Price of Oil, Capital Mobility and Oil Importers: A General Equilibrium Macro Analysis.

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Abstract

A three-region, three-commodity general equilibrium model is constructed to explore the impact of OPEC's pricing policies on major macro variables of importer economies.

The aim of this paper is to explore the general macro characteristics of the trading economies that can help us understand the world economy response afer OPEC I and OPEC II in terms of the evolution of the North-South terms of trade, rates of profit and output levels. Therefore, we support the view of the world economy in a three regions setting, North-South-OPEC.

The paper gives conditions for alternative outcomes from moves towards world equilibria with higher oil prices, thus highlighting the crucial parameters in determining the comparative static results: technological dualism between North and South, supply elasticities and patterns of demand across regions. If capital is inmobile across regions, and under plausible assumptions, at the new equilibrium the Southern terms of trade vis-à-vis the North will deteriorate and the rates of profit in the North and the South will drop, thus leading to a fall in the levels of activity in the two regions. This seems a good description of the aftermath of the world economy after OPEC II. Under a regime of perfect capital mobility and equalization of the rates of profit across regions, the model is capable of generating, under plausible assumptions, an improvement of the North-South term of trade and a decline in the world rate profit, the level of activity in the North decreases whereas the South may maintain or even raise it. This seems to represent a better description of the aftermath of OPEC I.

In general, the analysis increases our understanding of why regions respond differently to the same external shock and how from different regimes of capital mobility we should derive alternative policy implications. With the current fall in oil prices, the topic promises to be relevant for some time, although the direction of the shocks has been reserved.

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OIL PRICES, CAPITAL MOBILITY AND OIL IMPORTERS: A GENERAL EQUILIBRIUM MACRO ANALYSIS

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1. INTRODUCTION

The increasing interdependence between regional economies is an stylized fact of the world economy during the last two decades. The Global Interaction in the international economy takes place, at present, mainly through trade channels and capital flows. The North-South debate has promoted a rapidly-progressing literature in this area. Findlay (1980), Chichilnisky (1981a,1981b) and Taylor (1981) examine alternative models of the world economy where regions are linked through trade; Burgstaller and Saavedro-Rivano (1984) and Burgstaller (1985) extend further the degree of interdependence in the international economy by incorporating capital flows from the North to the South. A critical issue analyzed in all these articles is the North-South terms of trade endogenous behaviour. However, it has been pointed out that, at the present level of global interaction, a two-region classification is perhaps too coarse to capture some basic questions of interest, see Bhagwati (1984), González-Romero (1985) and Kanbur and McIntosh (1986). Specifically, Taylor (1981), Adams and Marquez (1983), and González-Romero and Kanbur (1985) call for a finer level of disaggregation at the world level in order to investigate the crucial role of the oil inputs in the world economy during the last decade.

Here, we examine a neoclassical world economy where markets are competitive throughout the world. Since the two most important factors in altering the patterns of interdependence has been the very substantial growth of world trade and the recent enormous expansion of capital flows, we will focus on two alternative models: the model of section 2 only allows for goods flows; whereas the model of section 3 also incorporates perfect capital mobility across regions. Consequently, we will be able to detect how the responses of the critical variables assuming a world of capital mobility differ from those when we assume a world of perfect capital mobility when the world economy moves towards world equilibria with higher oil prices. With the current fall in oil prices, the topic promises to be relevant for some tine, although the direction of the shocks has been reversed.

The plan of the paper is as follows: Section 2 presents a neoclassical three-region model with capital inmobility, each oil importing region produces a commodity which is different with respect to input requirements, this is where the asymetry between the two region stops. Despite the complex web of effects arising in the intersectoral analysis when the oil price changes, the endogenous variables of the system are seen to depend on different asymetries between oil importers (Tables 1 and 2). In Section 3, the precise model of Section 2 incorporates perfect capital mobility, the oil price shock impact is now seen to depend crucially upon the type of technological dualism across regions (Tables 3 and 4). Section 4 concludes the paper.

2. A Neoclassical model with capital inmobility

Let us assume that all three regions are each specialized in their production activities. Consequently, the North is specialized in an industrial (luxury-investment) commodity, "steel", the South in a primary product, "corn", and OPEC specializes in oil production. Technology is linear in the North and also in the South. Two inputs are required in production, capital and oil; we assume no labour for greater simplicity. a_{KI} (a_{KA}) and a_{RI} (a_{RA}) will denote the capital-output and oil-output coefficients required to produce one unit of Northern (Southern) output. Profit-maximizing behaviour of Northern and Southern firms under perfect competition and constant returns to scale will yield competitive prices which are set at the level of unit cost:

$$P_I = a_{RI} P_R + a_{KI} r_I P_I \quad (1)$$

$$P_A = a_{RA} P_R + a_{KA} r_A P_I \quad (2)$$

where P_I , P_A and P_R denote the prices of steel, corn and oil, respectively; r_I and r_A are the rates of profit in the North and South respectively and, $r_I P_I (r_A P_I)$ is the user's cost of capital in the North (South).

Factor demand Functions will then be linear functions of the level of output in each region. We further assume that the capital supply in the two regions is an increasing function of its own rate of profit (see, Chichilnisky (1980,1981) and Heal (1984)).

$$K_I = \beta_0 (r_I)^{\beta_1} \quad (3)$$

$$K_A = \gamma_0 (r_A)^{\gamma_1} \quad (4)$$

where $\beta_1 (\gamma_1)$ designates the constant capital supply elasticity in the North (South). The justification to this assumption is to interpret K_i , $i = I,A$, as a flow of capital services from a given stock of capital, and where profit-maximizing capitalists will supply capital services from its stock up to when the marginal revenue becomes equal to the marginal cost due to the depreciation[1].

Firstly, we examine a model where interregional capital inmobility holds. Hence, since all markets are competitive, we have an equilibrium condition for each separate market for capital services in the North and South. Thus:

$$K_I = a_{KI} \cdot Q_I \quad (5)$$

$$K_A = a_{KA} \cdot Q_A \quad (6)$$

where $Q_I (Q_A)$ is the steel (corn) output level in the North (South).

We now draw attention to the demand side of the two regions. We assume that the pattern of preferences of Northern (Southern) agents leads to a proportional expenditure system, where a fraction $\alpha_I (\alpha_A)$ of expenditure goes on corn whereas the rest $1 - \alpha_I (1 - \alpha_A)$ goes on steel; similarly, OPEC's oil revenue is assumed to be entirely devoted to the consumption of corn and steel in proportions α_R and $1 - \alpha_R$, respectively. We also assume that oil extraction costs are negligible; the introduction of such costs would be a routine exercise that would not illuminate the analysis futher.

