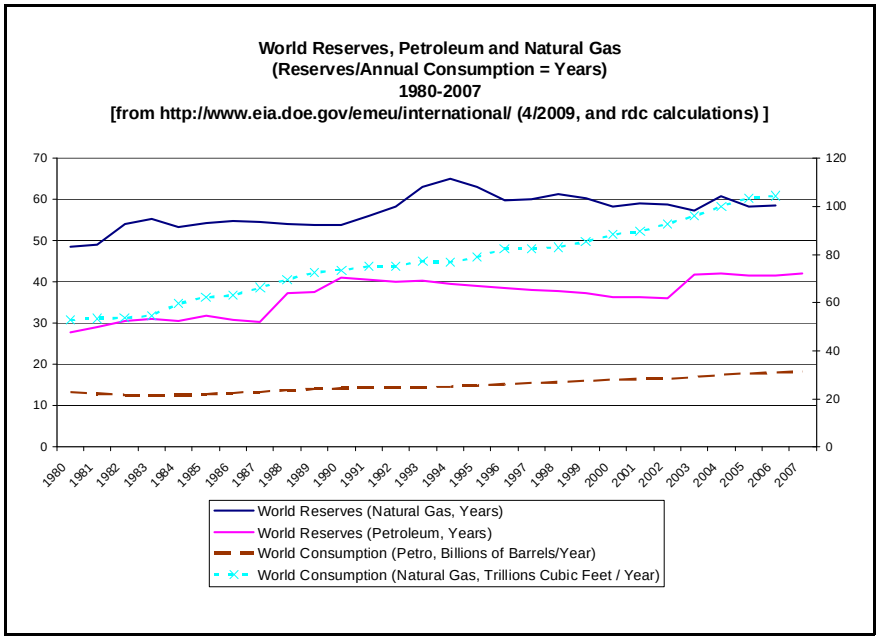
# Sustainable Growth?

## I. Can growth be sustained? On the limits of economic growth




A. There is a widespread concern among environmentalists that economic growth is fundamentally limited by the stock of natural resources on earth.

B. There are several reasons why limits to economic growth should be taken seriously by policy analysts:

**i. First**, there are cases in history where a society has faded away because local natural resource base ceased being able to support the society.

- (a) Irrigation may cause a build up of salts (because water is being constantly evaporated) which reduces the fertility of soil.
- (b) A forest or pasture land may be consumed at a rate that is too large to be sustained.
- There are a few cases in water, pastures, and forests have been overused, because. commons and environmental externalities were neglected.
- The results were treeless plains and desertification.
- Several species have disappeared or nearly disappeared because they have been over hunted--e. g. killed at rates in excess of birth and maturation rates (e.g. the dodo).

**ii. Second**, there is the simple mathematics of economic production and income. If every increase in income or personal consumption requires an increase in the use of natural resources, perpetual economic growth would require infinite resources. Consider the following:

**a.** The limit of $Y_t = Y_0(1+g)^t$ as time period $t$ approach infinity is infinity (where $g > 0$ is the long term growth rate and $Y_0$ is current income).

**b.** To the extent that income is based on natural resources, N, directly or indirectly, one may imagine that $Y = aN$ where $N$ is a vector of natural resources and $a$ is a vector of marginal revenue products.

- In this case, $Y_t = (aN_t)$

**c.** If a is constant, then "unbounded" income requires "unbounded" natural resources.

- Under these assumptions, perpetual growth is clearly impossible unless natural resources are unbounded.
- It could only happen, for example if natural resources were growing by rate g every year, as with $N_t = N_0(1+g)^t$

**d.** According to most physicists, however, there is only so much matter and energy in the Universe.

- So, N is bounded. *In that case, income growth in the very long run is clearly limited by the availability of natural resources.*

**iii. Third**, there is the Malthusian argument (1798) that population growth tends to cause most individuals to be stuck in poverty, in the long run, even if there is a period of sustained economic growth.

**a.** That is to say, even if total income increases average income may not increase, at least not for the working class.

- It bears noting that one "natural" resource that increases is population or labor force (L).
- If average product were constant, $L_t = L_0 (1+g)_t$ and $Yt = aL_t$ ,then world income could grow at rate g. $Yt = aL_0(1+g)^t$
- Average income would be total income divided by labor force which would be "a," the average product of labor.

