

2 An Introduction to Economic Growth Theory and the Oil Market

The reliance of production and economic growth on natural resources, specifically oil, may result in a decline on economic growth due to resource constraints.

Malthus (1803) was one of the first who attempted to answer the question whether natural resources hinder or even limit economic growth. He concluded that an exponential increase in population cannot be sustained with a modest linear increase of food production. The finite agricultural production possibilities due to limited land availability would result in the starvation of the excess population. The scarce natural resource, land, leads to long-term economic stagnation. Shortly after Malthus described his theory the industrial revolution began. The industrialization helped western European countries to escape the Malthusian trap.

In the pre-industrial era, the economy was based primarily on land and renewable resources, e.g. agricultural crops, wood, water, and wind. This changed dramatically with the industrial revolution. The economy is now based more heavily on exhaustible resources, initially coal and now oil. The finite nature of nonrenewable resources implies that an economy faces a trade-off between the present and the future. What effect the exhaustion of resources has on economic growth and welfare became relevant.

Starting with Hotelling (1931) various economists studied the optimal extraction of exhaustible resources and the resulting limits to economic growth. According to the basic Hotelling rule, the extraction of nonrenewable resources is most socially and economically profitable when the price of the resource increases with the

rate of interest (no arbitrage condition). Overall social welfare requires that the consumption of resources in production today is balanced with the consumption of future production. This would result in the partial extraction of the resource over time. It, however, has been empirically proven that there are many other factors affecting the price of natural resources.² A prominent example is crude oil. In the last century the real price of oil has fluctuated significantly.

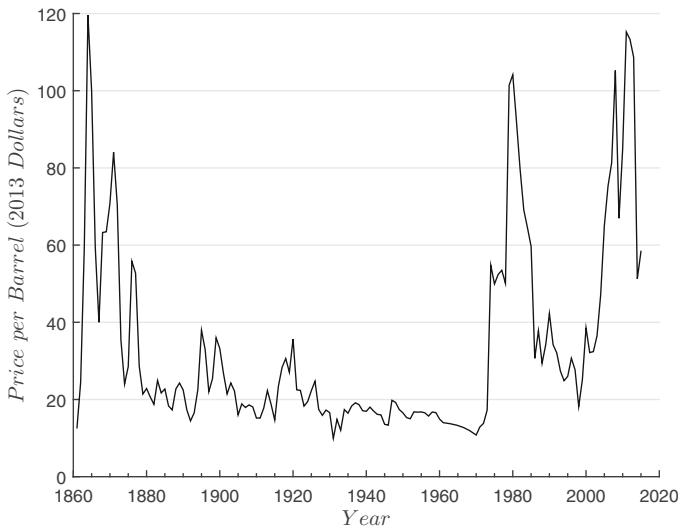


Fig. 2.1: Real Price of Oil, 1861-2015.

Source: BP (2014) Statistical Review of World Energy, extended to 2015.

The basic Hotelling's rule would suggest an increasing price behavior. The oil price, however, has been more dependent to political factors and to the market power of OPEC (Organization of the Petroleum Exporting Countries, the intergovernmental cartel that controls about 75% of the world's crude oil supply)

² Possible expansions of Hotelling's rule are suggested by e.g. Krautkraemer (1998) and Gaudet (2007).

than to the exhaustion of oil. The most significant price movements during the last century are associated with the first assertion of power by OPEC, the Arab oil embargo (1973), the first Gulf War (1990-1991) and the increase in commodity prices (around 2005). This increase was partly stopped by the Financial Crisis (2008). The supply cut by the OPEC (2009) and the Arab spring (2010) led to further price increases until mid 2014. The high oil prices and technological progress led to the increased utilization of “unconventional” sources, such as offshore oil, tar sands, tight oil, heavy oil, shale gas, coal-bed methane, shale oil, and oil shale. These oil sources are considered “unconventional” because previously the extraction process was economically not profitable. Recently hydraulic fracturing, or fracking has drastically changed the petroleum industry. Fracking is a technique for shooting water mixed with sand and chemicals into rock, splitting it open, and releasing previously inaccessible oil, referred to as tight oil. Fracking is criticized as an environmental menace to underground water supplies, and may eventually be greatly restricted. The increased accessibility of tight oils in North America would enable the United States to satisfy its own oil demand within a decade (at least for a while). Increased fracking led to a loss in market shares for Saudi-Arabia, the world largest oil producer. As a reaction Saudi-Arabia started to dump oil on the market to shake the weak production out of the market. This is one reason for the significant price decline until today.

