Oil prices and the dollar dilemma

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THIS PAPER EXAMINES the impact of changes in the United States dollar's exchange rate on the oil market. The discussion uses a partial equilibrium model to illustrate how disequilibrium in the oil market occurs, and how a new equilibrium may be reached when dollar exchange rates fluctuate.

Oil prices are influenced by a number of economic, political and psychological factors. In order to determine how exchange rates make an impact, it is useful to rely upon a model based on partial analysis. This method enables us to examine the impact of exchange rate fluctuations on oil prices, independently from other variables. Thus, in the model presented in this paper, we exclude such variables as how exchange rate fluctuations affect macro-economic conditions and subsequently oil demand, the effects of the substitution of other energy sources either globally or regionally, the fact that a number of countries have large debts and assets held in dollars, the fiscal policy each country applies to currency rate changes, and other economic and political factors which have an impact on the level and structure of demand, supply and the price of crude oil. We also exclude from our analysis the repercussions of oil price changes back onto currency markets.

The development of oil prices in different currencies in recent years is described in section 1. In particular, this discussion focuses upon the differences between oil prices denominated in European currencies and US dollars. In section 2, a partial equilibrium model of the oil market is introduced to illustrate how oil prices, both in US dollars and other currencies, react to fluctuations in exchange rates. Some concluding comments are made in section 3.

1. The US dollar and the crude oil market

Most primary commodities are priced in American dollars. To a large extent, however, trade occurs between countries that do not have the dollar as their national currency. Thus, the US dollar is a common converting unit for all actors in the market. But the price faced by each buyer and seller in the market is the price of the commodity determined in dollars multiplied by the

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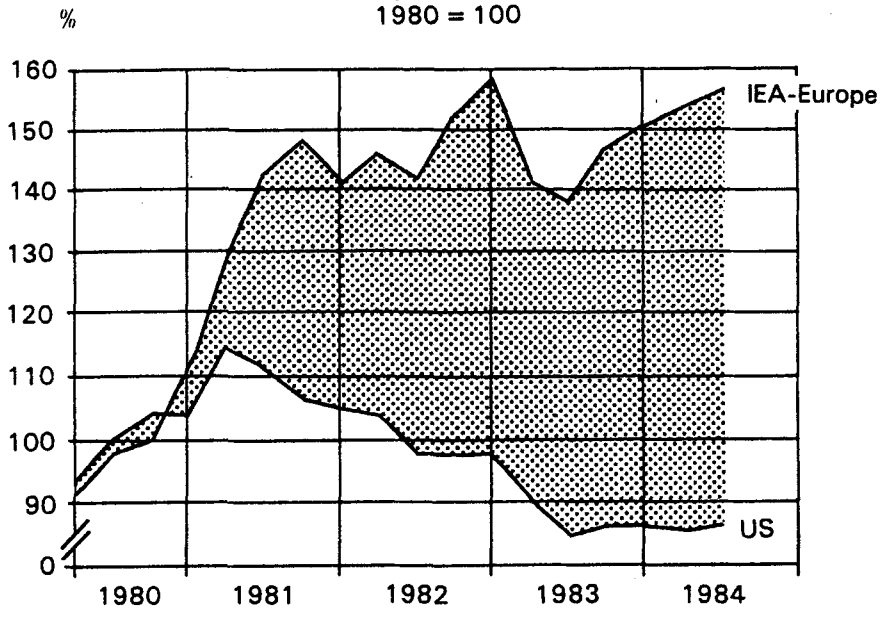
country's *exchange rate* against the US dollar (the number of units of national currency needed to buy one US dollar).

During the first half of the 1980s, the dollar price of oil decreased. But the rise in the value of the dollar against most other currencies led to an *increase* in oil prices in most other currencies. Depending upon the degree to which each national currency depreciated against the US dollar, oil price developments differed markedly. In Western Europe, oil prices increased by about 50 per cent in the period 1980–1984; at the same time, prices in US dollars decreased in the range of 15–20 per cent. Thus, European oil prices increased by more than 70 per cent in relation to prices in the US currency during this period. This development is shown in **figure 1.1**.

