Energia e Clima 1

SSST

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Sala Principi D'Acaja - Università di Torino

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Outline

1 Introduction (1 hour):

Course Overview

Energy and Climate - the challenges:

- energy, climate and sustainable energy,
- energy, climate and energy security

Some definitions:

- externalities,
- energy security,
- renewable and exhaustible resources,
- sustainable growth.

2 The economics of energy (2 hours)

- Economic theory of the exploitation of exhaustible resources,
- Hotelling's rule and its limits
- Hartwick's rule, physical capital, natural resources and sustainable growth
- Resource Curse and Dutch Disease Economic
- Theory of renewable resources. The tragedy of the commons: individual efficiency and collective inefficiency

3 Focus on Energy Sources: Prospects and Policy (3 hours)

- Perspectives and specific policies for
- Coal (with and without carbon sequestration)
- Oil
- Gas
- Renewables
- Energy efficiency

Outline del corso

4. Externalities and energy (2 hours)

The concept of externality. The Coase Theorem

Tools for the correction of negative externalities: taxes, subsidies, standards, and tradable permits.

Local and global externalities. Supra-national policies and local issues

Local energy externalities: oil spills

Global energy externalities of energy: climate change, greenhouse gas (GHG) emissions, human activities

5. Energy, climate and sustainability (2 hours)

Energy use and emissions of greenhouse gases: the link between GDP and GHG emissions.

The main drivers of change: population, economic growth, innovation

Responses to climate change. Mitigation and adaptation

Climate change mitigation policies and diplomacy: efficiency, equity and international agreements

Model Scenarios: Business as usual and stabilization scenarios

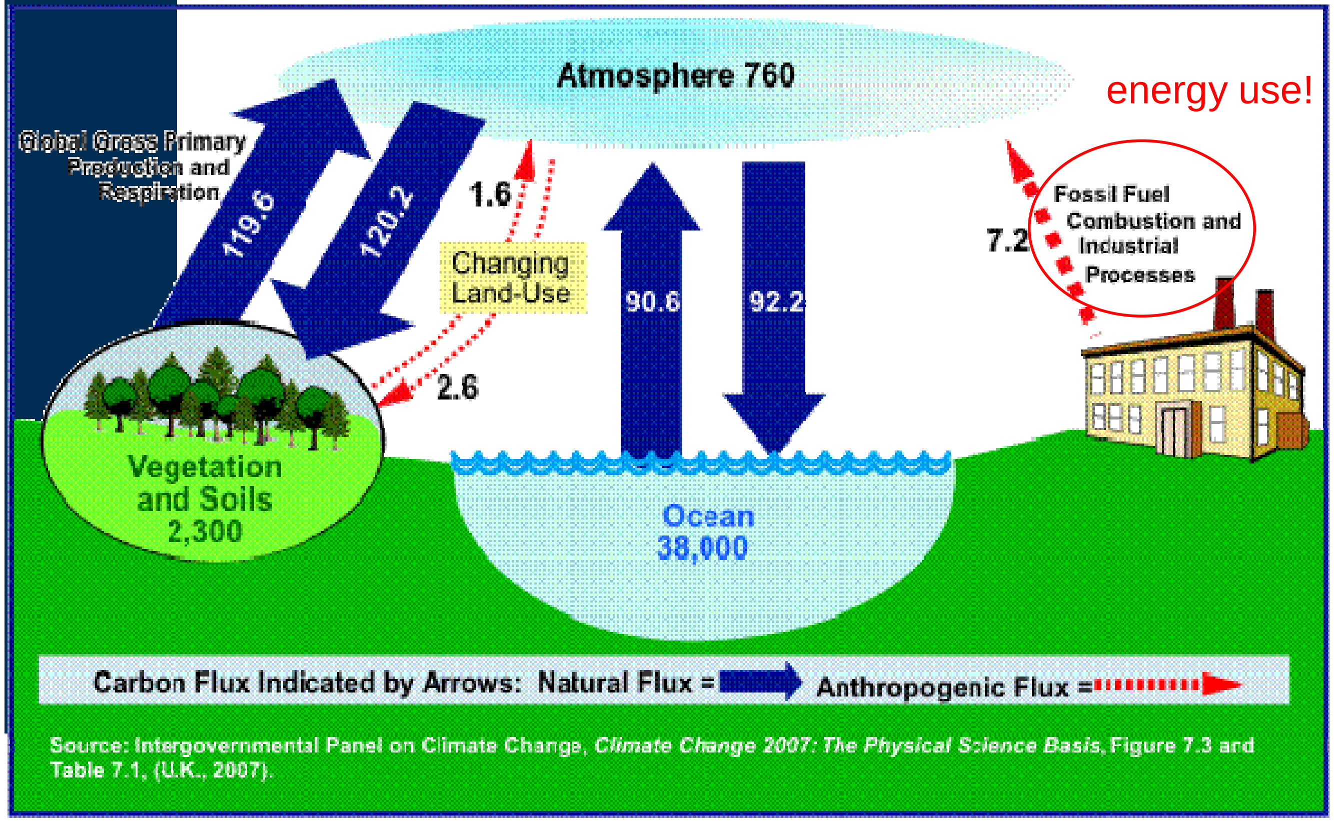
The stabilization energy mix. Desirable goals and realistic objectives

Conclusions: energy security and sustainability: conflicts and synergies.

Introduction: Energy and Climate - the challenges

- Energy, climate and sustainability
- Energy, climate and energy security supply

Energy, climate and sustainability: the carbon cycle



- Anthropogenic emissions: ~ 30 Gt CO_2 /year. 2km^3 cube
- Cumulated anthropogenic emissions: ~ 1000 Gt CO_2 since 1850
- Atmosphere's mass: ~ 5000000 Gt
- Current concentration of anthropogenic CO_2: 1000/500000 ~ 200 ppmv
- Natural CO_2 concentration: ~ 180 - 300 ppmv.
- Current total concentration: ~ 390 ppmv,
- **Net increase over natural concentration: ~100 ppmv**

Energy, climate and sustainability: from ppmv to W

Why higher CO_2 concentration means more heat?

The temperature of an object depends on the difference between the inbound heat flow or internally generated heat, and the outbound heat flow, To have an increase in temperature the net inbound flow must be positive.

In the case of Earth, CO_2 alters the heat flow of heat by absorbing the outgoing infrared radiation emitted from the earth. This is called **radiative forcing.**

“Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered. The word radiative arises because these factors change the balance between incoming solar radiation and outgoing infrared radiation within the Earth’s atmosphere. This radiative balance controls the Earth’s surface temperature. The term forcing is used to indicate that Earth’s radiative balance is being pushed away from its normal state.Radiative forcing is usually quantified as the ‘rate of energy change per unit area of the globe as measured at the top of the atmosphere’,and is expressed in units of ‘Watts per square metre’ When radiative forcing from a factor or group of factors is evaluated as positive, the energy of the Earth-atmosphere system will ultimately increase, leading to a warming of the system.” (IPPC AR4, WG1, chapter 2, 2007)

By how much? A good approximation is given by:

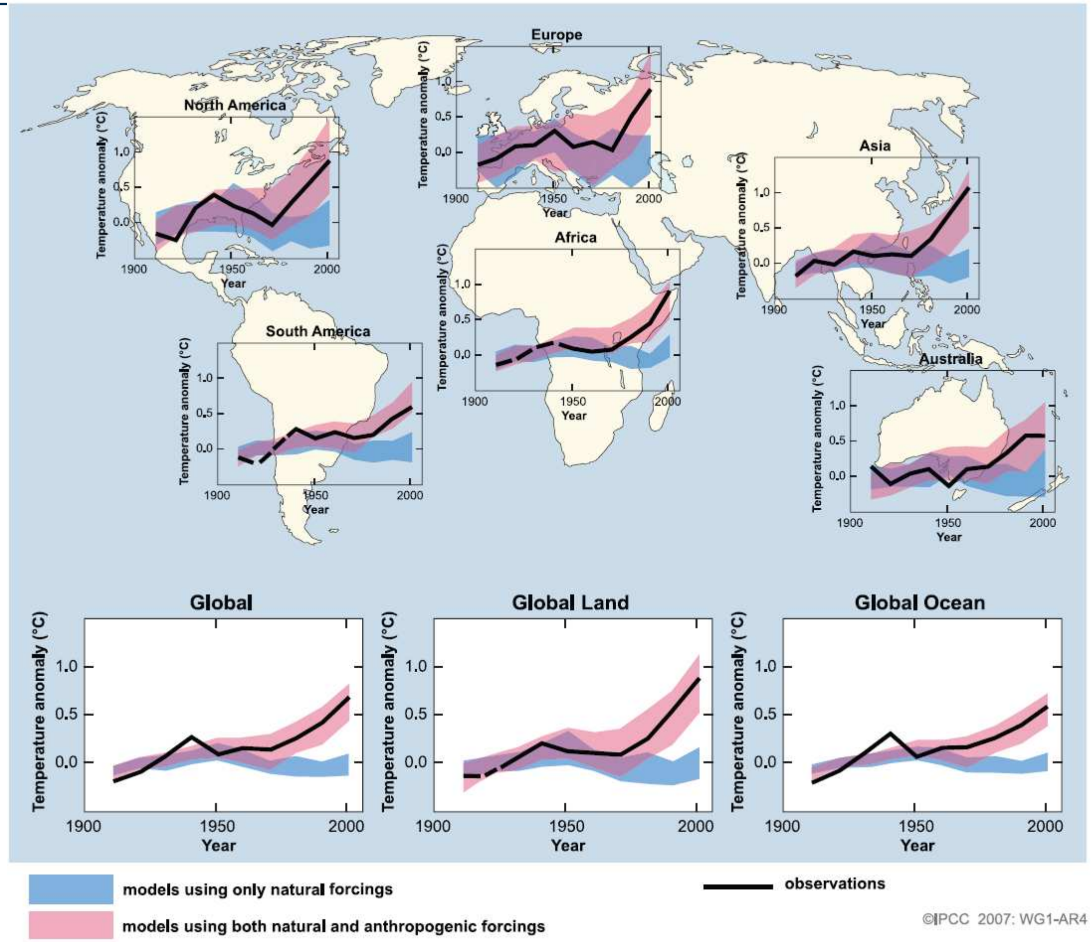
$$F=K*\ln(C/C_o)\ W/m^2\ ,$$

where K is a constant, C is the current concentration and C_o is a reference concentration. Taking pre-industrial concentration level as C_o , the excess energy in the atmosphere is 1.8 W/m^2.