Free trade is assumed, hence the "law of one price" will hold. In consequence, the world markets equilibrium conditions for steel, corn and oil are:

$$Q_I = r_I a_{KI} Q_I (1 - \alpha_I) + r_A a_{KA} Q_A (1 - \alpha_A) + \frac{P_R}{P_I} Q_R (1 - \alpha_R) \qquad (7)$$

$$Q_A = r_I \frac{P_I}{P_A} a_{KI} Q_I \alpha_I + r_A \frac{P_I}{P_A} a_{KA} Q_A \alpha_A + \frac{P_R}{P_A} Q_R \alpha_R \qquad (8)$$

$$Q_R = a_{RI} Q_I + a_{RA} Q_A \qquad (9)$$

where Q_R designates OPEC's oil supplies which, according to (9), adjusts instantaneously to any given level of world demand for oil.

To summarise, the equations (1)-(9) represent our three region model of global interaction. The endogenous variables of the model are: P_I , P_R , P_A , r_I , r_A , K_I , K_A , Q_I , Q_A and Q_R ; the model's exogenous variables are the technical coefficients $(a_{KI}$, a_{KA} , a_{RI} , $a_{RA})$ and the parameters

β_0 , β_1 , γ_0 and γ_1, denoting the responses of domestic factor supplies to prices.

When all markets are in equilibrium, Walras' Law is always satisfied; thus only eight of the nine equations in the model are linearly independent. Moreover, the simultaneous equation system is homogeneous of degree zero in prices, therefore the number of price variables may be reduced by normalization, i.e. $P_I = 1$. In sum, we focus on P_A , r_I , r_A , K_I , K_A , Q_I , Q_A and Q_R as endogenous variables and trace out this behaviour for different exogenously fixed values of P_R [2]. The assumption, then, is that OPEC sets the price and supplies whatever is demanded.

We first solve the model to look for the properties of the equilibrium: existance, uniqueness and stability. Substituting for Q_R from (9), for r_I and r_A from (1) and (2), for K_I and K_A from (3) and (4), and for Q_I and Q_A from (5) and (6), all into (8), we obtain the model's resolving equation in P_I , P_A and P_R .

$$\frac{\beta_0 \left(\dfrac{P_I - a_{RI} P_R}{a_{KI}} \right)^{\beta_1}}{\gamma_0 \left(\dfrac{P_A - a_{RA} P_R}{a_{KA}} \right)^{\gamma_1}} = \frac{P_A (1-\alpha_A) + a_{KA} P_R (\alpha_A - \alpha_R)}{P_I \alpha_I + a_{RI} P_R (\alpha_R - \alpha_I)} \qquad (10)$$

Given the normalization $P_I = 1$, and given P_R exogenously, equation (10) solves for P_A uniquely. Thus, notice that taking logarithms of both sides of (10) and differentiating with respect to P_A , the left-hand side (LHS) is monotonic decreasing in P_A from infinite, whereas the right-hand side (RHS) is monotonic increasing in P_A ; therefore, there will always exist an intersection point for a unique value of $P_A > 0$ at which both sides attain identical values[3]. Given the equilibrium solution for P_A, from equations (1) and (2) we then obtain the equilibrium values for r_I and r_A; from (3) and (4) K_I and K_A; from (5) and (6) Q_I and Q_A, and from (9), Q_R. This completes the computation of a general equilibrium of the North-South-OPEC model.

Let us now explore the comparative stetic properties of the model when the world economy shifts to a new equilibrium with a higher oil price[4]. We can first examine the impact on the North-South terms of trade P_A; differentiating (10) with respect to P_R, we obtain:

$$\frac{dp_A}{dp_R}\left[\frac{\gamma_1}{P_A - a_{RA}P_R} + \frac{(1-\alpha_A)}{P_A(1-\alpha_A) + a_{RA}P_R(\alpha_A-\alpha_R)}\right] =$$

$$= \frac{\gamma_1\ a_{RA}}{P_A - a_{RA}P_R} - \frac{\beta_1\ a_{RI}}{1 - a_{RI}P_R} + \frac{a_{RI}(\alpha_R-\alpha_I)}{\alpha_I + a_{RI}P_R(\alpha_R-\alpha_I)} -$$

$$- \frac{a_{RA}(\alpha_A-\alpha_R)}{P_A(1-\alpha_A) + a_{RA}P_R(\alpha_A-\alpha_R)} \qquad (11)$$

An interpretation of (11) can be provided by noting that, first, the term in square brackets on the LHS of (11) denotes the walrasian stability properties of the model, see Appendix 1. Secondly, the RHS of (11) indicates the changes in supply and demands for corn as long as the price of corn remains unchanged, see Appendix 2.

Notice that the term in square brackets on the LHS of (11) is always positive. Hence the sign of the derivative dp_A/dp_R will depend enterely upon the RHS of (11). Firstly, we make the simplest assumptions: we assume that patterns of preference are identical across regions and hence so will their spending behaviours. We then obtain the following proposition: whenever $\alpha_A = \alpha_R = \alpha_I$

$$\text{if} \quad -a_{RI}\, a_{KA} \left(\frac{\beta_1 \; r_A}{\gamma_1 \; r_I} - 1 \right) + D < 0 \quad \text{then} \quad \frac{dp_A}{dp_R} < 0 \tag{12}$$

where D is the matrix of technical coefficients,
$D = a_{RA}\, a_{KI} - a_{KA}\, a_{RI}$.

To get futher insight and sharper results, let us make the two following assumptions. First, the rate of profit in the North is lower than in the South, so that if capital is free to move it will flow from the North to the South, see for instance, Burgstaller and Saavedra-Rivano (1984) and Findlay (1984)[5].

Secondly, the supply of capital is at least as responsive to changes in the rate of profit in the North as in the South, see for instance Chichilnisky (1981b); and extreme case of this assumption is the special case where the capital supply in the South is fixed, i.e. $\gamma_1 = 0$; the reasons behind this assumption may lie either in an overall low state of confidence in the functioning of the Southern economy, i.e. "bad news" as Taylor (1985) refers to it, or in a poor functioning and inefficient organization of the Southern capital markets.

Therefore, we conclude $\beta_1\, r_I \geqq \gamma_1\, r_A$. In consequence, from the proposition (12), we get to:

$$\begin{aligned} &\text{if} \quad D \leqq 0 \qquad \text{then} \quad \frac{dp_A}{dp_R} < 0 \\ &\text{if} \quad D > 0 \qquad \text{then} \quad \frac{dp_A}{dp_R} \lesseqgtr 0 \end{aligned} \tag{13}$$

Thus, we obtain that the impact of an oil shock on the North-South terms of trade depends crucially upon the matrix D , the matrix D being a measure of technological dualism in the production activities of the North and South. If Northern commodities are more energy intensive than Southern commodities

$(D < 0)$, then an increase in the world price of oil will lead unambiguously to a deterioration of the Southern terms of trade. In contrast, technological dualism of the type $D > 0$ is seen to favour an improvement of the Southern terms of trade.