1.1 The denomination of oil prices in US dollars and Western European currencies, 1980–84



Source: IEA/OECD.

Further, oil consumption fell heavily during this period. As illustrated in **table 1.2**, OECD oil imports decreased by 25 per cent (approximately 278 million tonnes) during 1980–84. This decrease was a result of a number of factors, such as substitution by other primary energy sources, lower economic growth and increased energy efficiency. Nevertheless, the fact that three-quarters of the OECD area's total imports go to countries with national currencies other than the US dollar, raises some additional questions in

1.2 Oil imports to the OECD area 1980–84

million tonnes

1980	1,124	
1981	985	
1982	878	
1983	824	
1984	846	*100.0%*
Of which (1984):		
Western Europe	436	*51.5%*
US	207	*24.5%*
Japan	182	*21.5%*
Others	21	*2.5%*

Source: IEA/OECD.

this paper: Do the different patterns of development of national oil prices (caused by exchange rate fluctuations) have an impact on total oil consumption? What impact does the size of the US market share have on the stability of the oil price denominated in US dollars?

To take a closer look at some of these problems, we shall consider a partial equilibrium model illustrating the relationship between currency market fluctuations and oil prices.

2. Crude oil prices in purchasing countries with different national currencies

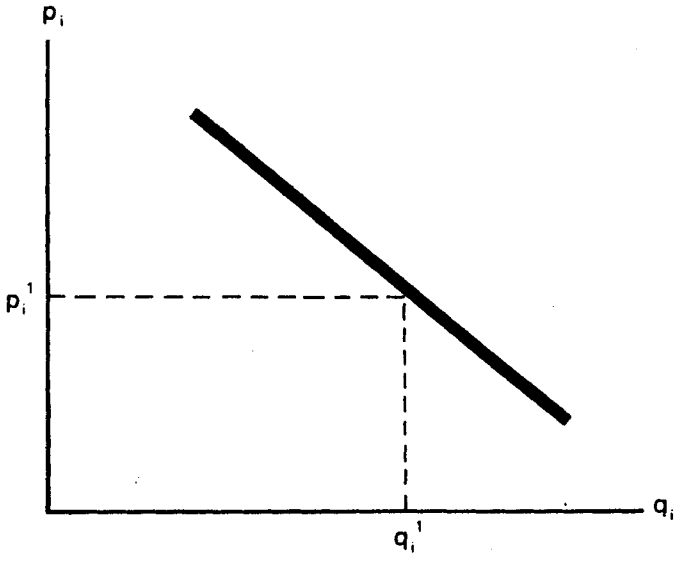
In the model, our world consists of only two countries, country A and country B; the US is country B and the "rest of the world" is country A. Crude oil demand in each country (q_i, i = A and B) can be expressed as a function of the price (p_i) denominated in their respective national currencies.

$$q_A = f(p_A), \quad \text{where } f' < 0$$

$$q_B = g(p_B), \quad \text{where } g' < 0$$

Crude oil demand is assumed to fall as prices rise (**figure 2.1**). The demand in each country is determined for any given price.

2.1 The demand for crude oil in country i



For country A, the demand curve will be the aggregate of each of the individual countries in the "rest of the world's" national demand curves for crude oil.[1]