**b.** For a given technology, however, economists normally assume that average product falls somewhat as the supply of an input used increases (because of diminishing marginal product).

- In this case, "a" tends to fall with population instead of remain constant.

**iv.** Malthus points out that population stabilizes when "a" falls to subsistence levels, which implies that total output is just sufficient to support the existing population.
- In a world with stable technologies, personal income can only rise temporarily, because an increase in income tends to induce an increase in family size,, which increases the supply of labor, and reduces wage rates.
- Malthus, thus, argued that family size had to be controlled in order to increase average income in the long run.

C. The past two hundred years of history in the West, however, demonstrates that income growth and increases in average income can continue for a long time without running into Malthusian limits.

**i.** The population of the earth is larger than it has ever been.

**ii.** Total world GNP and average personal income are also larger than they have ever been.

**iii.** Moreover, many, perhaps most, natural resources are less expensive today than they were fifty years ago, which implies that natural resources are NOT becoming increasingly scarce.
- (Recall the famous Julian Simon bet. See also B. Lomborg's book.)
- (As a partial defense of Malthus, it bears noting, however, that family sizes have been shrinking world wide for many years.)

**iv.** *In many cases, "new" resources have been discovered than consumed, which has had the effect of increasing "our" pool of economic resources.*
- *(For example, for the past three decades, this has evidently been the case for oil and natural gas. See the figure above that plots total reserves divided by annual consumption for petroleum and natural gas.)*

D. Technological growth and increased specialization have also increased our ability to produce valuable goods and services from the pool of known resources.

**i.** If we return to the simple mathematics of growth where Y = aN, consider what happens if "a" increases through time.
- $Y_t = L_{t0}(1+g)^t a_t (1+h)^t$ where "g" is population growth as before and "h" represents the rate of technological improvement
- Average income is now $a_t (1+h)^t$ ,which now tends to grow through time.

**ii.** Malthus suggests that this technological improvement tends to cause population growth.
- The world's population has increased, but the growth rate has been diminishing for the past few decades.
- This would surprise a pure Malthusian, because according to Mathusian theory economic innovation can only temporarily increase average income.

**iii.** However, as long as the average product of labor increases through technological advance, average income still increases.
- (Increases in average income requires technological growth to be faster than population growth.)

**iv.** Technological increases can also offset reductions in natural resources insofar as improved technology in mining and farming can increase the supply of a resource that can economically used.
- (Greenhouses and geothermal heat allow strawberries to be grown in Iceland)

E. Technological advances create "new" natural resources in several ways.

**i.** Additional natural resources can be mined or harvested economically when mining costs fall, new recovery techniques are developed, or geology improves.
- Deep sea mining and deep oil wells provide resources that were previously unavailable.
- Improved secondary and tercerary recovery from oil fields has increased the amount of oil that can be economically recovered from an existing oil field.
- (Oil fields are considered to be "used up" after it becomes uneconomical to recover oil, rather than because there is literally no oil left in the ground at a given point.)
- Improved dikes can increase the supply of useful farmland, as can improved farm equipment and pesticides

**ii.** Technological improvement also increases the extent to which outputs can be produced from given inputs.
- Materials used to build soda cans, plastic milk bottles, houses, and plastic bags can often be reduced--without affecting quality.
- Technological innovations in agriculture mean that we can produce a lot more food from the same acre of land than could have been produced 50 or 100 years ago.
- The windmills of today are much more efficient at "harvesting" energy from the wind than were the old wooden Dutch windmills.
- Computers, Cars, and Clocks become more energy efficient.