To see the intuition behind this, let us keep relative prices, P_A, constant as a device to trace through the arguments. In the first case, when technological dualism is of the type $D < 0$, we first examine the rates of profit responses to the oil shock, from equations (1) and (2), we get:

$$\frac{dr_I}{dp_R} = - \frac{a_{RI}}{a_{KI}} \qquad (14)$$

$$\frac{dr_A}{dp_R} = \left(\frac{dp_A}{dp_R} - a_{RA} \right) \cdot \frac{1}{a_{KA}} \qquad (15)$$

since P_A is kept unchanged and $D < 0$, it is inmediate from (14) and (15) that the North's capital market will experience a larger drop in the rate of profit than the South's. Therefore, as long as capital supply elasticities are the same, the decline in Northern output of steel will exceed that of Southern output of corn, see equations (5) and (6). Since we have also assumed that the capital supply elasticity is higher in the North than in the South, then the North's steel output will fall even further relative to the South's corn supply. Since patterns of demand across regions are identical, then the obvious fall in world demand for corn, due to the fall in incomes, will exceed the reduction in Southern output, leading the world market to an excess supply and, given Walrasian stability, to a deterioration of the Southern terms of trade vis-à-vis the North.

In the second case, when technologies are more homogeneous $D = 0$, and keeping P_A constant, from equations (14) and (15) we obtain an identical negative response of the rates of profit in the North and in the South. But, since the capital supply elasticity is assumed to be larger in the North than in the South, then, finally, the output supply will decrease more in the North. There is now excess supply in the world market for corn and the relative price of corn will, consequently, fall.

In the third case, when the world economy exhibits technological dualism of type $D > 0$, then from equations (14) and (15) the rate of profit is more responsive to the oil price rise in the South than in the North; in consequence, the drop in the South's profit rate will be larger than that of the North's. But, since capital supply elasticity is higher in the North than in the South, then the final relative impact on the two output supplies will be ambiguous. Notice that the lower the South's capital supply elasticity and the lower the technological dualism between the North and South, the more likely it will be that the reduction in output in the North exceeds that in the South and, consequently, it will be easier to observe a deterioration of the Southern terms of trade.

Two special conditions are also interesting to examine, since they are sufficient conditions to observe a deterioration of the Southern terms of trade when the oil price rises. If the South's capital supply elasticity is zero, i.e. $\gamma_1 = 0$, then capital supply in the South will be fixed and so will its output. Since world demand for corn falls, an excess supply in the world market for corn will be observed and, in consequence, the Southern terms of trade will tend to deteriorate. Alternatively, if we assume that the South does not employ oil as an input in production, $a_{RA} = 0$, as Taylor (1981) does, then the technological matrix D will be negative, $D < 0$, and the Southern terms of trade will unambiguously deteriorate (identical result to Taylor (1981)). All these results are collected in Table 1.

Table 1: Comparative static properties of the model assuming identical patterns of preferences.

$\alpha_A = \alpha_R = \alpha_I$	$\frac{dr_I}{dp_R}$	$\frac{dr_A}{dp_R}$	$\frac{dp_A}{dp_R}$	$\frac{dK_I}{dp_R}$	$\frac{dK_A}{dp_R}$	$\frac{dQ_I}{dp_R}$	$\frac{dQ_A}{dp_R}$
D < 0	(-)	(-)	(-)	(-)	(-)	(-)	(-)
D = 0	(-)	(-)	(-)	(-)	(-)	(-)	(-)
D > 0	(-)	(+/-)	(+/-)	(-)	(+/-)	(-)	(+/-)
$\gamma_1 = 0$	(-)	(-)	(-)	(-)	(-)	(-)	(-)

If we relax the assumption of identical pattern of preferences across regions, so that $\alpha_A \neq \alpha_R \neq \alpha_I$, then the situation is more complex and a clear cut result is less likely. Specifically, we can obtain the following proposition: whenever $\alpha_A > \alpha_R > \alpha_I$

$$\text{if} \quad \beta_1 > \frac{1 - a_{RI}\, P_R}{\frac{\alpha_I}{\alpha_R - \alpha_I} + a_{RI}\, P_R} \quad \text{and} \quad \gamma_1 < \frac{\alpha_A - \alpha_R}{1 - \alpha_A} \quad \text{then} \quad \frac{dp_A}{dp_R} < 0 \qquad (16)$$

Thus, a large elasticity of output supply in the North and a small elasticity in the South are seen to favour an improvement of the North-South term of trade. This result is identical to that obtained by González-Romero and Kanbur (1986), who abstract from capital requirements instead of labour. Moreover, from (16) it is also itneresting to note that the net effect depends, crucially upon how consumer preferences for steel and corn differ across regions (see González-Romero and Kanbur (1986) and Marion and Svenson (1986)) and upon the amplitude of these differences (see González-Romero and Kanbur (1986)).

If we futher assume that the OPEC does not recycles into purchases of Southern commodities, $\alpha_R = 0$, as Taylor (1981) and Adams and Marquez (1983) assume, then the condition on the supply elasticity β , can be relaxed: whatever happens to Northern output, the decline in Southern and Northern demands for corn will dominate the fall in corn output (note that γ_1 must be lower than a particular parameter especification), thus leading to an improvement of the Southern terms of trade. Alternatively, if we assume that OPEC does not employ oil, $\dot{a}_{RA} = 0$, then the condition on the supply elasticity γ , can now be relaxed: Southern output does not change whereas Northern ouput declines sufficiently (β_1 must be greater than a particular parameter specification), then the world demand for corn will fall, the corn market will experience excess supply and hence the Southern terms of trade will deteriorate. If the assumption $a_{RA} = 0$ is alternatively coupled with the assumption $\alpha_R = \alpha_I$, as Gonzãlez-Romero and Kanbur (1986) assume, then whatever is the supply elasticity in the North, the fall in Northern demand due to the decline in Northern output will dominate any positive net effect of OPEC's demand for corn; since Southern output remains invariant, the North-South terms of trade will improve. Similarly, we obtain identical results when $a_{RA} = 0$ and $\alpha_R = 0$; this specification is set by Taylor (1981) to infer an improvement of the North-South of trade, the same result holds here as a particular parameter specification of the model[6]. A summary of the results is presented in Table 2.

Table 2 : Comparative static properties of the model assuming biased consumption towards its own-produced good.