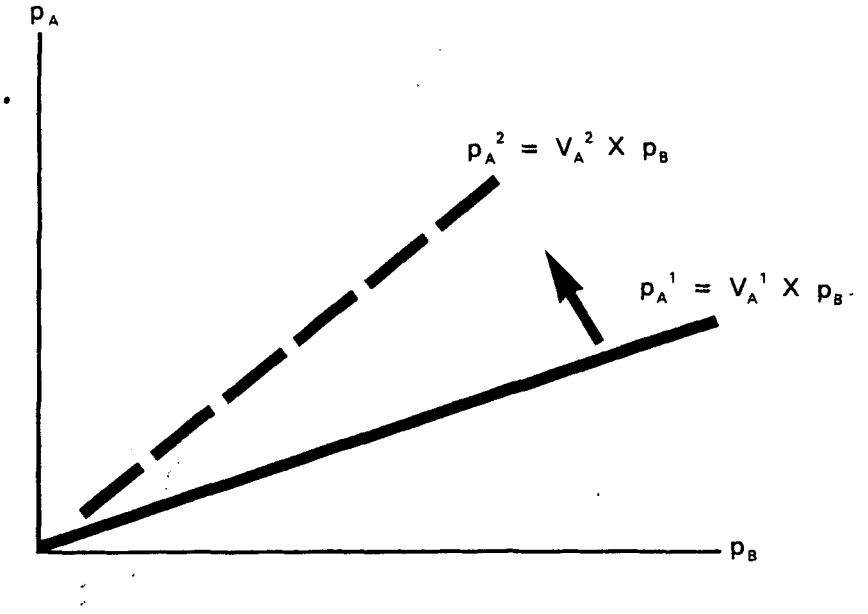
The difference between the two countries' national prices is represented by the exchange rate between their currencies:

$$p_A = V_A \times p_B$$

V_A is the number of units of country A's currency per unit of country B's currency (e.g. the number of German marks per US dollar).[2] The crude oil price in country A's currency fluctuates according to changes in the currency rate, at a given oil price in country B's currency. Thus, the relationship between the two oil prices can be expressed as a curve from the origin with the two oil prices on the axes. The initial rate is illustrated in **figure 2.2** by the slope of the curve V_A^1. For any given price in country B's currency, there is a corresponding price in country A's currency. The difference results from the exchange rate.

If country B's currency appreciates, country A must pay more units of its national currency per unit of country B's currency, and the slope of the curve will change from V_A^1 to V_A^2. Now country A has to pay more per barrel

2.2 The relations between oil prices in country A and country B



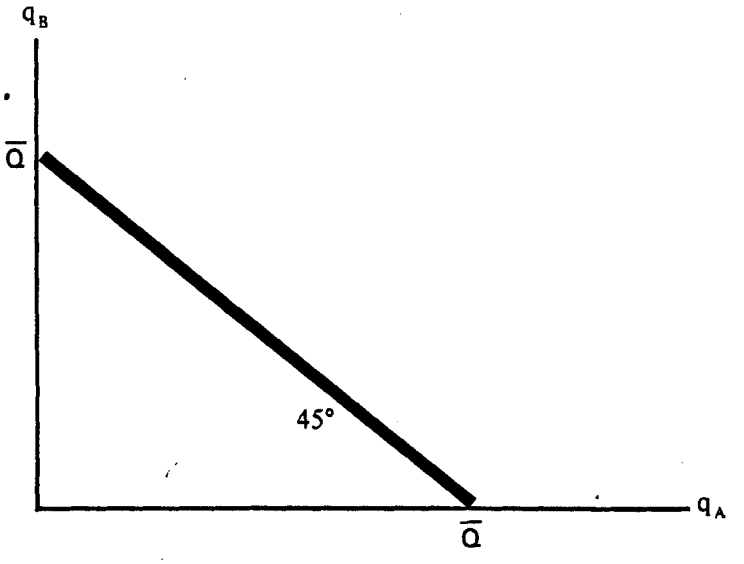
of oil than before, at a given oil price determined in country B's currency, p_B (US dollars). In the above figure, this is expressed by an upward movement of the curve, and oil prices in country A's currency will change from P_A^1 to P_A^2, where $P_A^2 > P_A^1$. Country A's currency is then de facto devalued; either through an administered devaluation of the currency in country A, an administered appreciation of the currency in country B, or a change in the exchange rate between the currencies caused by other market forces.