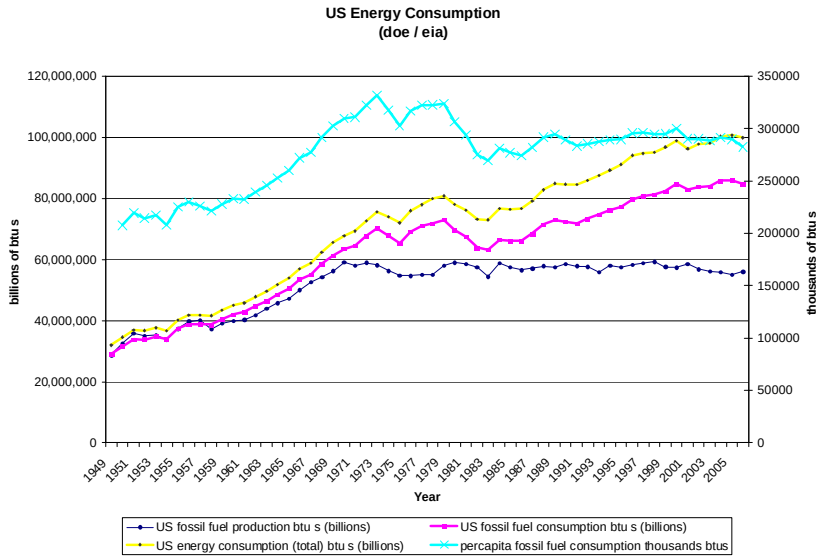
**iii.** Technological innovation can also discover new uses for previously existing resources that were not previously regarded to be "valuable resources."

- Many of the materials used in electronics were known, but not used prior to the electronics revolution of the twentieth century.
- That is to say, innovation can cause an old piece of rock to becomes a "new" valuable resource.

**iv.** Technological innovation also produces new products that can produce satisfaction at lower material cost than older technologies.

- Examples include indoor plumbing and heating
- Electricity, the telephone, and household appliances
- Trains, automobiles, trains, computers, and the Internet.

**v.** Most of these effects imply that more economic output can be produced from fewer resources--if only we knew how.




F. Most economic growth for the past two centuries has been the result of changes in vector "a" (technology that increases average product) rather than increases in N (natural resources).

**i.** Economic growth in the long run is ultimately limited by prospects for technological advance together with the available matter and energy in the universe.

**ii.** With luck, the limit, if it exists, will be so far out (in the future or in knowledge) that it is not worth worrying about now.

- As a rule of thumb, population growth increases scarcity, while technological advance diminishes scarcity.
- Although it bears noting that capital per unit of labor and education per unit of labor has also been increasing throughout much of the world, as has specialization--all of which tend to increase productivity and wages.
- (The law of conservation of energy and matter implies that natural resources in the universe cannot change through time (except through the effect of entropy), but the universe is very large.)

G. This does not mean that economic growth is always sustainable, because even if technological improvements continue to be discovered, economic growth is partly dependent on public policies.

**i.** Regulations can block the use of new technologies.

**ii.** Regulations may fail to address associated externality and commons problems.

H. For the past two centuries, it is clear that the efficiency and resource increasing aspects of technological growth and public policies have more than offset the associated increase externalities (pollution and commons problems) associated with economic development.

**i.** This has been especially true of democracies, which have had the strongest economic growth and most stringent environmental regulations (with minor exceptions).

**ii.** Here, it bears noting that technological advances also improve government policies by providing new tools for controlling emissions and a better understanding of existing problems.

**iii.** In the end, whether perpetual economic growth is *likely* or not depends on one's "guesses" about future technological developments, public policy, population growth, and savings rates.

I. The future, unfortunately, cannot be fully known before hand.

**i.** Innovations, for example, are new--and so are not things that can be anticipated in any detail.

- Computers and the internet were entirely neglected by science fiction writers of the 1950s and 60s.
- (In fact, my old spell checker fails to recognize internet as a word.)

**ii.** Thus, the extent to which technological progress will continue has to remain fundamentally matters of speculation.

- However, the past two centuries of experience is very hopeful in that respect.
- Technological advance and improvements in public policy began to accellerate at almost the same time as Malthus published his influential

papers and books on the relationship between population growth and economic well-being.

J. Countries with well-functioning market systems and a reasonably efficient set of environmental laws have so far avoided the traps of "unsustainable" growth, while creating very comfortable societies in which people live long productive lives.

## II. Naturally Green?

A. It is easy to exaggerate the extent to which government interventions are necessary to induce sustainable growth.

B. Markets, for example, induce firms to economize on the use of scarce natural resource through the price system.

**i.** In the figure above note that total fossil fuel use in the United States (the pink line) rises through time as does total energy consumption (the yellow line).