Returning to the original question of what effect the exhaustion of natural resources has on economic growth; the pessimistic view on limited economic growth remains. Meadows et al. (1972) concluded that the long-run prospect may be worse than stagnation. They predicted the starvation of mankind in the near future. Data from 1900-1970 established a baseline of past behavior on which a model to forecast the events of the period 1970-2100 was based. Based upon the observed trends of resource use, the world should have run out of the main exhaustible resources (oil, gas, iron and copper) within a thirty years range. The result is depicted in figure 2.2.

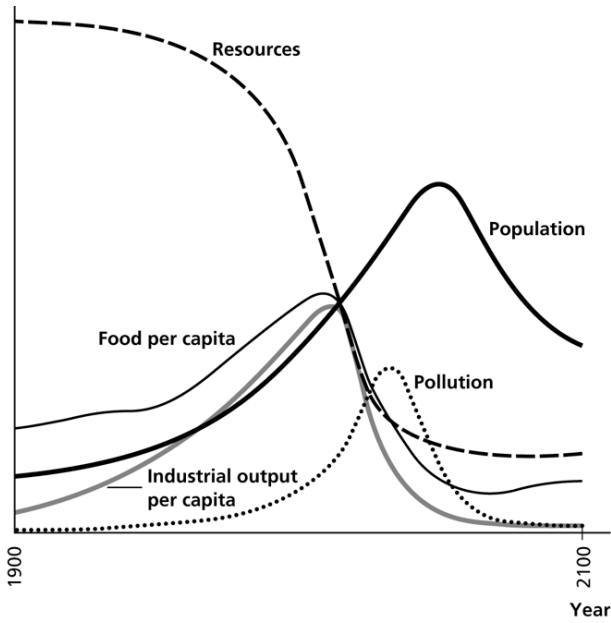


Fig. 2.2: Growth Forecast from the Limits to Growth.

Source: Meadows et al. (1972), Figure 35.

So far this doomsday scenario has been utterly wrong. Although the current level of resource consumption may not be sustainable, economic growth is not necessarily limited.

The evolution of the analysis process can be understood using the example of crude oil. For many years it has been the world's most important source of energy. It is used to generate heat, drive machinery, and fuel vehicles. Crude oil supplied about 33% of global energy needs in 2014 (followed by coal (30%), natural gas (24%), renewable resources (9%), and nuclear (4%)).³ Its components are used to produce almost all chemical products, such as plastic, detergent, paint, and even

³ Compare BP (2014, p. 40).

medicine. Oil affects all aspects of daily life. The percentage of market shares of oil associated with different aspects of daily life are depicted below.

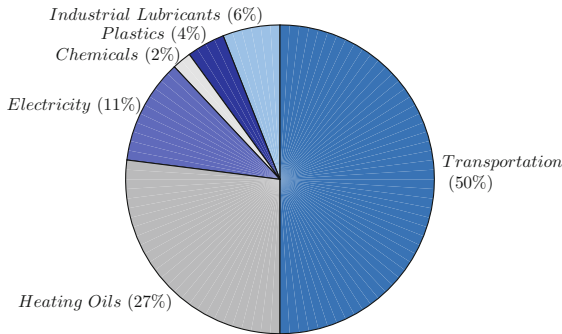


Fig. 2.3: Global Usage of Oil.

Source: National Oceanic and Atmospheric Administration (2011).

Oil is one of the world's largest traded commodities (measured in value or volume) due to its broad implementation range. Deutsche Bank (2013, p. 109) estimates that 59% of the commercially recoverable oil reserves have already been extracted and consumed. Weil (2013, p. 486) estimates that the remaining quantity of crude oil will last 61 years at the current rate of use. However, historically the exhaustion of raw materials has been continuously postponed despite a rising consumption rate. Two important explanations are newly discovered oil reserves and technological advancements. Over the last 40 years the oil consumption has been almost entirely covered by the discovery of oil reserves or technological advancements. This tendency is shown in the following graphic.

