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以下三題請詳讀題目後說明(1)題目之主要重點及(2)該題目在資源管理之意涵。(資料來源：Tom Tietenberg and Lynne Lewis (2009), Environmental & Natural Resource Economics, 8th Edition, Pearson International Edition.

(一) World population growth has slowed considerably in recent years. Population declines are already occurring in Germany and are expected in the near future in a number of northern European countries. The U.S. total fertility rate is below the replacement level. If maintained for a number of years, this fertility behavior would usher in an era of zero or negative population growth for the United States as well.

Those countries experiencing declines in their population growth will also experience a rise in the average age of their population. This transition to an older population should boost income per capita growth by increasing the share of the population in the labor force and by allowing more family wealth to be concentrated on the nutrition, health, and education of the children.

All other things being equal, lower population growth should also help to reduce income inequality. On average this effect will be felt most strongly in lower-income families, since they typically are larger. This tendency for incomes of lower-income families to increase faster than those of higher-income families should be reinforced by the effects on labor supply. By preventing an excess supply of labor, which holds wages down, slower population growth benefits wage earners. Wages are a particularly important source of income for lower-income families.

Finally, while population growth is not the sole or perhaps even the most important source of nonsustainability, it definitely plays a significant role. If, as seems reasonable, there exists a maximum level of economic activity that can be sustained without undermining the resource base upon which it depends, population growth determines how the fruits of that activity are shared. While a smaller global population could experience relatively high individual standards of living, a larger population would have to settle for less. (占 30 分)

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(二) The term *technological progress* plays an important role in the economic analysis of mineral resources. Yet, at times, it can appear abstract, even mystical. It shouldn't! Far from being a blind faith detached from reality, technological progress refers to a host of ingenious ways in which people have reacted to impending shortages with sufficient imagination that the available supply of resources has been expanded by an order of magnitude and at reasonable cost. To illustrate how concrete a notion technological progress is, consider one example of how it has worked in the past.

In 1947 the president of Republic Steel, C. M. White, calculated the expected life of the Mesabi Range of northern Minnesota (the source of some 60 percent of iron ore consumed during World War II) as being in the range from five to seven years. By 1955, only eight years later, *U.S. News and World Report* concluded that worry over the scarcity of iron ore could be forgotten. The source of this remarkable transformation of a problem of scarcity into one of abundance was the discovery of a new technique of preparing iron ore, called *pelletization*.

Prior to pelletization, the standard ores from which iron was derived contained from 50 to more than 65 percent iron in crude form. There was a significant percentage of taconite ore available containing less than 30 percent iron in crude form, but no one knew how to produce it at reasonable cost. Pelletization is a process by which these ores are processed and concentrated at the mine site prior to shipment to the blast furnaces. The advent of pelletization allowed the profitable use of the taconite ores.

While expanding the supply of iron ore, pelletization reduced its cost in spite of the inferior grade being used. There were several sources of the cost reduction. First, substantially less energy was used; the shift in ore technology toward pelletization produced net energy savings of 17 percent in spite of the fact that the pelletization process itself required more energy. The reduction came from the discovery that the blast furnaces could be operated much more efficiently using pelletization inputs. The process also reduced labor requirements per ton by some 8.2 percent while increasing the output of the blast furnaces. A blast furnace owned by Armco Steel in Middletown, Ohio, which had a rated capacity of approximately 1,500 tons of molten iron per day, was able by 1960 to achieve production levels of 2,700 and 2,800 tons per day when fired with 90 percent pellets. Pellets nearly doubled the blast furnace productivity! (占35分)

Source: Peter J. Kakela. "Iron Ore: Energy Labor and Capital Changes with Technology," *Science* Vol. 202 (December 15, 1978): 1151–1157; Peter J. Kakela "Iron Ore: From Depletion to Abundance," *Science* Vol. 212 (April 10, 1981): 132–136.

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(三) When can we expect to run out of oil? It's a simple question with a complex answer. In 1956 geophysicist M. King Hubbert, then working at the Shell research lab in Houston, predicted that U.S. oil production would reach its peak in the early 1970s. Though Hubbert's analysis failed to win much acceptance from experts either in the oil industry or among academics, his prediction came true in the early 1970s. With some modifications this methodology has since been used to predict the timing of a downturn in global annual oil production as well as when we might run out of oil.

These forecasts and the methods that underlie them are controversial, in part because they ignore such obvious economic factors as prices. The Hubbert model assumes that the annual rate of production follows a bell-shaped curve, regardless of what is happening in oil markets; oil prices don't matter. It seems reasonable to believe, however, that by affecting the incentive to explore new sources and to bring them into production, prices should affect the shape of the production curve.

How much difference would incorporating prices make? Pesaran and Samiei (1995) find, as expected, that modifying the model to include price effects causes the estimated ultimate resource recovery to be larger than implied by the basic Hubbert model. Moreover, a study by Kaufman and Cleveland (2001) finds that forecasting with a Hubbert-type model is fraught with peril.

> *... production in the lower 48 states stabilizes in the late 1970's and early 1980's, which contradicts the steady decline forecast by the Hubbert model. Our results indicate that Hubbert was able to predict the peak in US production accurately because real oil prices, average real cost of production, and [government decisions] co-evolved in a way that traced what appears to be a symmetric bell-shaped curve for production over time. A different evolutionary path for any of these variables could have produced a pattern of production that is significantly different from a bell-shaped curve and production may not have peaked in 1970. In effect, Hubbert got lucky. [p. 46]*

Does this mean we are not running out of oil? No. It simply means we have to be cautious when interpreting forecasts of the timing of the transition to other sources of energy. In 2005 the Adminsitrator of the U.S. Energy Information Agency presented a compendium of 36 studies of global oil production and all but one forecasted a production peak. The EIA's own estimates range from 2031 to 2068 (Caruso, 2005). The issue, it seems, is no longer whether oil production will peak, but when. (占35分)

Sources: M. Pesaran and H. Samiei. "Forecasting Ultimate Resource Recovery," *International Journal of Forecasting* Vol. 11, No. 4 (1995): 543–555; and R. Kaufman and C. Cleveland. "Oil Production in the Lower 48 States: Economic, Geological, and Institutional Determinants," *Energy Journal* Vol. 22, No. 1 (2001): 27–49; Caruso, G. "When Will World Oil Production Peak? A presentation at the 10th Annual Asia Oil and Gas Conference in Kuala Lumpur, Malaysia, June 13, 2005.