$\alpha_A > \alpha_R > \alpha_I$	$\frac{dr_I}{dp_R}$	$\frac{dr_A}{dp_R}$	$\frac{dp_A}{dp_R}$	$\frac{dk_I}{dp_R}$	$\frac{dK_A}{dp_R}$	$\frac{dQ_I}{dp_R}$	$\frac{dq_A}{dp_R}$
$\beta_1 > h$ and $\gamma_1 < \frac{\alpha_A - \alpha_R}{1 - \alpha_A}$	(-)	(-)	(-)	(-)	(-)	(-)	(-)
$\gamma_1 < \frac{\alpha_A}{1 - \alpha_A}$ and $\alpha_R = 0$	(-)	(-)	(-)	(-)	(-)	(-)	(-)
$a_{RA} = 0$ and $\alpha_R = \alpha_I$ or $\beta_1 > h$	(-)	(-)	(-)	(-)	(-)	(-)	(-)
and $a_{RA} = 0$, $\alpha_R = 0$	(-)	(-)	(-)	(-)	(-)	(-)	(-)

where $h = \dfrac{1 - a_{RI} P_R}{\dfrac{1 - \alpha_I}{\alpha_I - \alpha_R} + a_{RI} P_R}$

In sum, we have developed the following overall impresion of the model with capital inmobility: when the price of oil rises, the model tends to generate, at an initially fixed P_A, a downward pressure on the North's rate of profit larger than that of the South's, thus leading to a stronger decline in Northern output than in Southern output and consequently, the Southern terms of trade vis-à-vis the North will deteriorate. This scenario was present in the afterwath of OPEC II, with the North experiencing a deep fall in the level of activity and the South suffering from a deteriorated terms of trade vis-à-vis the North and also from a fall in output see van Wijnbergen (1985).

3. A Neoclassical Model with Perfect Capital Mobility

A major change from the last section's precise model has been made in order to allow for a complete integration of the capital markets in the North and South through capital flows.

Thus, we allow for perfect capital mobility across regions and, in consequence, capital flows will take place till rates of profit equalize across regions

$$r_I = r_A = r \tag{17}$$

A fundamental implication of (17), is that the two separate regional capital markets are integrated into a world capital market. Instead of (5) and (6), we now have,

$$K_W = K_I + K_A = \beta_0 (r)^{\beta_1} + \gamma_0 (r)^{\gamma_1} = a_{KI} Q_I + a_{KA} Q_A \tag{18}$$

Therefore, the model is a general equilibrium system given by eight equations, (1) to (4), (7) to (9) and (13), in nine endogenous variables, P_A , P_I , P_R , r , K_I , K_A , Q_I , Q_A and Q_R . The model differs from that of Burgsteller (1985) in assuming a neoclassical rather than a Lewisian South. It differs from the model of Burgstaller and Saavedra-Rivano (1984) also in assuming fixed coefficients. Of course the major difference between our model and those mentioned above is that it introduces oil as an input instead of labour, enabling us to draw attention to the role played by OPEC in the North-South context.

Walras Law and normalization collapse the model into a system of seven linearly independent equations in eight unknowns and a numeraire, P_I . As in the model of section 2, the solutions of the model are obtained by parameterization of the world price of oil at a given equilibrium value. First, let us examine the crucial differences with the model of section 2. For a fixed P_R , from equation (1) and (2), we obtain the equilibrium values for r and P_A , and the following comparative static results:

$$\frac{dr}{dp_R} = - \frac{a_{RI}}{a_{KI}} \tag{19}$$

and

$$\frac{dp_A}{dp_R} = \frac{1}{a_{KI}} D \tag{20}$$

Consequently, once the capital market is integrated, a rise in the price of oil will always have a depressive effect on the world rate of profit. This response does not depend at all on the North-South terms of trade response as it occurs in the model of section 2, where the two regional capital markets were not unified. However, the North-South terms of trade response will be given by the following proposition

$$\frac{dp_A}{dp_R} \lesseqgtr \quad \text{according as} \quad D \lesseqgtr 0 \tag{21}$$

One conclusion inmediately follows: if the oil price increases, then the regions that produces and exports the oil intensive commodity will experience a rise in the relative price of its exports in terms of its imports.

There is an interesting point to make here. Notice that the comparative static results in the two frameworks,-inter-regional capital inmobility and perfect capital mobility, are not identical. The difference is explained because of capital flows. Specifically, when capital is inmobile, the two regional markets for capital were separated; hence the oil price rise impact will depend upon the different techno-logical structure throughout the world, but also will depend upon the different degree of capital supplies responsiveness to changes in the rate of profit. Thus, for instance, if technologies are homogeneous $D = 0$, the oil price rise will still affect the Southern term of trade response as long as the capital supply elasticities in the two regional markets for capital differ.

In contrast, when an integrated world capital market replaces the two separate regional markets, the oil price shock impact on the North-South terms of trade will depend entirely upon the type of technological structure across regions. This is due to the world capital supply being unique; that is, different capital supplies responses across regions will not affect directly its respective output, but through its impact on the world supply of capital. Thus, when technologies are homogeneous, $D = 0$, the oil shock negative impact on the world capital supply will be diversified according to identical capital-output coefficients in the two regions; correspondingly, the North-South terms of trade will remain invariant.

In the particular case, when capital supply is fixed in the South $(\gamma_1 = 0)$, the oil price rise impact will only affect the world capital supply through its effect on the North's capital supply, in this way, the output supplies in the North and South will be finally affected according to their respective capital-output coefficient. In contrast, in the model of section 2, when $\gamma_1 = 0$, output supply in the South remains invariant and, in consequence, the Southern terms of trade deteriorate whatever is the technological structure across regions.

Let us now solve the model. Substituting for r from (1), for P_A from (2), for K_I and K_A from (3) and (4), for Q_I from (8) and for Q_R from (9), all into (18), we obtain the model's resolving equation in Q_A , P_I and P_R .

$$\left\{\left[\beta_0 \left(\frac{P_I - a_{RI} P_R}{a_{KI}}\right)^{\beta_1} + \gamma_0 \left(\frac{1 - a_{RI} P_R}{a_{KI}}\right)^{\gamma_1}\right] - a_{KA} Q_A\right\} \cdot$$

$$\left[P_I \alpha_I + a_{RI} P_R \ (\alpha_R - \alpha_I)\right] =$$

$$= a_{KI} Q_A \left[\left(\frac{P_R}{a_{KI}} D + \frac{a_{KA}}{a_{KI}} \right) (1 - \alpha_A) + a_{RA} P_R (\alpha_A - \alpha_R) \right] \qquad (22)$$

Given the normalization $P_I = 1$ and given P_R exogenously, it is inmediate that equation (22) solves for the equilibrium value of Q_A uniquely[3]. We can now compute the complete equilibrium of the model. From (1) and (2) we compute r and P_A ; given r from (3) and (4) we obtain K_I and K_A and, therefore, K_W . From (22) we solve for Q_A , and given K_I and K_A , from equations (8) and (9) we obtain the equilibrium solutions for Q_I and Q_R , respectively. Thus the complete solution of the North-South-OPEC model is fully determined.