We assume that the actual purchase of oil by the two countries equals the total oil supply, Q. Thus, the total oil supply is given in this model:

$$q_A + q_B = \bar{Q}$$

This equation can be illustrated graphically, as in **figure 2.3**. The supply is assumed to be totally inelastic and will not be influenced by price changes. Thus, in our partial equilibrium model, a certain level of demand in one country directly determines demand in the other. This is, of course, a simplification, carried out because of its usefulness in analyzing the problem at hand. But, to include supply changes in this pure economic model, we should have to assume that, in one way or another, the supply side would react uniquely to price changes. Experts disagree on how oil supply

2.3 Possible distributions of crude oil supply between country A and country B



reacts to changes in oil prices. Some experts even claim that prices are only a minor factor in the determination of crude oil supply, and that political factors determine crude oil supply. Thus, as a pure price-quantity scheme seems to be too uncertain and/or too simple to describe supply side behaviour, we exclude this discussion by considering supply exogenously in our model.[3] We shall, however, discuss some effects on our results, if we modify this assumption in section 3.

Our equations outline:

(1) how demand for oil in each country varies with respect to national prices;

(2) the relationship between national prices; and

(3) that total consumption equals total supply.

2.4 Analytical model for oil prices and exchange rates

2.4.1 $q_A = f(p_A)$

2.4.2 $q_B = g(p_B)$

2.4.3 $p_A = V_A \times p_B$

2.4.4 $q_A + q_B = Q$

The system consists of four equations and six variables (p_A, p_B, q_A, q_B, V_A, and Q). We assume Q to be exogenously determined in the model (supply is kept constant); thus changes in the system are dependent upon the determination of the exchange rate.

Differentiating 2.4.1 – 2.4.4 gives:

2.4.5 $dq_A = f' \times dp_A$ where $f' < 0$

2.4.6 $dq_B = g' \times dp_B$ where $g' < 0$

2.4.7 $dp_A = V_A \times dp_B + p_B \times dV_A$

2.4.8 $dq_A + dq_B = 0$

Reorganizing 2.4.5 – 2.4.8 gives the following results from altering the exchange rate (appreciating the dollar):

2.4.9 $$\frac{dp_A}{dV_A} = \frac{g' \times p_B}{g' + f' \times V_A} > 0$$

The price of crude in country A *increases*; an appreciation of the dollar results in an increase in oil prices outside the US.

2.4.10 $$\frac{dq_A}{dV_A} = \frac{f' \times g' \times p_B}{g' + f' \times V_A} < 0$$

The price increase in country A implies a *decrease* in demand in that country. An appreciation of the dollar in relation to other oil importers' currencies causes a decrease in oil demand outside the US.

2.4.11 $$\frac{dp_B}{dV_A} = \frac{-f' \times p_B}{g' + f' \times V_A} < 0$$

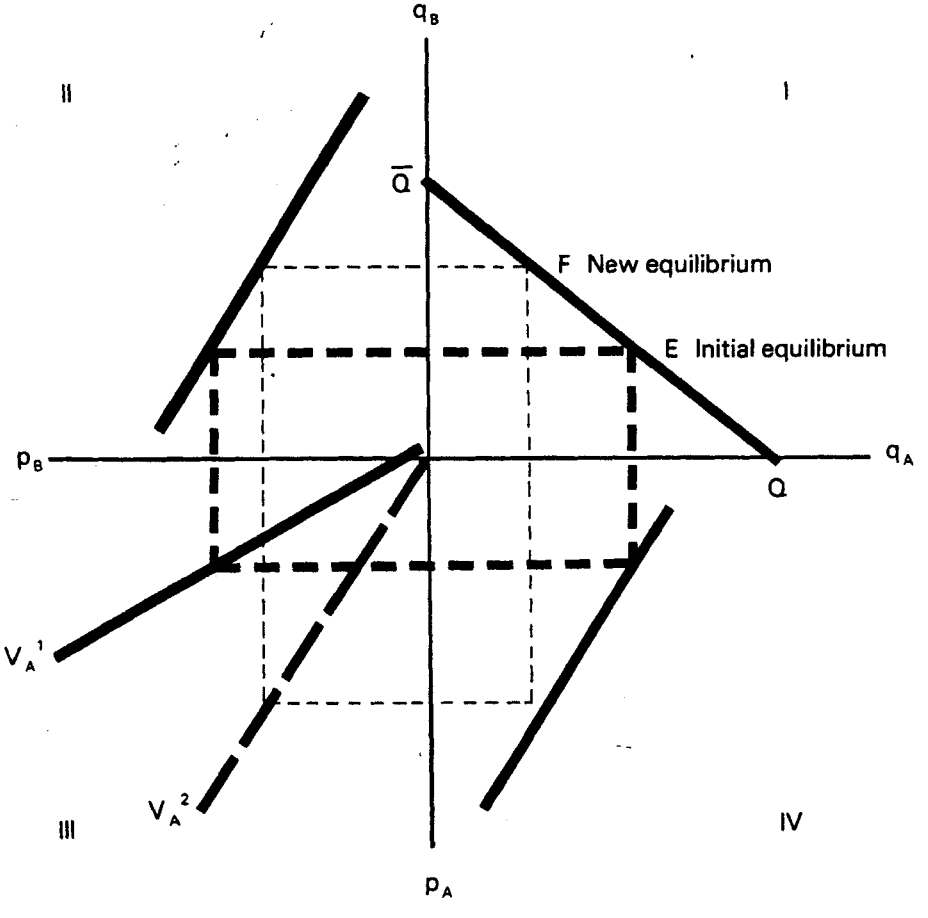
Equilibrium in our model implies a *decrease* in country B's price. An appreciation of the dollar in relation to other oil importers' currencies causes the crude oil price in dollars to decrease.