Energy, climate and sustainability: Climate change - historical data

- The current global temperature increase over preindustrial levels is + 0.7-0.8 °C

- It cannot be explained without considering anthropogenic forcing.



Source: IPCC Climate Change 2007: _ The Physical Science Basis, Summary for Policymakers (2007), p11

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Energy, climate and sustainability: the case for mitigation policies

- the last IPCC report (4AR, 2007), in its most ambitious scenarios, indicates that the increase in global emissions must be halved in the next 10-15 years, and that global emissions must be reduced by 50% compared to 1990 levels by 2050, to prevent harmful interference of climate change on socio-economic and environmental systems, limiting the temperature increase within + 2.0 / + 2.4 ° C.

- Without intervention, temperature may increase by up to 6.4°C in the worst case IPCC scenario

- The Kyoto Protocol currently includes obligations to reduce emissions for industrialized countries (Annex I) within the period 2008-2012 that amounted to a 5% reduction on a global scale compared with the 1990

- Working Group AWG-KP IPCC in 2007 proposed a commitment on the part of developed countries to reduce their emissions in a range between 25% and 40% by 2020

- the EU is aiming a 30% reduction of its CO_2 emissions by 2020. "on condition that other major emitting countries in the developed and developing worlds commit to do their fair share under a future global climate agreement. This agreement should take effect at the start of 2013 when the Kyoto Protocol's first commitment period will have expired" (EU DG Environment).

Introduction: Energy and Climate - the challenges

- Energy, climate and sustainability
- Energy, climate and energy security supply

Introduction: energy and security-worrying about resource scarcity

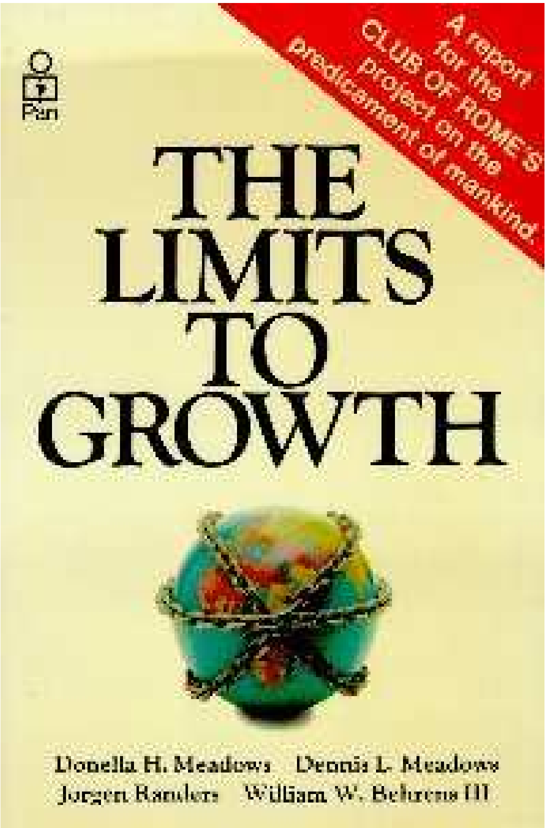
"The power of population is indefinitely greater than the power in the earth to produce subsistence for man."

"Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio".

"The cheapness of labour, the plenty of labourers, and the necessity of an increased industry amongst them, encourage cultivators to employ more labour upon their land, to turn up fresh soil."

THOMAS ROBERT MALTHUS
(1766-1834)

Introduction: energy security - worrying about resource scarcity

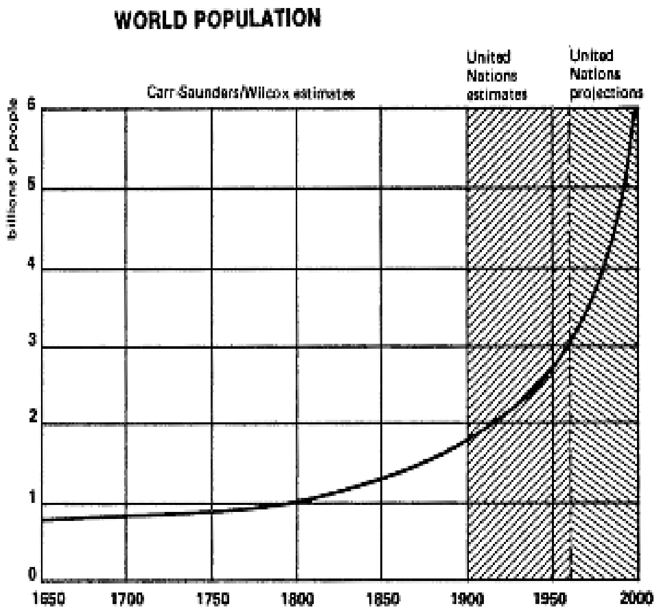


THE CLUB OF ROME

In the 1970's oil price shocks led to sharp price increases for many commodities. At that time many became alarmed at the rate of utilization of natural resources by mankind. It seemed that in just a few years real scarcity would become a major global problem.

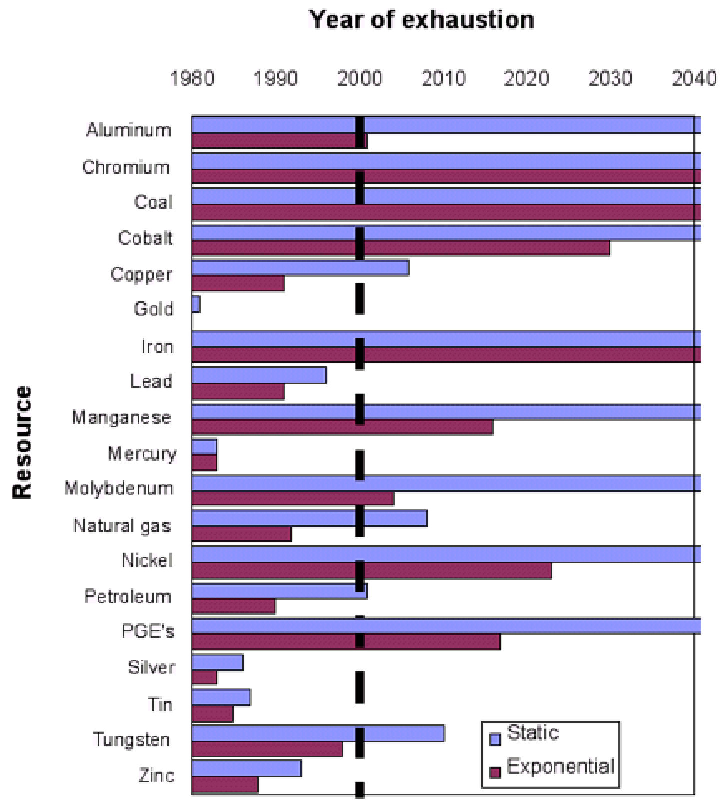
A clear reason for this alarm was the concept that certain natural resources are inherently limited in nature, and that current rates of use, or even the likely future rates of use would surely use them all up in the foreseeable future. The voice of this movement was the "Club of Rome", so named because they felt that western society, like ancient Rome, was doomed.

Introduction: energy security - worrying about resource scarcity



World population since 1650 has been growing exponentially at an increasing rate. Estimated population in 1970 is already slightly higher than the projection illustrated here (which was made in 1958). The present world population growth rate is about 2.1 percent per year, corresponding to a doubling time of 33 years.

SOURCE: Donald J. Bogue, *Principles of Demography* (New York: John Wiley and Sons, 1969).



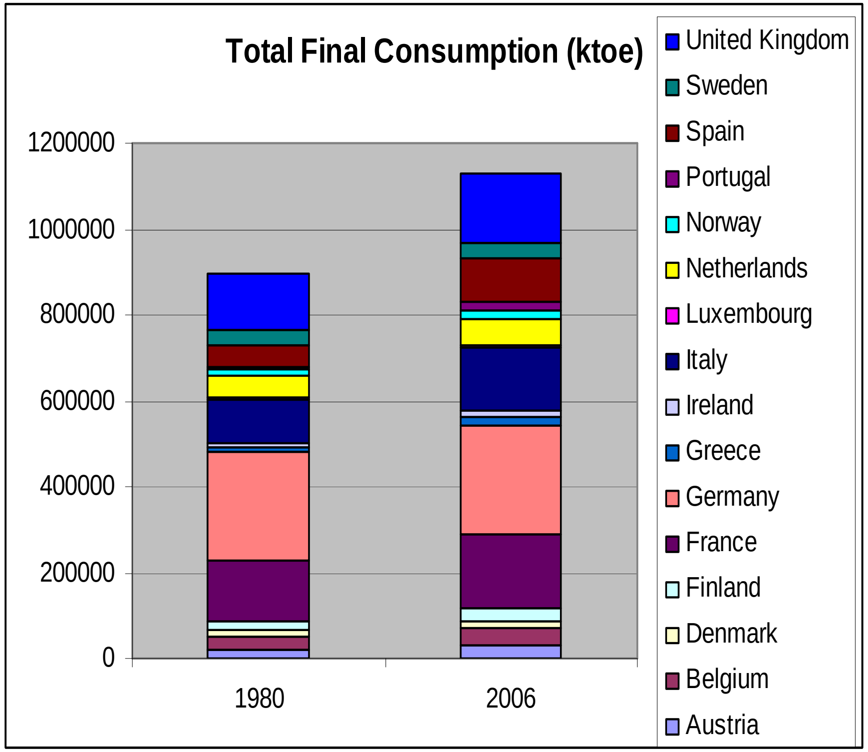
Population growth and resource depletion according to the predictions of the Club of Rome

Introduction: energy and security - is there enough energy?