**ii.** However, note that the personal use of fossil fuels (the blue lines) fell between 1970 and 1985, as real energy costs increased.

**iii.** Fossil fuel consumption per person has been more or less stable (per person) since 1990.

**iv.** In that period, increased fossil fuel use was a consequence of more people rather than economic growth.

- Evidently technological improvements offset most of the increase in real goods and services used by a typical person during the past two decades.
- (A larger version of this figure is available on the class website.)

C. Note also, that to economize on energy use does not require major innovations or policy changes, although it may be helped along by them.

**i.** There are reasonably strong market incentives to develop energy savings technologies, to recycle when it is cost effective to do so, and to find alternative energy sources.

**ii.** Fuel efficient cars already exist and are widely used around the world.

- For example the Prius gets two to three times the gas mileage of a typical SUV.
- The new super efficient VW (to be sold in 2010 or 2011, see class notes and website link) gets 4 or 5 times the gas mileage of a Prius.
- Other experimental cars get several times even that very high gas mileage, albeit with much less comfort for the driver.

**iii.** Energy saving light bulbs, insulation, and heating and cooling systems exist already, and there are economic incentives to use them.

**iv.** When the price of energy increases, economics predicts that people will substitute those products for more energy intensive ones.

- There is a bit of evidence of this in the last year or two of the above sequences.

**v.** In this sense, economics suggests that it is "**natural to be green**."

- In well functioning market systems, increased scarcity causes prices to rise.
- This causes firms and consumers to use less of the scarce resource, which both makes existing supplies last longer and helps to assuret that such scarce resources flow to their highest valued uses.
- These "allocation problems" are solved by ordinary market forces of Supply and Demand.
- As energy costs rise, people will use smaller cars, smaller houses, and live closer to work.
- As food costs rise, people will have substitute vegetables, fruits and grains (which are relatively less resource intensive to produce than meats and dairy products) for meats and dairy products, and tend to have smaller families.

D. This is not to say that markets are always "naturally green," but rather to say that modern property rights systems and regulations, together with the usual profit maximizing incentives tend to push markets in Green directions.

**i.** Energy costs are a substantial part of production costs and firms and consumers both have incentives to economize on them.

**ii.** If recycling is cheaper (uses less energy and other natural resources) than new materials, then recycling will take place.

**iii.** (There has been recycling of most metals and many building materials for thousands of years.)

E. Nonetheless, their are externalities that are associated with the private use of green technologies insofar as externalities are generated by mining, manufacturing, using, or disposing of goods and services.

**i.** It also seems clear that air and water quality throughout the West has increased dramatically in the past fifty years as environmental regulations have been tightened and new technologies for reducing emissions have been developed.

- Disseminating information about the energy consumption of alternative products and about the relative merits of alternative energy saving devices can also improve consumer choices by reducing errors

and reminding them of the **long term** impact of their day-to-day decisions.

**ii.** In some cases, however, environmentally useful outcome were associated with policies adopted for other purposes.
- For example, in societies in which opportunities for woman are more or less the same as those for men, population growth tends to slow, which reduces the demand for all sorts of goods and services.
- The net benefits of additional children are weighed against the opportunity cost of higher family income, careers, and convenience.
- In countries were woman's rights are more constrained by law, the result often looks a lot like Malthus' prediction, as in (Nigeria, Sudan, etc.)

**iii.** Similarly, Investment in education, research and development also tends to improve possibilities for growth by creating a more sophisticated workforce and citizenry.
- This tends to increase the rate of technological advance (by increasing the rate of innovation and also the use of new techniques).
- It also tends to improve public policy, insofar as a more sophisticated electorate tends to select more competent person to high office and do a better job of monitoring their behavior.

## III. Economic Growth, Politics, and the Tragedy of the Commons

A. Many of the concerns about sustainable economic growth involve pricing problems and market failures.

**i.** As populations grow, communal resources such as air and water tend to be more intensively used, increasing the range of possible commons problems.

**ii.** Natural resources that are "under priced" will be over used--and in some cases may lead to tragedies of the common and shortages.