Let us now explore the comparative static properties of the model if it shifts to a new equilibrium with a higher oil price. Firstly, the impact on r and P_A has been already examined, see equations (19) and (20). Secondly, differentiating (22) with respect to P_R , we get:

$$\frac{dQ_A}{dp_R} \left[\frac{1}{Q_A} + \frac{a_{KA}}{K_w - a_{KA} Q_A} \right] = \frac{1}{K_w - a_{KA} Q_A} \cdot \frac{dK_w}{dp_R} -$$

$$- \frac{\frac{1}{a_{KI}} D (1 - \alpha_A) + a_{RA} (\alpha_A - \alpha_R)}{\left(\frac{P_R}{a_{KI}} \cdot D + \frac{a_{KA}}{a_{KI}} \right) (1 - \alpha_A) + a_{RA} P_R (\alpha_A - \alpha_R)} + \frac{a_{RI} (\alpha_R - \alpha_I)}{\alpha_I + a_{RI} P_R (\alpha_R - \alpha_I)} \qquad (23)$$

where $K_w = \beta_0 \left(\frac{1 - a_{RI} P_R}{a_{KI}} \right)^{\beta_1} + \gamma_0 \left(\frac{1 - a_{RI} P_R}{a_{KI}} \right)^{\gamma_1}$ and, consequently,

$$\frac{dK_w}{dp_R} = - \frac{a_{RI}}{a_{KI}} \left[\beta_0 \beta_1 \left(\frac{1 - a_{RI} P_R}{a_{KI}} \right)^{\beta_1 - 1} + \gamma_0 \gamma_1 \left(\frac{1 - a_{RI} P_R}{a_{KI}} \right)^{\gamma_1 - 1} \right] < 0 ,$$

that is, an oil price rise will tend, through a decline in the world rate of profit earned by Northern and Southern capitalists, to reduce the supplies of phisical capital services to the market.

Let us now examine the expression (23). The response of the Southern output to an oil price change is thus seen to depend on a complex set of supply and demand factors. A clear interpretation of (23) can be provided by noting that the terms of the RHS of (23) denote the impact that a change in the world price of oil produces as the supply and demands for steel as long as the Southern output is kept unchanged, see Appendix 4. Once the economy is in desequilibrium, the LHS of (23) denotes the Shouthern output response to the disequilibrium produced in the steel market; note that the Southern output response will lead the Northern output supply and the world demands for steel torward its new equilibrium since the model exhibits Walrasian stability, see Appendix 3.

In order to get a better understanding of the essential functioning of the world economy, we impose some strategic assumptions in order to be able to identify the forces set in motion when an exogenous shock takes place. First, let us assume that patterns of demand across regions are identical, $\alpha_A = \alpha_R = \alpha_I$; the following proposition holds.

$$\text{if} \quad D \geqq 0 \qquad \text{then} \qquad \frac{dQ_A}{dp_R} < 0 \tag{24}$$

And the impact on the Northern output of steel will be consequently obtained by differentiating equation (18) and substituting for dQ_A/dp_R from (23) and using $\alpha_A = \alpha_R = \alpha_I$, we obtain:

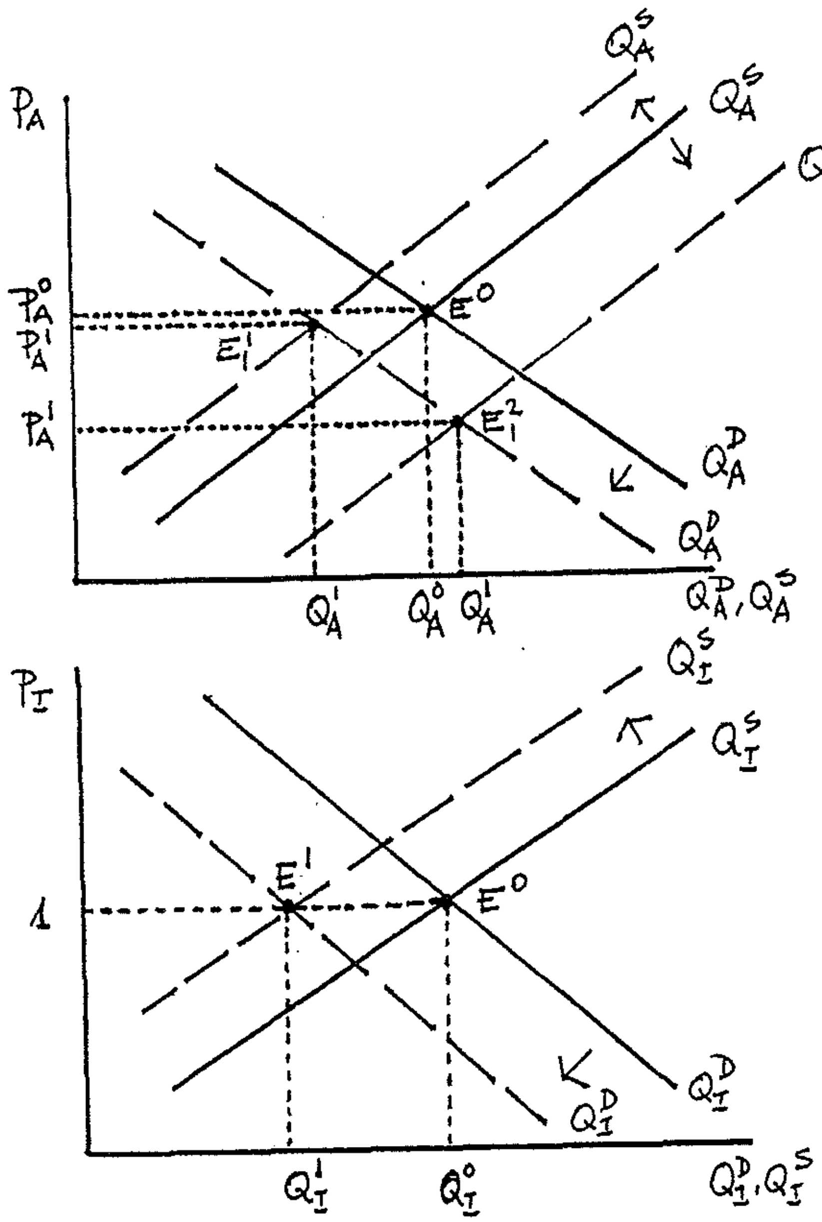
$$\frac{dQ_I}{dp_R} = \left(1 - \frac{a_{KA}Q_A}{K_w}\right) \cdot \frac{1}{a_{KI}} \cdot \frac{dK_w}{dp_R} + \frac{a_{KA}}{a_{KI}} \cdot \frac{\frac{1}{a_{KI}} D\, Q_A (K_w - a_{KA}\, Q_A)}{\left(\frac{p_R}{a_{KI}} D + \frac{a_{KA}}{a_{KI}}\right) K_w} \tag{25}$$

and therefore

$$\text{if} \quad D \leq 0 \qquad \text{then} \qquad \frac{dQ_I}{dp_R} < 0 \tag{26}$$

Thus, whenever $D < 0$, the Northern commodity is relatively energy intensive, an oil price rise will lead to a fall in the North's output supply whereas the South's output may or may not decline. One conclusion immediately follows: the only region that, when the oil price rises, may benefit from perfect capital mobility is the relatively capital intensive region, the South.

