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TRADE IN THE GREENHOUSE: EFFICIENT POLICY IN A GLOBAL MODEL

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ABSTRACT

The impact of environmental Kuznets curve (EKC) effects is evaluated in the context of a full model of production and trade within and between rich and poor economies. The shape of iso-emissions curves, defined in tariff and emissions tax space, is evaluated both in the presence and in the absence of an EKC. Gains in the income of developing countries are possible without compromising on emissions where there are inefficiencies in policy. However, where policy is efficient there exists an important trade-off, evaluated here, between emissions and developing country income.

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1. Introduction

The impact of increased international trade on the environment has continued to be a matter of some controversy (Copeland and Taylor, 2004). Early work by Perroni and Wigle (1994), using a computable general equilibrium (CGE) approach, suggested that the detrimental impact of trade on emissions is small. Antweiler *et al.* (2001), using a model capable of analytical solution, also find a small effect, suggesting that free trade is beneficial to the environment. This work did not, however, accommodate an important empirical regularity between pollution and *per capita* incomes – the so-called environmental Kuznets curve (EKC)[1]. Research which focuses on this regularity, albeit in a somewhat *ad hoc* manner, reverses the main conclusion of the earlier work (see, for example, Cole and Elliott, 2003), and suggests that the negative environmental impact of trade is non-negligible. Various other contributions to this literature are usefully surveyed by Ekins (2003).

The aim of the present note is to evaluate the impact of the EKC when it is placed in the context of a full model of the economy. We study the effect of trade on pollution when the regularity is switched on or off, and we evaluate the extent to which changes in green taxes can compensate for tariff reduction both in the presence and absence of the empirical regularity. Finally we investigate whether there is (and, if there is, the nature of) a trade-off between the environment and economic development under various policy assumptions.

2. Model

Consider a model in which two final goods, i=1,2, are produced in each of two countries, j=1,2. The production function for good i in country j is given by

$$Y_{ij} = A_{ij}L_{ij}^{\alpha_{ij}} \tag{1}$$

$\forall$i,j, where L_{ij} is the labour supplied to firm (or, we suppose synonymously, industry) i in country j. Differences in the parameters of this equation allow *per capita* incomes to differ across the two countries.

Consumers enjoy income that is made up of earnings and a *per capita* transfer from the government such that, in country j,

$$Y_j = \sum_i w_{ij}L_{ij} + \tau_j L_j \tag{2}$$

[1] The tendency for pollution to increase with *per capita* income up to a point, and then to decline, was dubbed the environmental Kuznets curve by Grossman and Krueger (1993), following the work by Kuznets (1955) on the relationship between *per capita* income and income inequality. For a thorough discussion of the EKC, see Dasgupta *et al.* (2002). The EKC literature has been criticised by Stern (2003) who argues that there is considerable imprecision in the estimates of the turning point of the curve, with some estimates suggesting that the turning point exceeds *per capita* income even in the most developed economies; moreover he points to the poor diagnostics attached to many estimates of the curve. The Antweiler *et al.* and Perroni and Wigle papers assume a relationship between pollution and income, but importantly do not model this as a nonmonotonic function. As a consequence it may be argued that these studies provide downwardly biased estimates of the impact of trade on emissions.

$\forall$j, where w_{ij} is the wage in industry i in country j, τ_j is the government transfer in country j, and L_j is the labour force in country j.

Total demand for each good in each country is determined by country-specific income and price, such that

$$Q_{ij} = \phi_{ij} Y_j - \xi_{ij}(1+p_{ij}) + M_{ij} \quad (3)$$

$\forall$i,j, where p_{ij} is the production price of the ith good in country j.

Imports to j from k are determined by

$$M_{ij} = \varphi_{ij} Y_j - \kappa_{ij}[(1+p_{ik})(1+t_j)]^{\sigma} \quad (4)$$

$\forall$i,j,k, k$\neq$j, where t_j represents the tariff rate set in country j. Trade is therefore determined by a mechanism similar to a simple Armington (1969) structure, with imperfect substitutability between domestically produced and foreign produced goods.

We suppose that the total supply of labour in each country is given and that the equilibrium involves no unemployment, such that

$$\sum_i L_{ij} = L_j, \forall j. \quad (5)$$

Labour supply to each sector within each country is determined by relative wages; hence the inverse labour supply function may be expressed as

$$w_{2j} = \theta w_{1j} L_{2j} / L_{1j} \quad (6)$$

The size of government transfer in each country is defined by the country's tax yield. This is given by

$$\tau_j = [t_j \sum_i p_{ik} M_{ij} + e_j \sum_i E_{ij}] / L_j \quad (7)$$

$\forall$j, k$\neq$j, where e_j is the tax rate on emissions in country j, and E_{ij} is the level of emissions by industry i in country j.