- **“By 2015, growth in the production of easily accessible** oil **and** gas **will not match the projected rate of demand growth. However, unconventional shale gas may solve part of the problem.**
- **While abundant** coal **exists in many parts of the world, transportation difficulties and environmental degradation ultimately pose limits to its growth.**
- **Meanwhile,** alternative energy sources **such as biofuels may become a much more significant part of the energy mix — but there is no “silver bullet” that will completely resolve supply-demand tensions.”** **Source:** Shell energy scenarios to 2050 **(2008)**
- **Uranium is also abundant. The issues posed by nuclear energy are related to the risk posed: nuclear accidents, nuclear proliferation, long run waste disposal.**

Introduction: energy and security - Energy consumption in Europe

- From 1980 to 2006, energy consumption has increased for the EU as a whole;
- The consumption share of each country has remained rather stable;
- The highest portion of energy consumption is ascribable to Germany, followed by France, United Kingdom and Italy;
- France, Italy and Spain registered the highest increase in energy consumption.



Introduction: energy and security- Energy consumption in Europe

Energy Consumption by Fuel.

Energy mix mainly composed by oil, gas and electricity;

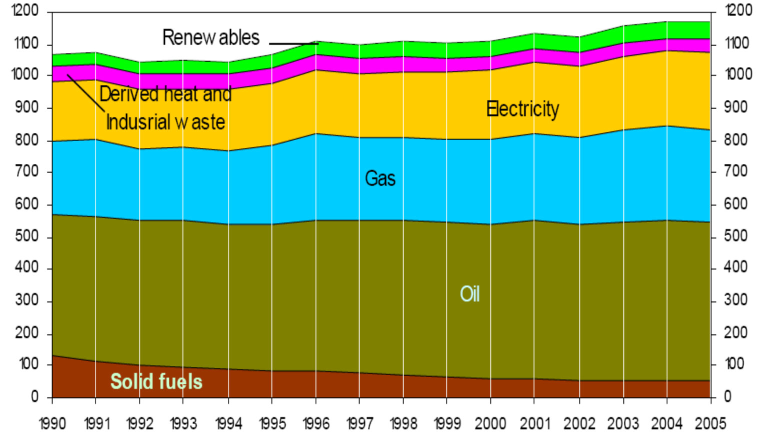
Solid fuels, renewables and industrial waste: limited share of total consumption.

Energy Consumption by Sector.

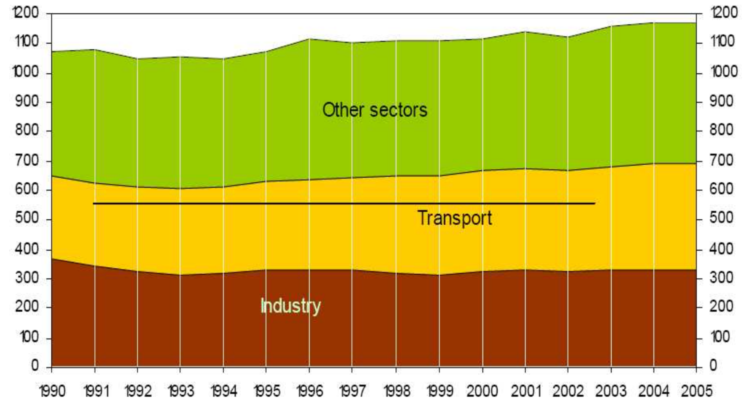
Largest share of total final energy consumption: households and service sectors ("other sectors").

Final Energy Consumption EU27, Mtoe

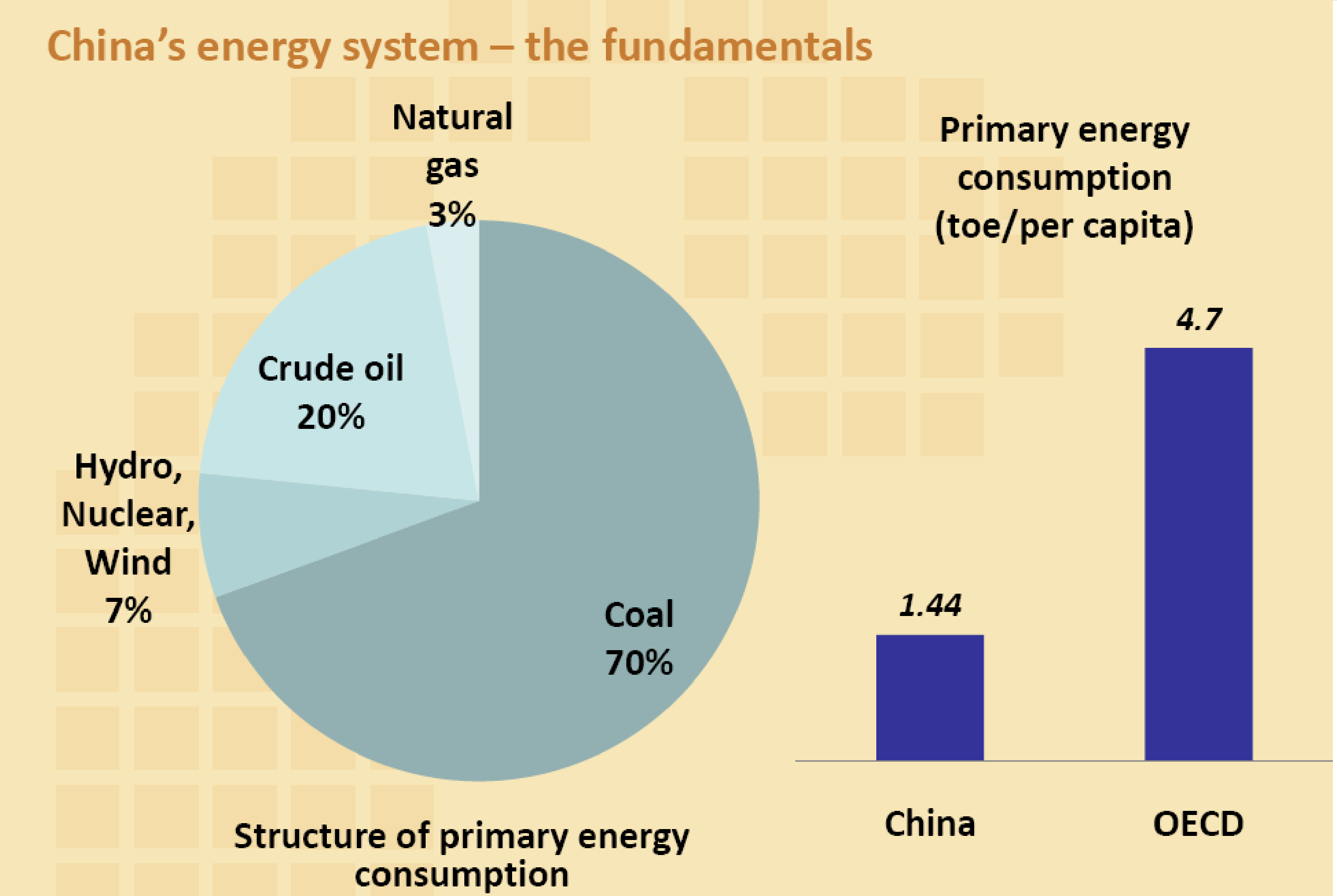
a) by Fuel.



b) by Sector.