Let us examine briefly the two possible sets of results. Firstly, the case when the two output supplies, in the North and the South, decline. The argument goes as follows: an oil price increase will lead, at a given world rate of profit, to current account deterioration in the North and South; hence the volume of oil imports will fall and so will capital demand, since they are complementary. Once the profit rate drops, capital supply will therefore fall according to the degree of Northern and Southern capitalists responsiveness to the decline in the profit rate. We also know that if corn is the relatively capital intensive commodity, $D < 0$, the Southern terms of trade vis-à-vis the North will tend to deteriorate when the oil price rises, since the world demand for corn has declined and the model exhibits Walrasian stability. then the Southern output of corn will have fallen or may have even risen. If the fall in world capital supply due to the rise in the price of oil is sufficiently large, then the South will be bound to run lower levels of capital demand and hence the Southern output will decline. However, if the fall in world capital supply is small and the Northern output is highly energy intensive (D is significantly large in absolute value), then the consequent fall in Northern capital demand due to the decline in output of steel will outweigh the fall in world supply of capital; thus, the South will have some room to increase capital demand and, consequently the Southern output will slightly rise. Figures 1 and 2 describe these two factible equilibria in the world markets for corn and steel[8]:



In the alternative case when D > 0 , the Northern commodity is now relatively capital intensive, then the argument and the results are exactly the opposite. Finally, when D = 0 , technologies are homogeneous in the North and the South, in this case capital demands, and therefore output supplies, will decline in identical proportion, thus unaltering the North-South terms of trade. A summary of these results is given in Table 3.

The ambiguous sign of dQ_A/dp_R when $D > 0$, can be understood by noting that if we assume that the world supply of physical capital services is fixed, i.e. $\beta_1 = \gamma_1 = 0$, then when $D < 0$, $dQ_A/dp_R = 0$. That is, if the oil price shock has induced a decline in Nothern output without altering the world capital supply, then Southern capital demand, and hence output, will increase so as to absorb the excess supply in the international capital market. Similar argument goes when $D > 0$, so that $dQ_I/dp_R > 0$. These results are also included in Table 3.

Table 3. Comparative static properties of the model assuming identical patterns of preferences.

$\alpha_A = \alpha_R = \alpha_I$	$\frac{dr}{dp_R}$	$\frac{dp_A}{dp_R}$	$\frac{dK_w}{dp_R}$	$\frac{dQ_I}{dp_R}$	$\frac{dQ_A}{dp_R}$
$D < 0$	(-)	(-)	(-)	(-)	(+/-)
$D = 0$	(-)	(0)	(-)	(-)	(-)
$D > 0$	(-)	(+)	(-)	(+/-)	(-)
$\beta_1 = \gamma_1 = 0$ and $D < 0$	(-)	(-)	(-)	(-)	(+)
$\beta_1 = \gamma_1 = 0$ and $D > 0$	(-)	(+)	(-)	(+)	(-)

We now draw attention to the general case where demand patterns differ across regions. First of all, we should notice that the oil price rise impacts on the world rate of profit, North-South terms of trade and world capital supply are identical whatever is the pattern of consumption assumed. Therefore, the consumption preferences will only affect the levels of activity in the North and South. Let us assume, as in the model of section 2, that $\alpha_A > \alpha_R > \alpha_I$ is a plausible assumption. The results obtained in the model under this assumption are collected in Table 4. First, large capital supply elasticities in the North and South are seen to favour a decline in Northern and Southern output. Alternatively, if these elasticities are zero and we also assume that the South does not recycle into purchases of Suthern commodities, $\alpha_R = 0$, then the oil price rise impact will again depend upon the type of technological dualism between North and South.

If we futher assume that the South does not use oil as an input, $a_{RA} = 0$ (and therefore $D < 0$), then the oil price rise will have an ambiguous impact on Northern and Southern output. Moreover, if we also assume that OPEC does not recycle into the consumption of Southern commodities, $\alpha_R = 0$, the effects are not clear cut either. Southern and Northern demands for corn will decline whereas Southern supply will also fall, the final impact on Southern output will be therefore unclear and so will the impact on Northern output (see Appendix 4 using $a_{RA} = 0$ and $\alpha_R = 0$).

Table 4: Comparative static properties of the model assuming biased consumption towards its own-produced good.

$\alpha_A > \alpha_R > \alpha_I$		$\frac{dr}{dp_R}$	$\frac{dp_A}{dp_R}$	$\frac{dK_W}{dp_R}$	$\frac{dQ_I}{dp_R}$	$\frac{dQ_A}{dp_R}$
β_1 and γ_1 sufficiently large		(-)		strong (-)	(-)	(-)
$\beta_1 = \gamma_1 = 0$ and $\alpha_R = 0$	$D > 0$	(-)	(+)	(0)	(+)	(-)
	$D = 0$	(-)	(0)	(0)	(+)	(-)
	$D < 0$	(-)	(-)	(0)	(+/-).	(+/-)
$a_{RA} = 0$ $(D < 0)$		(-)	(-)	(-)	(+/-)	(+/-)
and $a_{RA} = 0$ $(D < 0)$, $\alpha_R = 0$		(-)	(-)	(-)	(+/-)	(+/-)

The overall impression of the model with perfect capital mobility is that under plausible assumptions, when the oil price rises, the model tends to generate a drop in the world rate of profit and a deterioration of the North-South terms of trade, Northern output will unambiguously fall whereas Southern output may or may not decrease. This scenario represents a good description of the world economy response after OPEC I, when Northern economies exhibit a high degree of oil dependence, a strong decline in the world rates of profit took place and Southern commodity prices in real terms fell dramatically, the North suffered an output contraction whereas the South managed to maintain or even raise its level of activity. See Sachs (1979) and van Wijnbergen (1985). It is also clear that depending on the type and degree of technological dualism, for a given decrease in the world capital supply the levels of activity in the North and South are inversely related.

4. Conlusion

It has been argued, see for instance Sachs (1979) and van Wijnbergen (1985) that after the first oil shock in 1973/74, OPEC I, persistent OPEC surpluses were recycled largely to the developing countries through a major change in the structure of capital flows between industrial and developing countries. This change allowed the developing countries to increase capital demand and, consequently, to maintain or even raise its level of activity. However, after the second oil shock in 1979/80, OPEC II, OPEC surpluses were short lived and not only the industrial countries came into a very deep contraction, but also the developing countries reduced output, see van Wijnbergen (1985). In this paper we have attempted to explore this argument in the context of a general equilibrium model with perfect capital mobility and, alternatively, capital inmobility. We explore the impact of an oil price rise on major macro variables of the importer economies. The two scenarios highlight the alternative parameters that will be crucial in determining the comparative static results. Under perfect capital mobility the type of technological dualism between the North and South is highly critical for the results. Under perfect capital inmobility, the model emphasizes mainly supply elasticities and, also the type and degree of technological dualism and the degree of OPEC's recycling into Southern commodities.