Emissions by industry i in country j are given by

$$E_{ij} = \rho + (\zeta + \gamma c_j) Y_{ij} - \omega e \quad (8)$$

$\forall$i,j, where c_j is a country-specific abatement cost which is specifically defined by

$$c_j = c + \lambda(Y_j/L_j) - \mu(Y_j/L_j)^2 \quad (9)$$

If $\lambda=\mu=0$ then EKC effects are absent. These parameters are therefore of key interest in the context of the present paper; switching them on and off allows the importance of the EKC to be evaluated.

We assume further that a zero profit condition applies in each industry in each country, such that

$$p_{ij}Y_{ij} = w_{ij}L_{ij} + e_jE_{ij} + c_j(\omega e-\gamma c_jY_{ij}) \quad (10)$$

$\forall i,j$. This equation says that revenues equal the sum of all costs faced by the firm, namely wage costs, emissions taxes, and costs of abatement (where we suppose the amount of abatement activity rises with the level of environmental taxes but falls with the cost of abatement).

Finally we assume that for each good in each country, output equals global demand

$$Y_{ij} = Q_{ij} + M_{ik} - M_{ij} \quad (11)$$

$\forall i,j,k,\ k\neq j$. For simplicity we suppose that both countries use the same currency, and so there is no need to model the exchange rate.

It is also convenient to assume that $e_j=e$ and $t_j=t\ \forall j$. It is then possible, assuming values for the remaining parameters of the model, to evaluate the set of pairings of e and t that define an iso-emissions curve. If we picture such a curve drawn in two dimensional space with e on the vertical axis and t on the horizontal axis, the work of Perroni and Wigle (1994) suggests that the iso-emissions curve is rather flat while that of Cole and Elliott (2003) suggests that it is relatively steep. The merit of our model is that we can evaluate the shape of the iso-emissions curve under a variety of assumptions about the EKC. We therefore solve the model for two separate closures: one with the EKC switched off ($c=0.05$; $\lambda=0$; $\mu=0$) and the other with the EKC switched on ($c=0.05$; $\lambda=0.5$; $\mu=1.25$).

3. Results

Reasonable values are assumed for the remaining parameters, supposing the two ‘countries’ to represent the developed economies and developing economies respectively, and the two ‘industries’ to represent respectively the production and service sectors. The specific values of the parameters are given in Table 1.

We initially adopt the following values for the tax parameters: $t=0.1$ and $e=0.1$. Solving for the model[2], initially with the EKC switched off, yields values of all the key variables in the solution that are in line with the stylised facts. For instance, output and employment are concentrated in services and production respectively in the developed and developing economies. Wages in the developed economy are an order of magnitude higher than those in the developing economy. The full results are reported in Table 2.

[2] This has been done using (i) both the Euler solution routine and the homotopy method in GEMPACK, and (ii) the NAG routine c05nbf in FORTRAN.

Starting from this solution, we ask two questions, again initially with the EKC switched off. First, if t were to fall to zero, *ceteris paribus*, by what percentage would global emissions, $\sum_i \sum_j E_{ij}$, rise? The answer is 0.7%. This in effect defines the shape of the iso-emissions curve in (t,e) space. Secondly, if t were to fall to zero, by how much would e need to change in order to keep global emissions at, at most, the same level as before? The answer is that e would need to rise to 0.113.

Consider now the model where EKC is switched on, assuming the same starting values as before for t and e. If t were to fall to zero, in the absence of any other changes to parameters, global emissions would rise by 0.8%; this follows from the fact that developing countries have *per capita* incomes that lie below the turning point of the EKC. In the model with EKC switched on, if, as t falls to zero, e is also permitted to vary, then keeping global emissions unchanged would imply raising e to 0.135. These findings accord with intuition in that, *ceteris paribus*, the impact of tariff removal on either (i) emissions or (ii) the hike in environmental taxes needed to prevent increased emissions is greater when an EKC exists than is the case when emissions do not vary with *per capita* incomes in each group of countries.