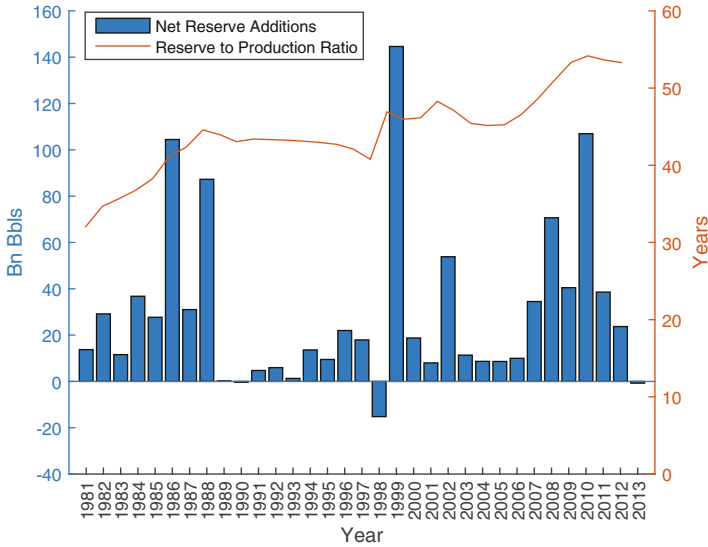


Fig. 2.4: Net Difference Between Annual Reserves Additions and Annual Consumption.

Source: Own illustration, based on data from BP (2014) Statistical Review of World Energy.

Despite increased consumption the reserve to production ratio has been steadily increasing. However, the oil supply is limited and with continuous consumption will be exhausted. The question remains whether the world economy can persist without considerable extraction of crude oil.

The negative effect of resource depletion has historically been compensated by other factors leading to continued economic growth. Substitution is one of the most basic factors. The exhaustible resource can be substituted by physical capital or another natural resource (if available). Natural substitutes for oil are natural gas or coal. In addition, a machine that uses oil more efficiently is an example of capital substitution.

Another factor is recycling. The increasing use of exhaustible resources is associated with increased waste. This offers new opportunities. The waste can be

recycled and used as a secondary material. Around 4% of world's oil production is used as a feedstock to make plastics.⁴ The plastic market is a good example of how waste can be recycled thus reducing the total consumption of oil. In the European Union 62% of post-consumer plastics waste is recovered through recycling and energy recovery processes while 38% ends up on the waste dump.⁵ Even though a lot of plastic is recycled worldwide, the effect on the depletion of oil is rather small. However, recycling may be a medium-term solution to continued growth. Additionally, recycling is interesting from an environmental point of view.

In the long-run technological progress is needed. Technological progress not only extends the economic lifetime but eases resource constraints that impede economic growth. Resource-augmenting technological progress can increase the efficiency of natural resource use, i.e. more output can be produced from a given amount of natural resources or less resources are needed for a given output. A specific example is the supplementation of fossil fuels with ethanol (E10).

Innovation reduces the cost of oil extraction from “unconventional” sources, increasing the lifetime of oil. A specific example is fracking. Moreover, technological progress can lead to an alternative technology which uses a different natural resource. New technology may allow oil to be replaced by methane hydrate, a crystalline natural gas located beneath the seafloor which exists in immense quantities. Methane hydrate is estimated to be twice as abundant as all other fossil fuels combined. However, all nonrenewable resource substitutes can only serve as temporary solutions. These “bridge fuels” will substitute oil until a technology is found which uses renewable resources and thus leads to sustained economic growth. A specific example is the use of alternative energy sources like sunlight, wind, water, and geothermal heat.

The thesis explains recycling and technological progress as a solution to the limited availability of fossil fuels using theoretical economic growth models.

⁴ Compare PlasticsEurope (2014, p. 3).

⁵ Compare PlasticsEurope (2015, p. 20).

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