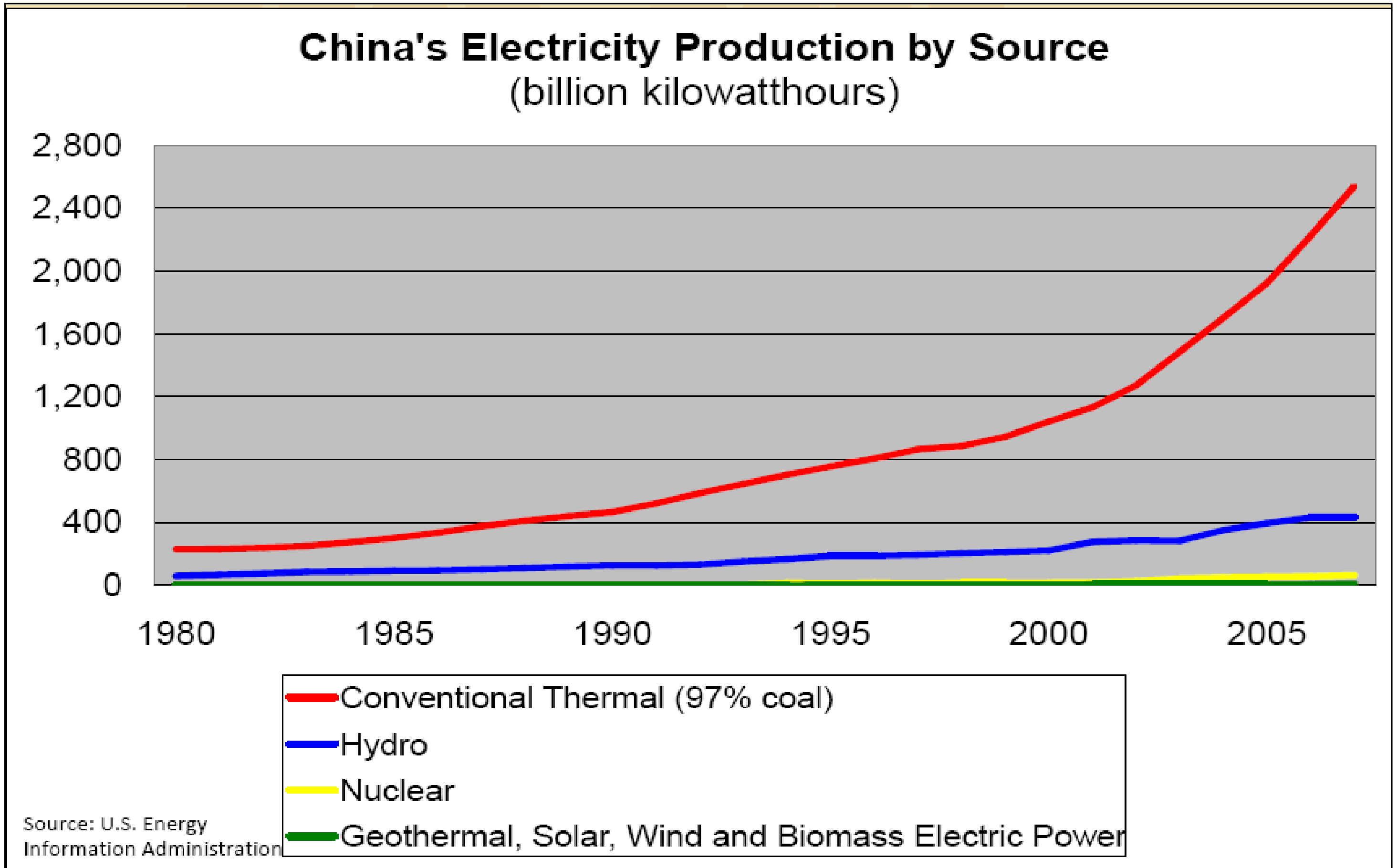


Energy Consumption in China



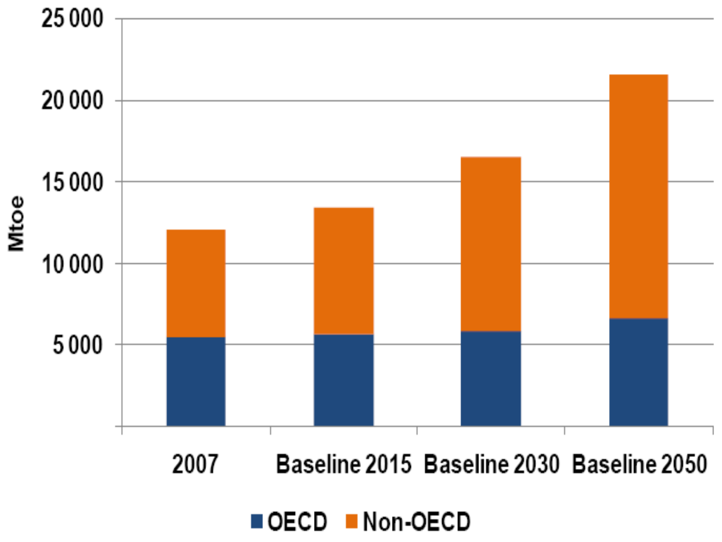
Source:Clingendael (2009)

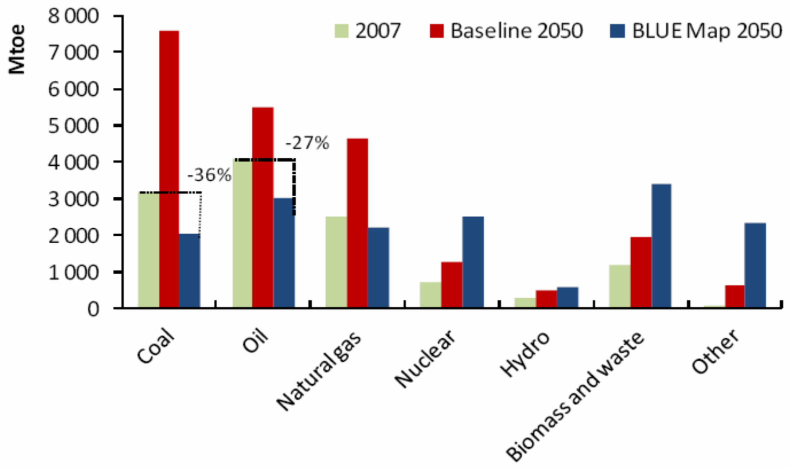
Introduction: energy and security- energy consumption in China



Source:Clingendael (2009)

Introduction: energy and security- IEA's primary energy demand projections





Source: International energy Agency, Energy technology perspectives, 2010

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Introduction: climate and energy security - twin problems

Between now and 2050, humanity have to face a twin problem:

- The growing scarcity for oil and gas (not for coal !)
- The accumulation of GHGs in the atmosphere

These « twin problems » cannot be considered independently as:

- Hydrocarbon scarcity paves the way to coal, and thus to increasing carbon emissions
- Conversely, climate policies open the path to low carbon societies, and to different ways to deal with energy needs

« Smart energy policies » thus have to deal with the two sides of the problem.

Introduction: energy and climate - some definitions

- Energy security
- Externalities
- Renewable resources
- Exhaustible resources
- Sustainable growth

Definitions: Energy Security

The IEA's **definition** of SoS is "the availability of a regular supply of energy at an affordable price"

In physical terms we can distinguish between energy (what concerns flows, that is time x power) and capacity (power). Security of flows is not exactly security of capacity. While the second is needed for the first, the first is more about short term disruption, the second is more about infrastructures and hence long term decisions.

Thus the short term definition becomes "avoiding the lack of & interruption of immediate 'power' delivery to whatever end consumer whenever requested"

The long term definition is split in two components: strategic security as "continued provision of *primary* fuels/sources, adequacy as "sufficient *investments* in consumer (or transit) countries" and " avoiding power cuts".

This definition does not capture the economics (" the affordable price") and the environmental aspects (security means also avoiding catastrophic accidents).

Moreover, the relevance of any definition (and of the policy recommendations it underpins), depends ultimately on the objective function of the policy maker.

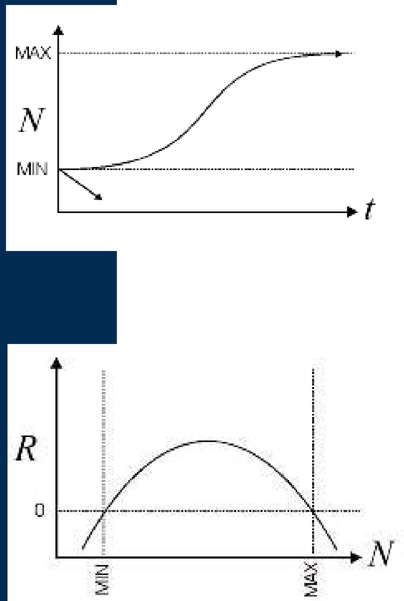
Definitions : Renewable natural resources

Renewable natural resources are those that can regenerate themselves within human timeframes.

Consider the evolution of population (N) of a renewable resource with time. Above a certain minimum population, the population rises exponentially until the carrying capacity of the environment is reached at NMAX. Below the minimum population NMIN, the individuals cannot find each other to mate, or the population is otherwise spread too thin to survive. Above NMAX, the environment becomes overcrowded and population growth is negative. This implies a certain maximum sustainable catch as the population growth rate (R) has a maximum between NMAX and NMIN.

Negative growth rates for underpopulation imply that a species can be doomed long before the last one is dead. This is thought to be the case or nearly the case with a great many species today, including commercial ones (e.g. tuna).

B.



Stock and harvest rate curves for renewable resources.

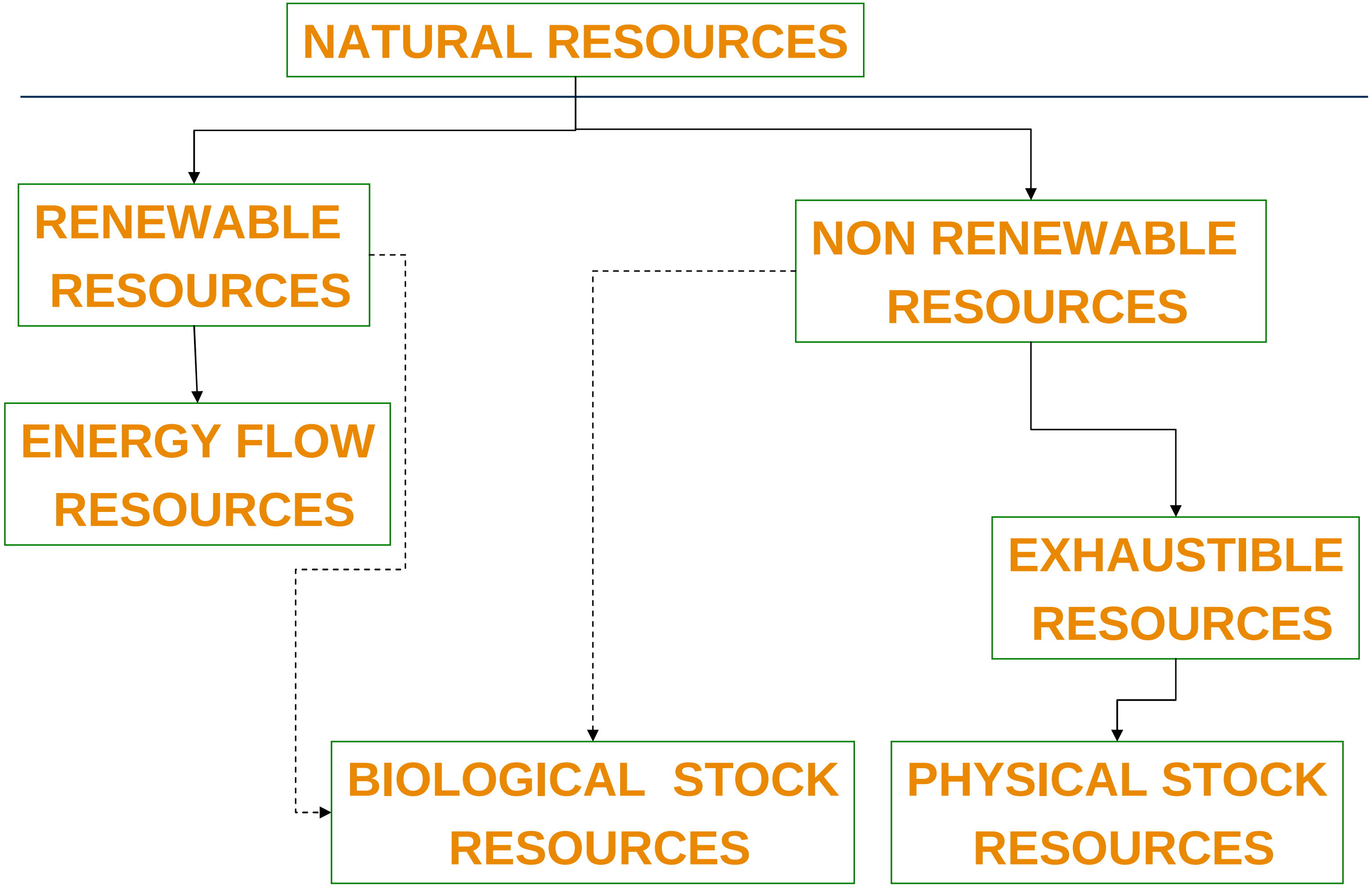
Definitions : Non- Renewable and Exhaustible natural resources

Exhaustible natural resources are resources that even if left alone do not reproduce themselves – at least over any time scale relevant to humankind.