$$2.4.12 \qquad \frac{dq_B}{dV_A} = -\frac{dq_A}{dV_A} = -\frac{f' \times g' \times p_B}{g' + f' \times V_A} > 0$$

Oil demand in country B *increases*. An appreciation of the dollar towards other oil importers' currencies causes oil demand in the US to increase.

Graphically 2.4.1 – 2.4.4 can be illustrated as in **figure 2.5**. We illustrate, in the first quadrant, the distribution of the total crude oil supply (2.3), in the second quadrant crude oil demand in country B, and in the fourth quadrant oil demand in country A (both 2.1); while, in the third quadrant,

2.5 Graphical model for oil prices and exchange rates



the curves V_A^i $(i = 1, 2)$ illustrate the relationship between the prices in the two countries (2.2) with two different exchange rates between them.

Initially equilibrium is at point E, where demand is distributed between the countries at the prevailing prices and exchange rates. This initial equilibrium is illustrated by the thicker broken lines.

If country A's currency de facto is devalued, the relationship between the national oil prices is affected. This is expressed by a shift of the curve from V_A^1 to V_A^2 in the third quadrant.

After the devaluation, the initial distribution of crude oil no longer represents a state of equilibrium, since it is inconsistent with the new relationship between the prices in the two countries. The new equilibrium is at point F, where country A's oil price has increased. This implies that demand decreases in that country. Accordingly, country B's price has decreased, since oil demand in country A has increased. Thus, a switch in oil consumption from country A in favour of country B has taken place.

In this model, the quantity effects of a devaluation will be of the same size in both countries, with opposite signs. The decline in consumption in one country will be met by a corresponding rise in consumption in the other.[4] Thus, the numerical value of the elasticity of demand in each country, with respect to the exchange rate, can be expressed as:

$$2.5.1 \qquad \left| El_{V_A} q_i \right| = \left| \frac{dq_i}{dV_A} \right| \times \frac{V_A}{p_i} = \left| \frac{f' \times g' \times p_B}{g' + f' \times V_A} \right| \times \frac{V_A}{p_i} \quad (i = A, B)$$

This elasticity gives an impression of by how many per cent q_i will change when V_A changes by one per cent. It illustrates that a low numerical value of the demand derivatives with respect to prices f' and g', also corresponds to a low numerical value of the demand elasticity with respect to exchange rates. Since demand elasticities have the same sign as the corresponding demand derivatives, but give an expression of relative (as opposed to absolute) changes, we can conclude that the transfer effect in quantity of a devaluation of one of the currencies is *lower*, the *more inelastic* the demand is with respect to national prices. The demand elasticity with respect to prices in one of the countries will (in this model) have as strong an impact on demand in the other country as the demand elasticities (with respect to prices) in the country itself.