A further key question for those interested in trade and the environment is whether it is possible to increase incomes in developing countries while ensuring no increase in global emissions. An important relationship can be identified as an efficiency frontier that shows combinations of $\sum_i \sum_j E_{ij}$ and Y_2 for which it would be impossible to reduce the former without also reducing the latter by way of changes in e and t. This trade-off is illustrated, for the range of Y_2 which can be affected by e and t, by the upward sloping curves in Figures 1 and 2, respectively for the EKC-off and EKC-on cases. If the current equilibrium is one in which the pairing of global emissions and developing country income is above and to the left of this trade-off, then it is possible to adjust e and t to secure improvement in either or both of these important policy objectives. An interesting feature of this trade-off is seen by comparing the results in Figures 1 and 2. When the EKC is off, the slope of the trade-off becomes flatter as developing country income increases. When the EKC is on, however, the trade-off initially becomes steeper, then becomes flatter.

4. Conclusion

In any model of this type, much inevitably depends on the assumed values of the parameters. Even the qualitative results of studies of this type may be sensitive to the precise assumptions made. This makes the traditional call for further research especially pertinent.

That said, as emphasised earlier, the predictions of this model are in line with the stylised facts. This being so, the findings reported above carry some implications that we deem to be particularly noteworthy. If we accept that an environmental Kuznets curve exists, then we should accept also that trade can have an impact on the environment that is greater than is suggested by models which do not embody a realistic EKC. This is not to suggest that the EKC is fixed by some immutable law –

Dasgupta *et al*. (2002) have argued convincingly that it is likely to flatten out over time. But it would involve an heroic assumption to suggest that it is already absent.

The parameters that define the EKC are also of importance in determining the shape of the iso-emissions curve. The results of studies that do not accommodate EKC effects within a CGE model should therefore be treated with a large measure of caution. Finally, the policy trade-off identified above renders possible an assessment of the extent to which trade and environmental policies serve to ensure that goals related to green issues and poverty are realised.

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Table 1 Parameter values

A_{11}	4	A_{12}	1	A_{21}	4	A_{22}	1
α_{11}	0.8	α_{12}	0.7	α_{21}	0.9	α_{22}	0.5
ϕ_{11}	7	ϕ_{12}	7	ϕ_{21}	8	ϕ_{22}	3
φ_{11}	3	φ_{12}	1	φ_{21}	5	φ_{22}	2
ξ_{11}	0.02	ξ_{12}	0.01	ξ_{21}	0.01	ξ_{22}	0.01
κ_{11}	0.05	κ_{12}	0.05	κ_{21}	0.02	κ_{22}	0.05
σ	0.1	L_1	0.5	L_2	2.5	ρ	-1
θ	1	ζ	1	γ	0.1	ω	0.1

Table 2 Results for the EKC-off tariff-on case

Y_{11}	1.095	Y_{21}	1.361	Y_{12}	1.204	Y_{22}	1.094
L_{11}	0.198	L_{21}	0.302	L_{12}	1.303	L_{22}	1.197
Y_1	0.156	Y_2	0.122	w_{11}	0.160	w_{21}	0.244
w_{12}	0.038	w_{22}	0.035	τ_1	0.101	τ_2	0.012
Q_{11}	1.431	Q_{21}	1.975	Q_{12}	0.868	Q_{22}	0.481
M_{11}	0.361	M_{21}	0.739	M_{12}	0.025	M_{22}	0.125
p_{11}	0.038	p_{21}	0.081	p_{12}	0.058	p_{22}	0.047
E_{11}	0.091	E_{21}	0.358	E_{12}	0.200	E_{22}	0.090

Figure 1 The policy trade-off

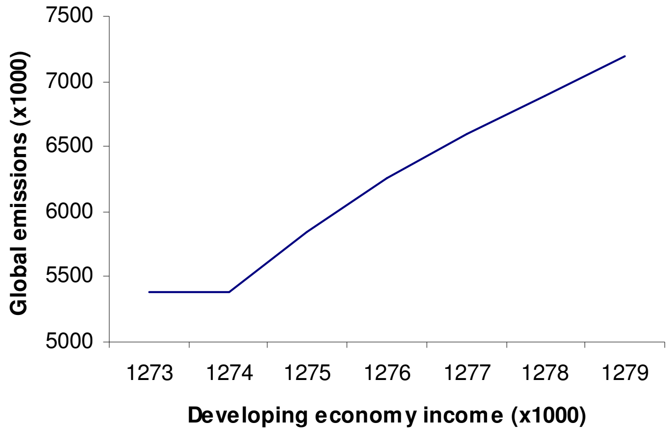

Figure 2 The policy trade-off, with EKC