Of course, they are non-renewable. Though the geologic processes that created most types of nonrenewable resources in the past are still operating today, the time frames are too long compared with their use to be considered renewable.

A "renewable" resource may become non renewable, if the species approaches extinction. Non-biological renewable resources, including solar and hydro power do not have these restrictions.

Surprisingly, the economics of exhaustible resources extraction dictates that they hardly ever become exhausted – contrary to sadly many renewable ones.


NATURAL RESOURCES
RENEWABLE RESOURCES
NON RENEWABLE RESOURCES
ENERGY FLOW RESOURCES
EXHAUSTIBLE RESOURCES
BIOLOGICAL STOCK RESOURCES
PHYSICAL STOCK RESOURCES

Definitions: Externalities

"An externality is present whenever the wellbeing of a consumer or the production possibilities of a firm are directly affected by the actions of another agent in the economy".

Mas-Colell et al. 1995

Negative externalities can be viewed as overexploitation by individuals of some common resource (air, water, climate, biodiversity etc.)

Definitions: sustainable development

- The Bruntland Commission (1987) defined sustainable developments as those that "**meet present needs without compromising the ability of future generations to meet their needs**"(WECD, 1987).

- In strictly economic terms sustainable growth consists of an increasing path in real incomes or output that could be sustained for long periods of time. However this restricted definition is questionable also on economics ground – the ”green GDP” approach broadens the economic approach to growth by allowing for natural capital and ecosystem services.

The economics of energy sources

- The tragedy of commons
- Optimal extraction of exhaustible resources
  - The Hotelling rule
- Sustainable growth and exhaustible resources
  - The Hartwick rule
  - Resource Curse and Dutch Disease

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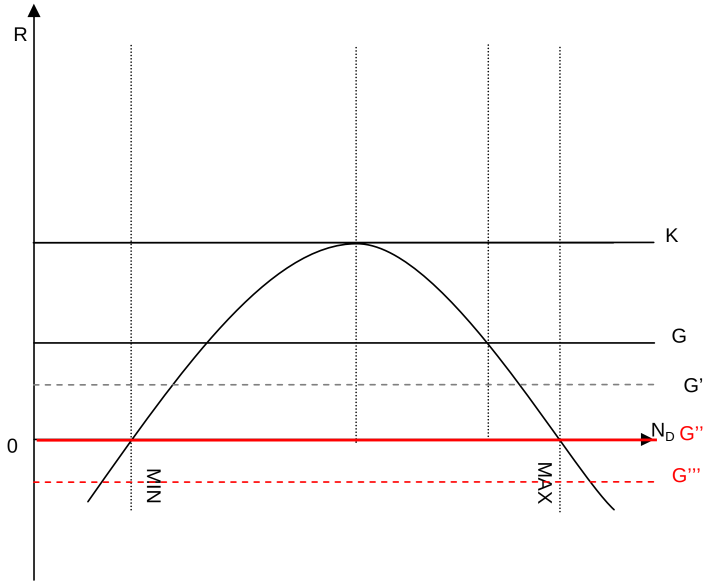
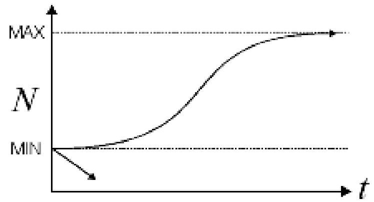
How renewable becomes non-renewable: Geordie and the the Tragedy of the Commons



Ah my Geordie will be hanged in a golden chain
'Tis not the chain of many
Stole sixteen of the king royal deer
And sold them in Bohenny

XVIII century English Ballad

Così lo impiccheranno con una corda d'oro
E' un privilegio raro
Rubò sei cervi dal parco del Re
Vendendoli per denaro.
Fabrizio de Andrè, Geordie 1965

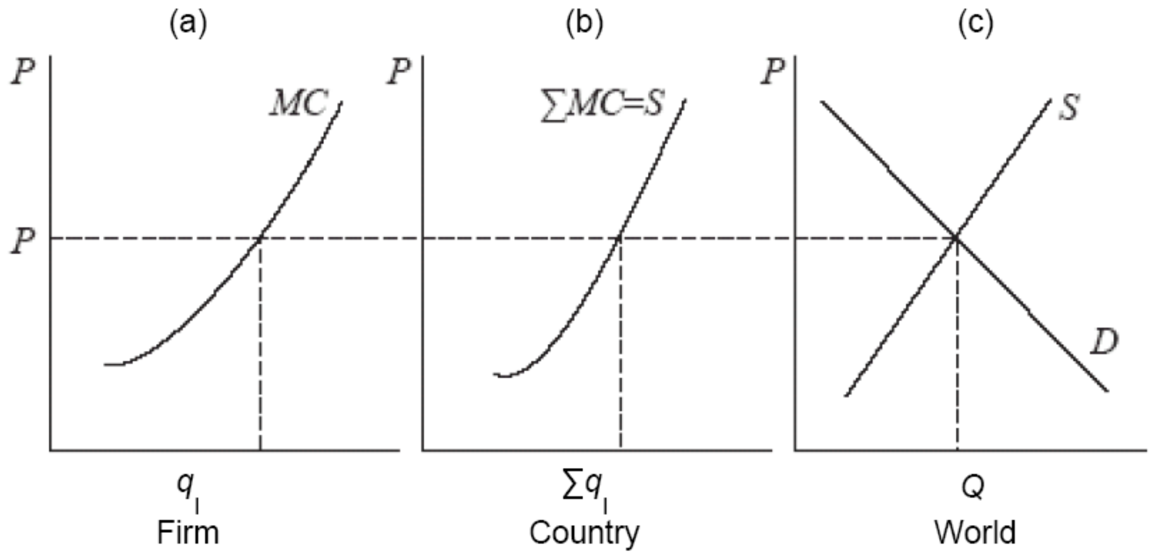


The Tragedy of the Commons (Hardin, 1968, Science)

The problem arises when property rights are not well defined.

- private property then provides a mechanism to avoid externalities – he who owns (the king), cares about the property and controls its use and can exclude others (Geordie) from overusing it.
- private property is not the only available mechanism – regulations work as well (with legal system to enforce them).

Extraction of exhaustible resources: Economic Theory

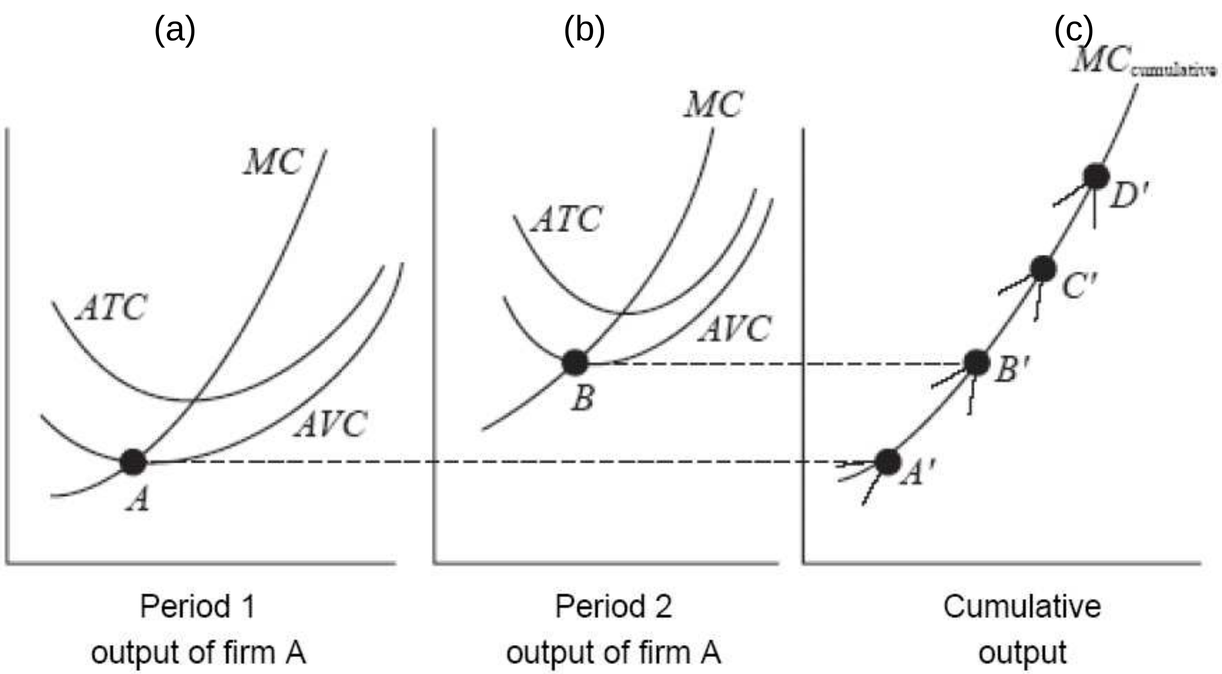


a) In a competitive market, firms sell as long as prices are higher or equal to their marginal costs.
   Competitive pressure drives marginal firms (those whose MC > P) out of the market.

b) Surviving firms equate their MC,minimizing industry's total costs. Hence aggregate supply is the orizontal sum of firms' MC costs.

