a level that is too low relative to the cooperative benchmark). This will reduce welfare. Consider the special case where opening up for trade does not ‘really’ change the resource price, but where countries can still (albeit barely) be identified as resource scarce: $p_{aut} = p_{trade} + \varepsilon$, where $\varepsilon > 0$. In the absence of terms of trade effects, trade liberalization has no effects in the Brander and Taylor or Hannesson model. But the current model is different; it predicts that a race to the top or bottom will result. The resource scarce country will therefore gain or lose, depending on the dynamics that unfold.

[12] More accurately: trade lowers steady state welfare when production is diversified in equilibrium, such that labor is allocated to both harvesting and manufacturing. When the steady state economy is specialized in harvesting the welfare impact is ambiguous.

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Appendix 1: Proofs of results

1) Proof of result 1.

By differentiation of (10):

$$W_{sE'} \equiv \frac{d^2W}{dsdE'} = \left(-\frac{bIq^2E}{e(r-q(E+E'))^2}\right)\frac{dE}{ds}$$

Note $\left(-\frac{bIq^2E}{e(r-q(E+E'))^2}\right)\frac{dE}{ds} < 0$ since $\frac{dE}{ds} > 0$.

Thus by total differentiation:

$$\frac{ds}{ds'} = -\frac{(d^2W/dsdE')(dE'/ds')}{d^2W/ds^2} < 0 .$$

The sign follows since by the SOCs the denominator is assumed negative. *Q.E.D.*

2) Proof of result 2:

The SOCs for (14) imply that the denominator is negative. Differentiating (14)

$$\frac{d^2I}{dsdE'} \equiv I_{sE'} = \left(\frac{-pq^2k}{rL}(1+\frac{dE'}{dE})\frac{dE}{dE'}\right)\frac{dE}{ds} > 0 .$$

The sign follows from the fact that:
$-\frac{pq^2k}{rL}(1+\frac{dE'}{dE}) < 0$ and that $\frac{dE}{dE'} < 0$.
Further, by (12), *dE/ds* > 0. When both countries are symmetric then by the above reasoning we have *dE'/ds'* > 0. Thus:

$$\frac{ds}{ds'} = -\frac{(d^2I/dsdE')(dE'/ds')}{d^2I/ds^2} > 0 \qquad \textit{Q.E.D.}$$

3) Proof of result 3:

Totally differentiating (16):

$$\frac{ds}{ds'} = -\frac{\frac{d^2W}{dEdE'}\overset{+}{\frac{dE'}{ds'}}}{\underset{-}{\frac{d^2W}{\partial E^2}}} < 0 ,$$

where by the second order condition the denominator is negative and by total differentiation of (15) $\frac{dE'}{ds'} > 0$. It therefore remains to determine the sign of:

$$\frac{d^2W}{dEdE'} = \frac{\partial^2 W^R}{\partial E \partial E'} + \frac{\partial^2 W^R}{\partial E'^2}\frac{dE'}{dE} + \frac{\partial W^M}{\partial E \partial E'}\frac{dE'}{dE}.$$

Note that $\frac{\partial W^M}{\partial eE\partial E'} = 0$. Expanding terms in (15):

$$\frac{\partial W^R}{\partial E} = \int_0^{R^d} \frac{\partial p}{\partial E} dv + p\frac{\partial R^d}{\partial E} - \frac{\partial p}{\partial E} R^d - p\frac{\partial R^d}{\partial E} + \frac{\partial p}{\partial E} H^d + p\frac{\partial H^d}{\partial E}$$

where $H^d = qEx$ is the domestic harvest.

Upon further differentiation:

$$\frac{\partial^2 W^R}{\partial E \partial E'} = \int_0^{R^d} \frac{\partial^2 p}{\partial E \partial E'} dv - \frac{\partial^2 p}{\partial E \partial E'} R^d - \frac{\partial p}{\partial E}\left(\frac{\partial p}{\partial E'}\frac{\partial R^d}{\partial p} + \frac{\partial R^d}{\partial I}\frac{\partial I}{\partial E'}\right) - \frac{\partial p}{\partial E'}\frac{\partial p}{\partial E}\frac{\partial R^d}{\partial p}$$
$$+ \frac{\partial^2 p}{\partial E \partial E'} H^d + \frac{\partial p}{\partial E}\frac{\partial H^d}{\partial E'} + \frac{\partial p}{\partial E'}\frac{\partial H^d}{\partial E} + p\frac{\partial^2 H^d}{\partial E \partial E'} \qquad \text{(I)}$$

where we have used the result that $dI/de = 0$ by the first order condition.
Further differentiate W^R:

$$\frac{\partial^2 W^R}{\partial E'^2} = \int_0^{R^d} \frac{\partial^2 p}{\partial E'^2} - \frac{\partial^2 p}{\partial E'^2} R^d - 2\frac{\partial p}{\partial E'}\frac{\partial p}{\partial E'}\frac{\partial R^d}{\partial P} + \frac{\partial^2 p}{\partial E \partial E'} H^d + 2\frac{\partial p}{\partial E'}\frac{\partial H^d}{\partial E'} \qquad \text{(II)}$$

Comparing (I) and (II) when the countries are symmetric such that: $\frac{\partial p}{\partial e} = \frac{\partial p}{\partial e'}$:

$$\frac{\partial^2 W^R}{\partial E \partial E'} - \frac{\partial^2 W^R}{\partial E'^2} = -\underbrace{\frac{\partial p}{\partial E'}}_{-}\underbrace{\frac{\partial R}{\partial I}}_{+}\underbrace{\frac{\partial I}{\partial E'}}_{-} + \underbrace{\frac{\partial p}{\partial E}}_{-}\underbrace{\left(\frac{\partial H^d}{\partial E} - \frac{\partial H^d}{\partial E'}\right)}_{+} + p\underbrace{\frac{\partial^2 H^d}{\partial E \partial E'}}_{-} < 0 .$$

Moreover $\frac{dE'}{dE} < 0$ and $\left|\frac{dE'}{dE}\right| < |1|$. Hence,

$$\frac{d^2W}{dEdE'} = \frac{\partial^2 W^R}{\partial E \partial E'} + \frac{\partial^2 W^R}{\partial E'^2}\frac{dE'}{dE} < 0.$$

Thus it follows that:

$$\frac{ds}{ds'} = -\frac{\overset{-}{\frac{d^2W}{dEdE'}}\overset{+}{\frac{dE'}{ds'}}}{\underset{-}{\frac{d^2W}{\partial E^2}}} < 0 \qquad \textit{Q.E.D.}$$