The model with capital inmobility is capable of generating, under plausible assumptions, an improvement in the North-South terms of trade and a downward pressure on the North and South rates of profit, thus leading to a fall in activity in the two oil importing regions, larger in the North. This seems to represent the stylized facts in the world economy aftermath of OPEC II. The model with perfect capital mobility is also able to generate, under plausible assumptions, a deterioration of the Southern terms of trade vis-à-vis the North and a decline in the world rate of profit and the level of activity in the North, however, the output of the other oil importer region, the South, may or may not decline. This alternative scenario is a better description of the response of the world economy after OPEC I. The strength of the results lie, in the fact that we, with the help of the model, are able to see the basic interrelationships between supply and demand factors in the oil price rise process.

I hope the analysis also help us, firstly, understanding the reasons (the parameters highlighted) why regions respond differently to the same external shock and, secondly, noting that from differents regimes of capital mobility we should derive alternative policy implications. Thus, for instance, we have found that for a particular parameter specification, one of the two oil importers regions may benefit from an oil shock under a regime of perfect capital mobility.

Footnotes

1.- A formal justification of the capital supply functions can be found if we assume that the physical depreciation of the machine is an increasing and convex function of the machine services, see Mahran (1984).

2.- Notice that the variable we choose as a model closure does not affect at all either the equilibrium solutions of the model or its comparative static properties. For futher details, see Heal (1984).

3.- The posibility of factor prices requires the price of oil to be bounded: $0 < P_R < \frac{1}{a_{RI}}$.

4.- Despite of analyzing the effects of an oil price rise, the analysis of an oil price decrease merely involves a change in the sign of the results which are symmetric.

5.- Note that $Q_i^D(N)$, $Q_i^D(S)$ and $Q_i^D(R)$, $i = I,A$, designate the Northern, Southern and OPEC's demand for good i , and Q_i^S the supply for that good, and Q_i^D the world demand.

6.- Capital is inmobile in this model. The model in section 3 incorporates capital mobility. Rental differential will be necessary for capital to flow. And as Findlay (1984) points out:

> "If capital is free to move in either direction, it is natural to suppose that the incentive is for it to flow from North to South".

7.- In order to understand these exercises, it is useful to incorporate the assumptions we make in Appendix 2.

8.- The world demand schedules for corn and steel have been drawn under the assumption that they are downward sloping, however they might be upward sloping, but since the markets are Walras stable the final effects are not altered by this assumption.

Appendix 1: Stability under capital inmobility[5]

A rather common approach to stability in trade theory is to assume that domestic factor prices remain at their equilibrium values and factor markets clear, therefore the burden of the adjustment is placed on the international markets. Furthermore, in the world market for oil, oil producers fix the price and supply whatever is demanded, hence this market is also always in equilibrium. In consequence, the emphasis of the adjustment is finally placed on the two international commodity markets. Of course, if one of the two markets is stable, the other market will also be stable by Walras Law.

Our stability analysis focus on the world market for corn, First, let us define excess supply in this market as:

$$\emptyset(P_A) = Q_A^S(P_A) - Q_A^D(P_A)$$

walrasian stability in the corn market will require $\emptyset'(P_A) > 0$

$$\emptyset'(P_A) = \frac{\partial Q_A^S(P_A)}{\partial P_A} - \frac{\partial Q_A^D(P_A)}{\partial P_A} > 0$$

Substituting, we obtain the following derivatives:

$$\frac{\partial Q_A^S}{\partial P_A} = \frac{\gamma_1}{P_A - a_{RA}P_R} Q_A P_A + Q_A$$

$$\frac{\partial Q_A^D(S)}{\partial P_A} = (\gamma_1 + 1)\ \alpha_A\ Q_A$$

$$\frac{\partial Q_A^D(N)}{\partial P_A} = 0$$

$$\frac{\partial Q_A^D(R)}{\partial P_A} = \frac{\gamma_1}{P_A - a_{RA}P_R} \alpha_R\, P_R\, a_{RA}\, Q_A$$

$$\left.\frac{\partial Q_A^S}{\partial p_R}\right|_{\bar{p}_A} = - \frac{\gamma_1 \, a_{RA}}{p_A - a_{RA} p_R} \, Q_A \, p_A$$

$$\left.\frac{\partial Q_A^D(S)}{\partial p_R}\right|_{\bar{p}_A} = -(\gamma_1 + 1) \;\; \alpha_A \, a_{RA} \, Q_A$$

$$\left.\frac{\partial Q_A^D(N)}{\partial p_R}\right|_{\bar{p}_A} = -(\beta_1 + 1) \;\; \alpha_I \, a_{RI} \, Q_I$$

$$\left.\frac{\partial Q_A^D(R)}{\partial p_R}\right|_{\bar{p}_A} = - \frac{\beta_1 \;\, a_{RA}}{1 - a_{RI} p_R} \, \alpha_R \, a_{RI} \, p_R \, Q_I \; + \; \alpha_R \, a_{RI} \, Q_I \; -$$

$$\frac{\gamma_1 \;\, a_{RA}}{p_A - a_{RA} p_R} \, \alpha_R \, a_{RA} \, p_R \, Q_A \; + \; \alpha_R \, a_{RA} \, Q_A$$

Adding up these therms, we obtain:

$$\left.\frac{\partial Q_A^D}{\partial p_R}\right|_{\bar{p}_A} - \left.\frac{\partial Q_A^S}{\partial p_R}\right|_{\bar{p}_A} =$$

$$= Q_A \left[\frac{\gamma_1 \, a_{RA}}{p_A - a_{RA} p_R} - \frac{\beta_1 \, a_{RI}}{1 - a_{RI} p_R} + \frac{a_{RI}(\alpha_R - \alpha_I)}{\alpha_I + a_{RI} p_R (\alpha_R - \alpha_I)} - \right.$$

$$\left. - \frac{a_{RA}(\alpha_A - \alpha_R)}{p_A(1 - \alpha_A) \; + \; a_{RA} p_R (\alpha_A - \alpha_R)} \right]$$

Notice that the terms in square brackets have an ambiguous sign. Note further that the terms in square brackets correspond identically with the RHS of (11).

Adding up these terms and rearranging, we finally have:

$$\emptyset'_A(P_A) = Q_A \left| \frac{\gamma_1}{P_A - a_{RA}P_R} + \frac{(1-\alpha_A)}{P_A(1-\alpha_A) + a_{RA}P_R(\alpha_A - \alpha_R)} \right|$$

and obviously $\emptyset'_A(P_A) > 0$ always. Hence the world market for corn is Walras stable and so will the world market for steel. Notice that the terms in square brackets are identical to those in square brackets on the LHS of equation (11).