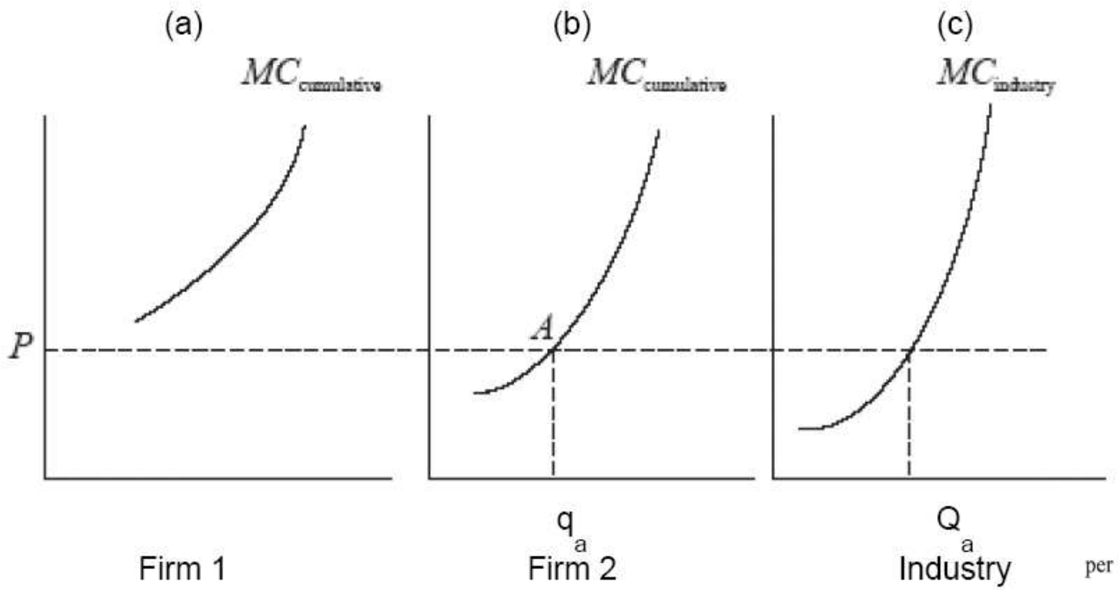
c) Price is determined in the market at the quantity that matches supply and demand. In a price-taking world, output is produced at minimum cost.

Extraction of exhaustible resources: Economic Theory



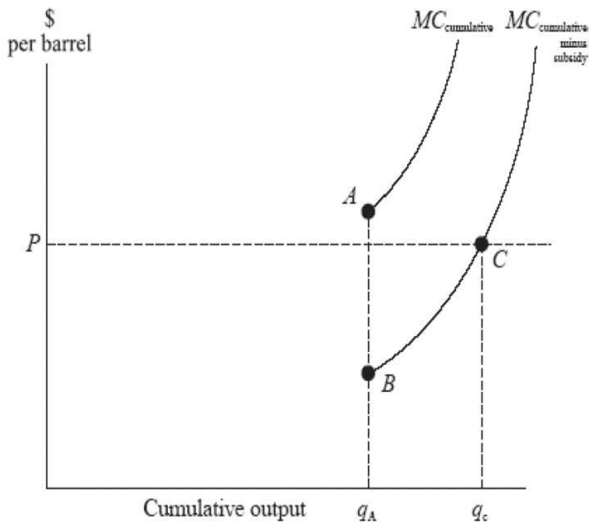
a) **A firm will select its output to set marginal cost equal to price, or produce no output if price lies below minimum average variable costs**
b) **the firm in period 1 will not operate if price lies below point A, and in period 2 will not operate if price lies below point B. MC rises from Period 1 to Period 2 because easier to reach resources are extracted first**
c) **The MC curve for cumulative output of the firm is thus unidirectional (A’ cannot be reached once at B’) *coeteribus paribus***

Extraction of exhaustible resources: Economic Theory

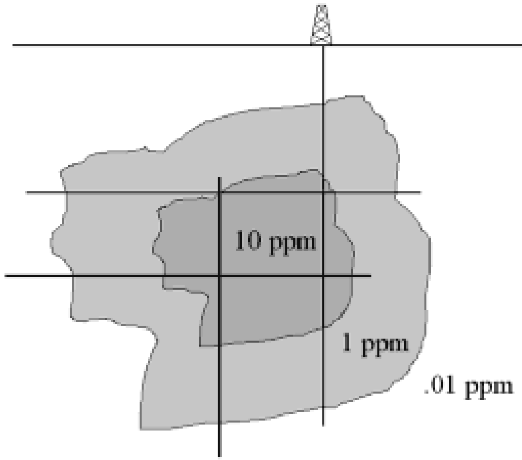


- If price falls, perhaps due to discoveries abroad, then some firms will stop producing while others continue to produce, but at a lower rate of production
- If production is subsidized, more domestic firm will produce.
- Is this good or bad for energy security?

- Firm 1 will not produce output because the price is too low. Its oil will be preserved for the future when prices rise. Firm 2 will produce q_A at price P_A and the industry output is shown by the summation curve (of a large number of firms) with industry output of Q_A
- Thus some firms are not producing, the rest are, and a rise in price will increase not only the total output of the industry but also the number of producing firms.



Finding exaustible resources



Estimating the amount of a natural resource is not a simple task, even for a single ore body.

The first consideration is the concentration of the material of interest, and its distribution in the rock.

Sinking exploratory shafts or diamond drilling combined with geochemical determination of the concentration (also called "**assay**") allow an estimate of the number of tons of rock in the ground at a given grade.

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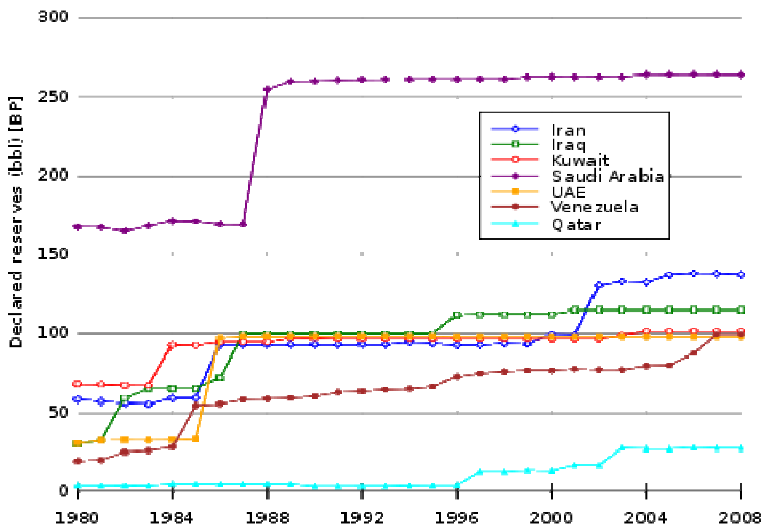
Exhaustible Resources: defining reserves and resources

In the case of OIL there are three generally recognized categories.

1. Proven Reserves; "the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions." (BP)
2. EUR (Estimated Ultimately Recoverable) oil. This is oil that is infeasible to recover for reasons that are either economic or technical. This category also includes yet-to-be-found oil.
3. Non Conventional:oil from coal, oil shale, oil sands, tar sands, bitumen, heavy and extra heavy oil, deep water oil, polar oil and natural gas condensates.



	World	OPEC
2003	1213	819
2002	1031	819
2001	1028	814
2000	1016	802
1999	1034	800
1998	1019	797
1997	1019	789
1996	1007	777
1995	1000	770
1994	999	772

There is some arbitrariness in the classification, and the access to the real data is often considered a business critical information. The strategic use of reserves information is typical of OPEC countries.

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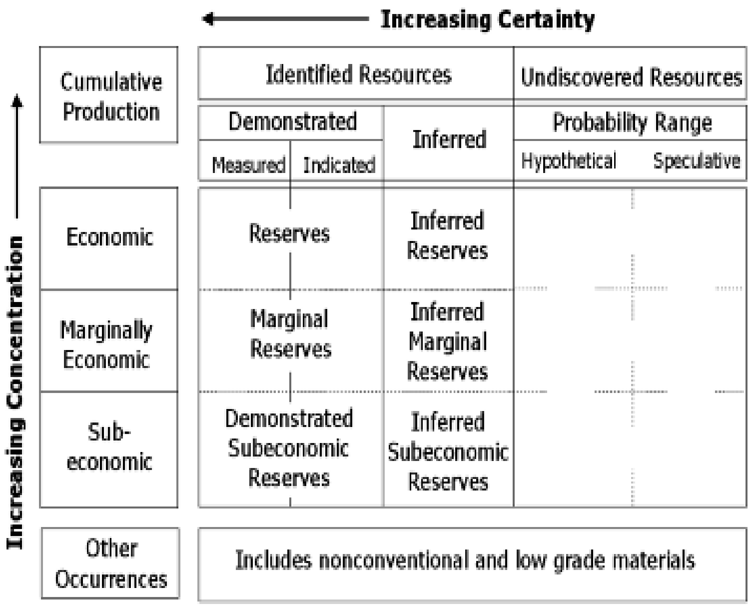
Exhaustible Resources: defining reserves and resources

The next consideration is the technology of extraction. Only a certain amount of the ore is extractible, given the geometry of the ore body, its mineralogy and the accessibility of the surface location. These all factor into the **costs of extraction.**

The final factor is the price, which determines whether a given piece of rock below the ground is worth exploiting. Deposits are divided into economic and sub-economic depending on whether it is economically feasible to extract ore from them.



McKelvey diagram, USGS 1980

Extraction of exhaustible resources: Hotelling's rule

Thus economic theory tells us that *coeteribus paribus*, the price of an exhaustible resource must rise. But how exactly?

Harold Hotelling (The Economics of Exhaustible Resources, JPE, 1931) proved that, *coeteribus paribus*, exaustible resource price rises at the market rate of interest.

Intuition: minerals in the ground are not so different from money in the bank.