An appreciation of the dollar, however, will not necessarily result in a total redistribution of the volume of oil between the US and other importing countries. Because of a rigid production structure and other features unique to the US, there will be some limitations on how much oil the nation can

absorb in the short run, independently of the price. In addition to the downward pressure on the dollar price of oil in the adjustment towards a new equilibrium, an appreciation of the dollar would probably lead to a decrease in the total quantity demanded as well.[5]

The elasticities of the national price with respect to the exchange rate between the two countries' currencies can be expressed as:

$$2.5.2 \qquad El_{V_A} p_i = \frac{dp_i}{dV_A} \times \frac{V_A}{P_A} \begin{array}{l} > 0 \quad \text{if } i = A \\ < 0 \quad \text{if } i = B \end{array}$$

The equations 2.4.9 and 2.4.11, respectively, provide us with the sign of the above equations for each country. From these, we can see that the difference in the numerical values of the two countries' price derivatives with respect to exchange rates is the numerical value of the demand derivatives with respect to prices, f′ and g′. In relative terms, this implies that the difference between the numerical value of the elasticities of national oil prices with respect to the exchange rate is also the numerical value of f′ and g′:

$$2.5.3 \qquad \left| El_{V_A} p_A \right| \begin{array}{l} > \\ = \\ < \end{array} \left| El_{V_A} p_B \right| \quad \text{if} \quad \left| g' \right| \begin{array}{l} > \\ = \\ < \end{array} \left| f' \right|$$

This means that the elasticities of price with respect to the exchange rate depend on the elasticity of demand in each of the countries with respect to national oil prices. This implies that the oil price changes in the devaluing country will be *larger* the more *inelastic demand* is with respect to prices in that country. The effect will be *smaller*, the more *inelastic demand* is with respect to prices in the other country.

Thus, an appreciation of the dollar leads to a smaller price decrease for oil denominated in dollars, the more elastic demand is in the US and the more inelastic it is in other oil-importing countries. The more elastic demand is in the US *relative to* demand in other importing countries, the less the dollar price will be pushed downwards, and vice versa.

Experts do not always agree whether oil production will rise or fall with increasing oil prices. The picture becomes even more complex when political factors are added. In the model, we have assumed that supply is kept constant; i.e. that supply is exogenously determined. But if, for example, supply increases with rising prices, an appreciation of country B's currency will lead to decreased oil production in that country, and increased oil production in country A. Total world oil supplies will increase, remain the same or decrease, depending upon whether the elasticities of supply with respect to

prices multiplied by each country's crude oil output are larger, equivalent to or smaller in country A than in country B. Thus, an appreciation of the dollar would normally lead to an increase in world oil production, since supply to the world oil market is much larger from outside than from inside the US.[6] If supply reacts negatively to price increases (backward bending supply curve), similar arguments can be put, with the signs reversed. To say more precisely how total supply will react to exchange rate fluctuations, one would have to include more comprehensive models for the crude oil market, which in their turn would require precise presumptions about the frames for, and rules of, the market, in both the economic and the political sense.

The decrease in total demand and the probable increase in total supply resulting from the appreciation of the dollar, creates (in, and of, itself) an imbalance in the market. This results in further downward pressure on oil prices denominated in dollars.

The US's share of the oil market will also be one of the factors determining the degree to which changes in the value of the dollar have an impact on oil prices. If the US has a small market share, the dollar is less representative for denominating oil prices than if it has a larger share. The dollar price will have to *change more* to rectify an imbalance in the market, *the smaller the US's share of the world oil market*, and the entire system will be more volatile.