Appendix 2: An oil price shock[5]

We know that the corn world market equilibrium requires:

$$\emptyset(P_A, P_R) = Q_A^S(P_A, P_R) - Q_A^D(P_A, P_R) = 0$$

In consequence, if an oil price shock takes place, the corn world market adjustment to the new equilibrium will be defined by:

$$\frac{\partial Q_A^S}{\partial P_A} \cdot \frac{dp_A}{dp_R} + \frac{\partial Q_A^S}{\partial p_R} \Bigg|_{\bar{P}_A} - \frac{\partial Q_A^D}{\partial p_A} \cdot \frac{dp_A}{dp_R} - \frac{\partial Q_A^D}{\partial p_R} \Bigg|_{\bar{P}_A} = 0$$

where

$$\frac{dp_A}{dp_R} = \frac{\dfrac{\partial Q_A^D}{\partial p_R}\Bigg|_{\bar{P}_A} - \dfrac{\partial Q_A^S}{\partial P_R}\Bigg|_{\bar{P}_A}}{\dfrac{\partial Q_A^S}{\partial p_A} - \dfrac{\partial Q_A^D}{\partial p_A}}$$

Notice that the denominator is positive since the model presents Walrasian stability (see Appendix 1). Let us find out the numerator:

Appendix 3: Stability under perfect capital mobility[5]

To study the stability properties of the model, we use the same approach as in Appendix 1. Therefore, the burden of the adjustment is placed on the two international commodity markets. We now concentrate on the world market for steel. We define excess supply in this market as:

$$\emptyset(Q_A) = Q_I^S(Q_A) - Q_I(Q_A)$$

walrasian stability in the steel market will require $\emptyset'(Q_A) < 0$

$$\emptyset'_A(Q_A) = \frac{\partial Q_I^S(Q_A)}{\partial Q_A} - \frac{\partial Q_I^D(Q_A)}{\partial Q_A} < 0$$

Substituting, we obtain the following derivatives:

$$\frac{\partial Q_I^S}{\partial Q_A} = - \frac{a_{KA}}{K_w - a_{KA}Q_A} \cdot Q_I$$

$$\frac{\partial Q_I^D(S)}{\partial Q_A} = (1 - \alpha_A)(p_A - a_{RA}\, p_R)$$

$$\frac{\partial Q_I^D(N)}{\partial Q_A} = - \frac{a_{KA}}{K_w - a_{KA}Q_A} (1 - \alpha_I)(1 - a_{RI}\, p_R) Q_I$$

$$\frac{\partial Q_I^D(R)}{\partial Q_A} = - \frac{a_{KA}}{K_w - a_{KA}Q_A} (1 - \alpha_R)\, p_R\, a_{RI}\, Q_I + (1 - \alpha_R)\, p_R\, a_{RA}$$

Adding up these terms and rearranging we obtain:

$$\emptyset'(Q_A) = Q_I \left[- \frac{a_{KA}}{K_w - a_{KA}Q_A} - \frac{1}{Q_A} \right]$$

and obviously $\emptyset'(Q_A) < 0$ always. In conclusion, the world market for steel is Walras stable and so will the world market for corn. Notice that the terms in square brackets are identical to those in square brackets on the LHS of equation (23) with changed signs.

Appendix 4: An oil price shock[5]

We know that the steel world market equilibrium requires:

$$\emptyset(Q_A , p_R) = Q_I^S(Q_A , p_R) - Q_I^D(Q_A , p_R) = 0$$

Therefore, if the oil price changes, the world market for steel will adjust to the new equilibrium according to:

$$\frac{\partial Q_I^S}{\partial Q_A} \cdot \frac{dQ_A}{dp_R} + \left.\frac{Q_I^S}{p_R}\right|_{\bar{Q}_A} - \frac{\partial Q_I^D}{\partial Q_A} \cdot \frac{dQ_A}{dp_R} - \left.\frac{\partial Q_I^D}{\partial p_R}\right|_{\bar{Q}_A} = 0$$

where

$$\frac{dQ_A}{dp_R} = \frac{\left.\frac{\partial Q_I^D}{\partial p_R}\right|_{\bar{Q}_A} - \left.\frac{\partial Q_I^S}{\partial p_R}\right|_{\bar{Q}_A}}{\frac{\partial Q_I^S}{\partial Q_A} - \frac{\partial Q_I^D}{\partial Q_A}}$$

Notice that the denominator is negative since the model presents Walrasian stability (see Appendix 3). Let us examine the numerator:

$$\left.\frac{\partial Q_I^S}{\partial P_R}\right|_{\bar{Q}_A} = \frac{1}{K_w - a_{KA} Q_A} \frac{dK_w}{dp_R} Q_I$$

$$\left.\frac{\partial Q_I^D(S)}{\partial p_R}\right|_{\bar{Q}_A} = (1-\alpha_A) D\, Q_A - (1-\alpha_A)\, a_{RA} Q_A$$

$$\left.\frac{\partial Q_I^D(N)}{\partial p_R}\right|_{\bar{Q}_A} = (1-\alpha_I)(1-a_{RI}\, p_R) \frac{1}{K_w - a_{KA}Q_A} \frac{dK_w}{dp_R} Q_I - (1-\alpha_I)\, a_{RI} Q_I$$

$$\left.\frac{\partial Q_I^D(R)}{\partial p_R}\right|_{\bar{Q}_A} = (1-\alpha_R)\, a_{RI}\, p_R \frac{1}{K_w - a_{KA}Q_A} \frac{dK_w}{dp_R} Q_I + (1-\alpha_R) a_{RI} Q_I +$$

$$+ (1-\alpha_R) a_{RA} Q_A$$

Adding up these terms, we obtain:

$$\left.\frac{\partial Q_I^D}{\partial p_R}\right|_{\bar{Q}_A} - \left.\frac{\partial Q_I^S}{\partial p_R}\right|_{\bar{Q}_A} =$$

$$= Q_I \left[-\frac{1}{K_w - a_{KA}Q_A} \frac{dK_w}{dp_R} + \frac{D(1-\alpha_A) + a_{RA}(\alpha_A - \alpha_R)}{(\frac{p_R}{a_{KI}} D + \frac{a_{KA}}{a_{KI}})(1-\alpha_A) + a_{RA}\, p_R(\alpha_A - \alpha_R)} + \right.$$

$$\left. - \frac{a_{RI}(\alpha_R - \alpha_I)}{\alpha_I + a_{RI}\, p_R(\alpha_R - \alpha_I)} \right]$$

Notice that the term in square brackets has an ambiguous sign. Note further that the terms in square brackets are identical to the RHS of (23) with changed signs.

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