Extraction of exhaustible resources: Hotelling's rule

The extraction of an exhaustible resource can be seen in its simplest form as a simple profit maximization problem, for a society the same as for an individual. The society or individual face the same problem, namely that

$$\frac{dX}{dt} = -H(t)$$

where *X* is the stock of the resource and *H* is the "harvest" per unit time. The profit is (leaving costs aside for the moment)

$$\Pi = PH$$

Society maximizes its profit over all times, not just the present time. For this, the value of future profits must be *discounted* at a rate *r* that roughly equivalent to the interest rate. The maximization problem is thus :

$$Max \int_{t=0}^{\infty} \Pi\left(e^{-rt}\right)dt = \int_{t=0}^{\infty} PH\left(e^{-rt}\right)dt$$

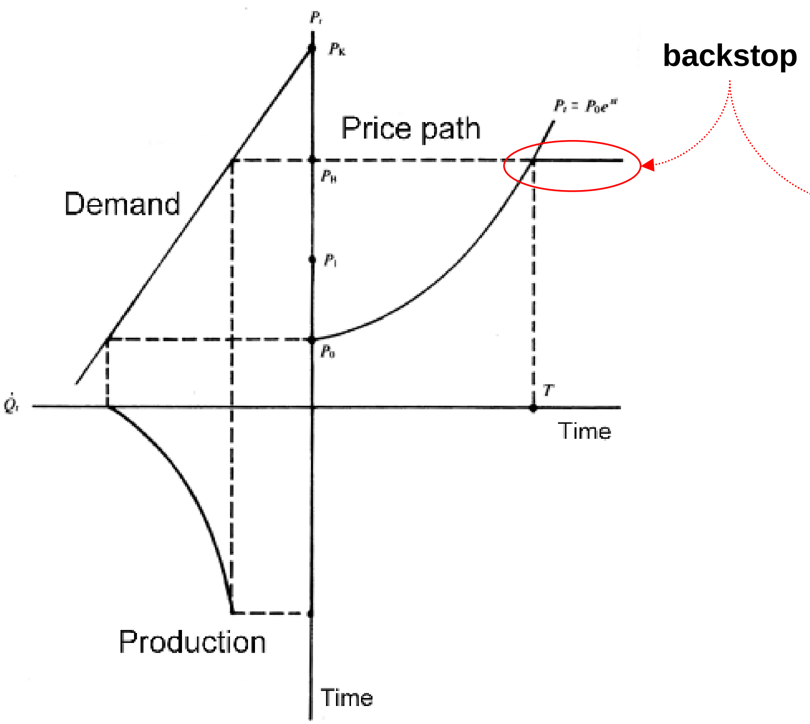
This is the fundamental problem in all of exhaustible resource economics. The almost trivial solution is that the maximum total profit is given by:

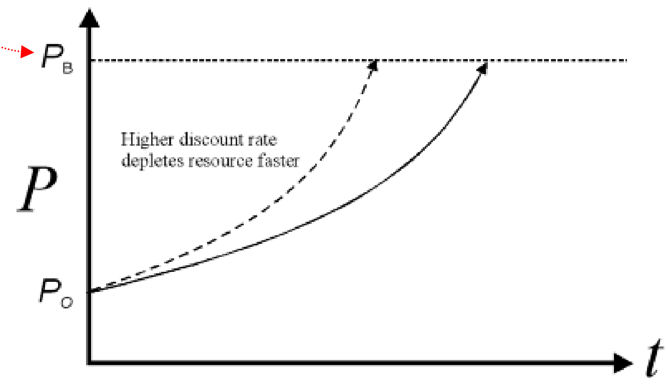
$$P_t = P_0 e^{rt} \quad or \quad \frac{dP}{dt} = r$$

A mineral deposit in the ground has the same significance as a bond, and is in some sense interchangeable with such a financial instrument. Proof: if not, then the price will rise either faster or slower than the rate of interest. If slower, then it is better to decrease extraction and invest in financial instruments that will by definition grow at the rate of interest. If faster, then it is better to invest in increased extraction, since the oil price is growing faster than the value of financial instruments. So, the equilibrium rate of extraction will keep the price rising at the rate of interest.

Extraction of exhaustible resources: Hotelling's rule

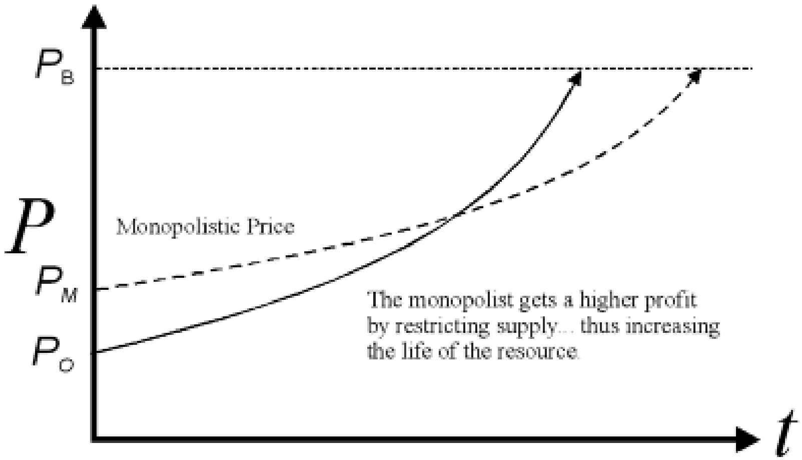
$$P_t = P_0 e^{rt} \quad or \quad \frac{dP}{dt} = r$$





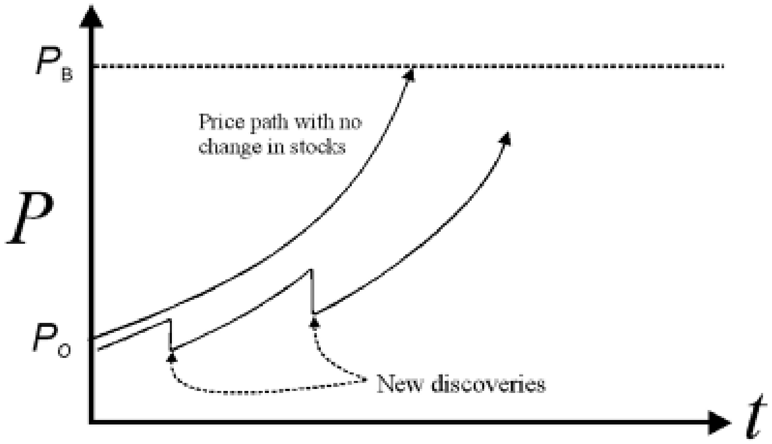
exhaustible resources usually do not get exhausted!

Extraction of exhaustible resources: Hotelling's rule

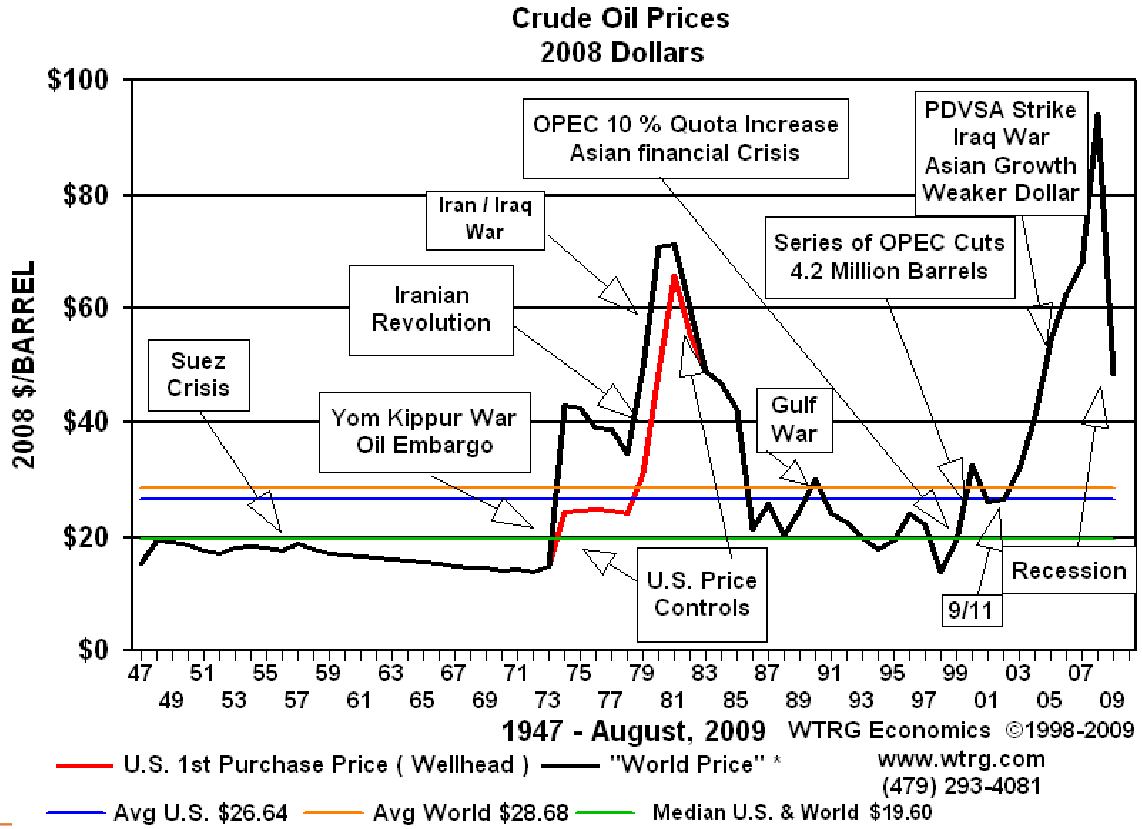


The monopolist is the environment's friend (?)

What if resources are larger than expected?



Mineral resources' prices appear to be fluctuating or declining, rather than costantly soaring : consider oil



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Was Hotelling right?