3. Closing comments

Depending upon currency market developments, nations can face different oil prices, with demand and supply conditions held constant. The model presented in this paper illustrates that an increase in the exchange rate of the dollar against other currencies (as in the first half of the 1980s) leads to a lower oil price in dollars, higher crude oil demand in the US and lower crude oil demand in the rest of the world. If, on the other hand, the exchange rate of the dollar *depreciates* (as in the 1970s), the oil price denominated in dollars increases, crude oil demand in the US decreases and crude oil demand in the rest of the world increases.[7] Since it seems likely that there are some *time lags* between exchange rate fluctuations and crude oil market reactions, the model may be viewed as an illustration of a long-run equilibrium in the crude oil market.[8]

Thus, as a result of the steadily increasing exchange rate of the American dollar in the first half of the 1980s, most countries' oil prices increased rather than decreased.[9] Since OPEC reduced their output in the period simultaneously, one could say that they have followed a relatively aggressive pricing policy in the first half of the 1980s. The strategy of decreasing supply

to prop up oil prices in dollars, has, together with a lower economic growth rate, contributed to the sharp decrease in oil consumption.

In 1987, the continued decline in the value of the US dollar has been contributing, on the other hand, to an increase in oil demand outside the US. This is in addition to the increased demand initiated by lower dollar oil prices and otherwise increased economic activity. If the decline in the value of the dollar continues its trend in future years, one could expect stronger price increases in dollar terms, as compared with projections based solely on the development of demand and the utilization of capacity in OPEC Member Countries alone.

Thus, developments in the currency market represent a factor of uncertainty in the prognoses of future oil prices denominated in dollars. The divergent development of oil prices contributes to different regional growth rates, and thus to different patterns in oil demand. Accordingly, the projections of future oil demand must incorporate considerations about possible currency market developments. If one, for example, uses only US dollars as a measure of the development of oil prices, the consumer's total reaction to price changes might well be over- or under-estimated.

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Footnotes

1. *We consider taxation levels on petroleum and other internal factors in the two countries to be constant. Fluctuating exchange rates will also alter the prices of all goods paid in dollars. This will make a contribution to the substitution between the dollar paid goods and goods paid in other currencies. The nations' national incomes and assets will change as a result of the altered exchange rates as well. These substitution and income effects are unsure in direction and strength and are excluded in this analysis.*

2. *In fact, country A's currency (the world outside the US) will be a currency basket where all individual countries' dollar exchange rates are included. The weights given to each currency could, for example, be each nation's import share of crude oil.*

3. *For a more detailed discussion about using economic and political approaches to analyze the oil market, and how this can be included in theory on the formation of crude oil prices, see, for example, Austvik 1986.*

4. *This can be seen directly from 2.3.*

5. *From table 1.2, one can see that a decrease in imports of ten per cent in the world outside the US should roughly require an import increase of the size of 30 per cent in the US. This seems rather unlikely, at least in the short run.*

6. *In our model, if the supply increases (as would be the case at "normal" price levels), the line Q-Q in the first quadrant will shift to the right in figure 2.5. Depending on the demand elasticities, the extra quantities supplied will be distributed to the two countries. This will, in effect, lower prices in both countries. In the country that appreciates its currency (country B), the incremental quantities will strengthen the downward trend in prices which the changes in the currency rates initiated. Depending on the size of the devaluation, the demand elasticities existing in the two countries and the size of the incremental supply, the price increase in the devaluing country will be moderated, neutralized or reversed by the increased supplies.*

7. *The model is a partial one, however, and other factors important for the development of prices might well be strong enough to bring about both an appreciation of the dollar and an increase in the dollar price, or vice versa. This could happen if, for example, the oil-exporting countries simultaneously reduced the quantity of oil exported.*

8. *The degree by which the total quantity is reduced, the distribution on the different markets, and the effects on the two oil prices depend on the size of the demand elasticities (with respect to prices) in the different markets and reactions from actors in the market, especially the oil-exporting countries. With regard to certain assumptions about developments in demand and supply, Huntington (1986) has calculated a possible scenario for prices in 1990 to be in the range of $25-34/b (1985 prices). If changes in exchange rates only affect demand, he estimates the difference of $9/b between the highest and the lowest prices, alternatively, to represent five mb/d in the market. He calculated this range of possibilities to be larger than the effect of different realistic growth rates.*

9. *Huntington (1986) has calculated that, if oil prices had fallen for all buying countries as they did for the US in the period 1980-84, the demand for crude would have been 3.0 mb/d higher than the actual level of 1984 (6.6 per cent).*