# Solutions to Tutorial Questions

**Chapter 9 Non-renewables**

**9.1 Why do the predictions of the simple version of Hotelling’s rule rarely hold?**

For Hotelling’s rule to work as a predictive model it requires a number of unrealistic conditions to hold. Without exhaustively listing what all of these are, they can be summarised as rationality and perfect foresight. For markets to drive prices up exactly at the interest (discount rate) would require them to be profit maximizing through time and anticipate exactly how resource extraction will unfold for many years ahead. Not surprisingly mining and oil extraction firms find this task impossible, and in any case may have little incentive to adjust the output of a resource so that they ensure the price increases at the interest rate. Here are some specific reasons why prices or marginal profit (when costs are positive) may not rise at the interest rate. Mining and oil extraction is a capital intensive industry and investments are irreversible, therefore it is often optimal to maintain a constant output regardless of price. Technological change has meant that costs per barrel of oil and per tonne of iron ore extracted have fallen sharply, by reducing marginal costs through time this counteracts the Hotelling’s rule effect, and may actually lead to price reductions. Resource stocks are not fixed and new discoveries may actually reduce scarcity and lead to reductions in resource prices.

For these reasons the simple version of Hotelling’s rule has been a poor predictor of the actual time paths for non-renewable resource prices.

**9.2 Is the market price of oil an accurate measure of resource scarcity?**

Resource scarcity is measured by the value of a unit of the resource in the ground. The problem is that the value of the resource stock, unlike the price of the extracted resource, is not recorded on any market. Let us take a competitive profit maximizing firm that owns a stock of oil. At the margin the firm determines extraction so that:

**price per tonne =marginal extraction cost per tonne+ value of the resource stock per tonne**

From this it is apparent that the price (the variable that is observed) is not a direct measure of the resource scarcity because of the marginal extraction cost. In fact, only if the marginal cost were zero would the price be an accurate measure of scarcity. The price is likely to be correlated with the value of the resource stock, but not perfectly correlated. For instance, if technological change reduces marginal cost across an industry this, all other things being equal, may lead to a reduction in price but not a reduction in the value of the resource stock and thus its scarcity.

**9.3 Define the idea of lifetime of a resource as a measure of resource scarcity. Why do most economists think that it is not a good measure of scarcity?**

The lifetime of a resource is the current known economic reserves divided by the current annual rate of consumption. Most economists do not view this as a useful measure of scarcity, because it does not allow for the working of markets. As a resource becomes scarcer the price rises. This leads mining firms to bring previously uneconomic deposits into production, and to devote more resources to exploration. Evidence of this market effect can be found in the number of resource exhaustion dates that have come and gone without the resource actually running out. Fisher (1981) cites the example of copper: copper in 1974 was predicted to have 45 years left taking it to 2019. Cohen in 2007 predicts it has another 61 years reserves remaining at current consumption levels.

**9.4 Why could it be argued that OPEC is reducing the rate of oil extraction?**

OPEC works as a cartel, which has the aim of increasing the profitability of the major oil exporters, that are part of the OPEC “club”. They do this by agreeing export quotas, that in turn limit supply and increase the world price of oil. By raising the oil price OPEC reduces demand and thus the rate of extraction. OPEC operates like a firm with market power: it limits output to increase the price. In more recent years the power of OPEC has been limited by the increase in the production of oil from shale from Canada and the USA.

**9.5 What is the backstop price? Give three examples of backstop technologies.**

The backstop price is the price of a substitute (in the simple model a perfect substitute) to a non-renewable resource. The substitute may be a manufactured alternative or an alternate non-renewable resource. Examples in include: plastic pipes for copper, oil from shale for conventional oil, and wind energy to provide electricity (for instance in Europe) for coal and natural gas energy