Mineral resources' prices appear to be fluctuating or declining, rather than costantly soaring :

consider copper

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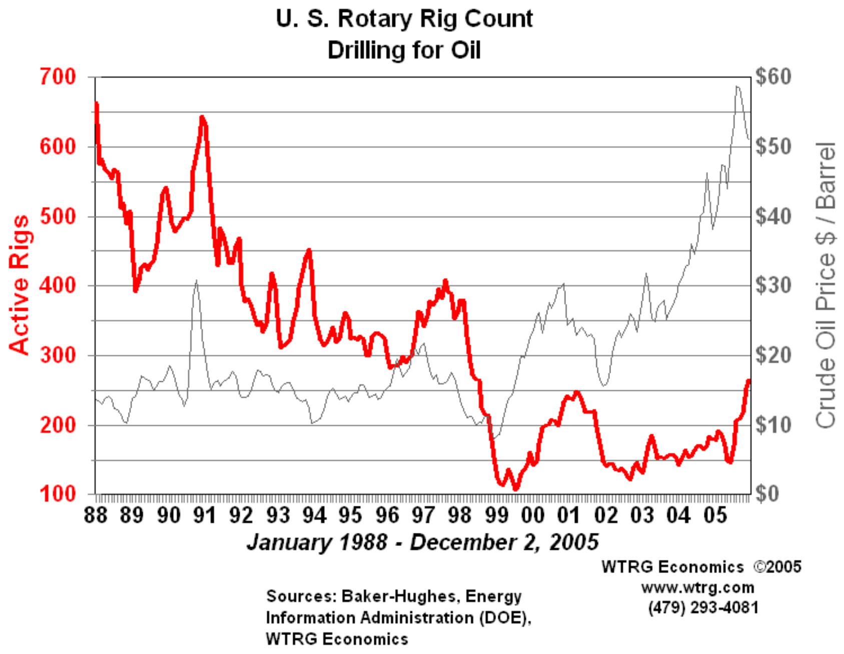
What Hotelling's Rule did not cover



Copper is not expensive relative to wages or prices and never has been. Throughout this time, the amount of proven reserves of copper has held nearly constant, even as production has risen tremendously.

Exploration (the identification of new proven reserves) is an expensive undertaking, and tends to occur primarily in times of rising prices - this puts a strong brake on the upward spiral in real terms.

New methods of exploration and new methods of extraction have more than kept pace with demand over time, resulting in lower prices even though the producers are still turning a profit

Petroleum companies have a strong incentive to explore and drill for new petroleum reserves, when petroleum prices are high:

Companies are exploring where extraction is much more expensive

- Extremely deep wells
- Extreme downhole temperatures
- Environmentally sensitive areas
- Allow extraction from the deep waters of the Gulf of Mexico or the cold Alaskan climate

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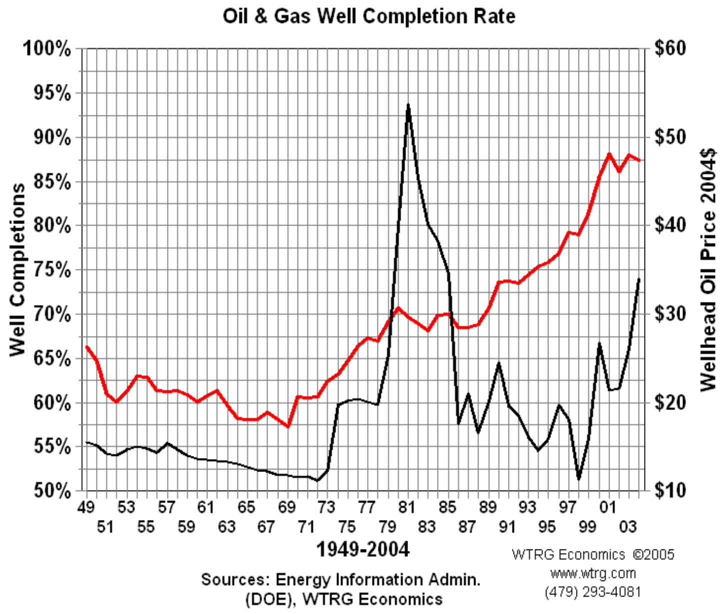
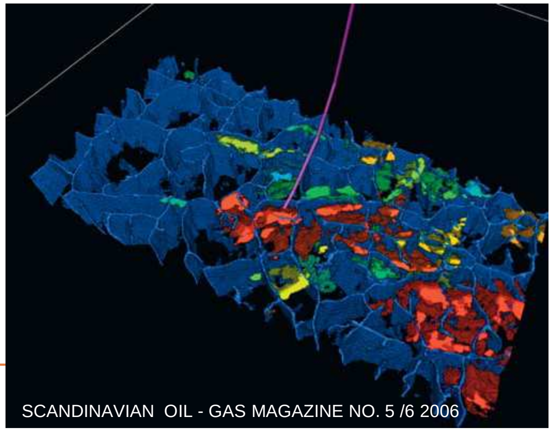
What Hotelling's Rule did not cover: technological progress





Technology has improved substantially in the mineral resource sector in the last decades. In the early days successful exploration was largely a matter of luck. Nowadays a significant fraction of oil wells drilled for exploration actually become production holes.

If the price is high, even a marginal hole may be put into production or completed if the expected production seems likely to at least cover the completion costs. This explains the rise in exploratory well completion throughout the seventies, but not the much higher rise in well completion in the nineties.

This increase is mainly due to advances on high-speed computing for the **3D imaging** of source and rocks in the subsurface.

Another technology advance is **directional drilling**, which allows a single hole to turn in any direction while drilling, even horizontal. Much more ore can be extracted, or a much larger region of an ore body using a single hole can be explored, with huge savings.

What Hotelling’s Rule did not cover: Other issues

Hotelling’s prices depend on the petroleum reserves being known and fixed, but **extracting companies do not know the location of all reserves**.

Demand for petroleum can change:

- Consumers reduce quantity demanded for petroleum products, and fossil fuels when prices increase;
- Innovation works also on the demand side: consumers can now buy more fuel efficient cars. New automotive and energy generation technologies are more fuel efficient than they were 20 years ago;
- Consumers can move closer to work.

Geopolitics: If a resource producing country cannot supply the market for political reasons, other countries can step in.

Strategic use of spare capacity.

Resources and sustainable growth: the Hartwick's Rule

Although empirically questionable, Hotelling's rule has a fundamental role to play in terms of preserving the opportunity of future generations to live satisfactorily In then words of Sudhir and Sen (1994):

"Preserving productive capacity intact is not, however, an obligation to leave the world as we found it in every detail. […]. But if society's broad stock of capital is to be maintained, we have to replace the non-renewable resources that are used up with something else. That has to be reproducible capital, whether physical or human"

[Hartwick] "showed exactly how much from the use of a depletable resource should be set aside and invested in reproducible capital so that the total return (i.e. income) could be sustained over time.

***Hartwick's Rule says that if the entire competitive rents from an economy's use of a wasting resource are invested in reproducible capital, then it will be able perpetually to maintain a constant level of consumption**. The competitive rents, or pure return to the non-renewable resource, are given by Hotelling's (1931) classic result that the shadow value of the resource rises at a rate equal to the current marginal product of reproducible capital.*

***The accumulation of reproducible capital through investment of the Hotelling rents exactly offsets the (efficient) depletion of the exhaustible resource**. "*

NB. 1) This is not just about oil, but about the whole resource stock!

2) Substitutability between natural capital, physical and human capital is far from perfect!

Resources and sustainable growth going wrong: the Dutch Disease

The Symptoms:

Direct deindustrialization effect: increasing labour demand for the resource sector and away first from lagging manufacturing sector and then from service sector.

Spending effect: extra revenues boost purchasing power of domestic labour and hence domestic demand for non-traded goods, for which prices will increase, and for internationally traded goods (different from resources) for which prices are set internationally and cannot change.

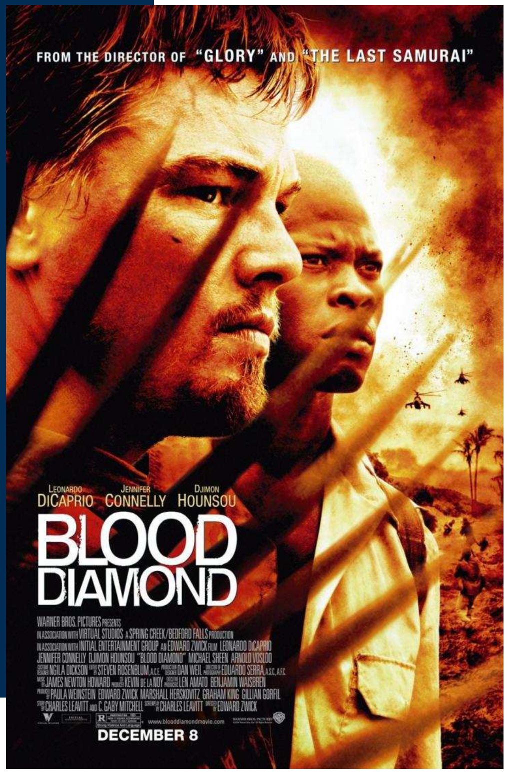
The **increased supply of foreign currency** would drive up the value of the domestic currency, which also implies an **appreciation in the real exchange rate** that **weakens the competitiveness** of the country's exports and, hence, causes the manufacturing export sector to shrink.

There will be increasing imports of traded goods and increasing exports of the extractive industry. But **this specialization is fragile** for an economic system once the reserves of natural resources deplete or if there's the chance of volatile prices. The countries that specialize in trade of natural resources are subject to **swings in terms of economic growth**.

The cure: active industrial policy promoting **diversification** of the productive sector (mainly towards technologically advanced production.

Source: POLINARES Project (2010), WP1

Resources and sustainable growth going very wrong: the Resource Curse



Resource-abundance and international specialization in extractive sectors can do worse.

Natural capital intensity tends to crowd out capital, whether financial or human, thereby impeding economic growth.

Hence the definition of **resource-curse**, according to which countries that depend heavily on their natural resources tend to have less trade and foreign investment, more corruption, less equality, **less political liberty, less education, less domestic investment and less financial depth than other nations that are less well endowed with natural resources.**

With respect to Dutch Disease, the resource curse thesis involves also **poor quality of institutions and scarce human capital** (no clear causality).

Moene and Torvik (2006) identify the existence of a group of losers and a group of winners within the wider group of resource-abundant countries, build a model to explain the role of the initial level of institutions and verify that in fact an empirical positive relationship exists between **economic growth and the quality of institutions.**

Source: POLINARES Project (2010), WP1

Grazie!

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