**iii.** Underpricing, however, is often caused by public policy "failures."
- Scarce water supplies in the western United States are underpriced by the government agencies that provide them.
- This causes water to be over used and used for less than the most valuable purposes.
- Oil is often "owned" by nation states that do not always try to maximize their long run return from those resources but rather short run returns or other political objectives (e.g. Nigeria, Saudi Arabia, Mexico, Venezuela ...)

**iv.** Other goods are sometimes "over" priced as a consequence of public policies.
- For example, low density development, which tends to increase t ransportation costs, is promoted by zoning laws and building codes.
- (Often, this is what the median voter wants)
- (On the other hand, greater densities of people also tends to create more externalities, as spillovers become more common, so even though this tends to increase transportation costs, it has benefits as well as costs.)

B. Even without government mistakes and bias, there are still many externality and commons problems that tend to emerge as economic growth takes place.

**i.** As exploitation of commonly held resources becomes more intensive, tragedies of the commons become more likely.
- In the case of land held in common, the land may support the herds of a few small farmers without problem, but not that of a large number of farmers, or even a few large scale farmers.
- In the case of communal fishing areas, there may be no "tragedy" associated with unrestricted access by a few fishermen using primitive harvesting technologies, but problems (depletion) tend to arise as more fishermen using more sophisticated harvesting methods attempt to catch fish.

**ii.** The use of rivers, lakes, and the air as methods of waste disposal also create a variety of commons problems (some aesthetic and some that have clear health effects).
- Such commons problems tend to arise as economic development takes place.
- As more and more waste products are dumped into the air and water, eventually a point is reached where the waste products are no longer readily diffused by water flows and wind.
- An unregulated commons eventually becomes *over used* as it is used more and more intensively.

C. Commons problems and other environmental problems can be solved through public policies, as noted in this class.

**i.** If these common problems are simply ignored or impossible to solve, then there will by many tragedies of the commons--and economic development will be synonymous with erosion, depletion, and pollution (as occasionally argued).

**ii.** *The extent to which environmental problems are associated with economic development depends on whether or not effective public policies are put in place to address those problems.*

**iii. Politics (good and bad), thus, plays an important role in determining whether growth is sustainable or not.**

D. **Global Warming is a New Commons Problem.**

**i.** If it turns out to be a major one, it is not clear that we will be able to solve it.

**ii.** The technologies required to stabilize carbon densities are very expensive to use and/or require significant changes in lifestyles.

- Essentially it requires a shift to an electric and hydrogen based transport and production system
- Electricity may be produced via nuclear, hydro electric, and various solar and wind sources
- If necessary, these will require major investments in infrastructure and in new power plants.

**iii.** Again technological innovation can reduce the cost of minimizing net carbon emissions, but again it not necessarily that inexpensive methods for reducing emissions or increasing the effectiveness of carbon sinks will emerge.

- Innovations often occur, but cannot always be anticipated.

**iv.** Global warming also requires essentially every government on the planet to adopt stringent new regulations for carbon emissions, which is not likely to be possible through Coasian contracts--e.g. international treaties.

- **A ban on net carbon emissions, however, is very costly under current technologies and so incentives for cheating are likely to continue**
- **Only if new carbon sinks can be developed, which can be implemented by a small number of countries, is global warming likely to be effectively addressed.**

**v.** Fortunately, it is quite possible that global warming is not a serious problem in the short and medium run, or even in the long run.

- In that case, steps to reduce fossil fuel use may simply stretch out our existing supplies, which might be justified using national security or equity rationales.
- (Such steps, however, **could be over done** and produce significant problems. Imagine, for example, the economic effects of poorly implemented, but demanding, carbon cap and trade system.)

## IV. Economic Growth, Environmental Policy, and Democracy

A. If we look about the world, it is important to note that the **most developed countries are NOT the ones that have the greatest environmental problems**.

- The most developed countries tend to be democracies.
- And, the median voter has preferences for environmental quality (and amenities), as well as for economic growth.
- She has, therefore, demanded policies that address her environmental concerns.

B. The most severe environmental problems tend to be those associated with dictatorships where the demands of ordinary citizens are not automatically reflected in public policies--as in China and the former Soviet Union.

**i.** (This is not to say that there are no problems, nor that the solutions are perfect, but it is to say that democratic politics is an important part of the environmental picture in modern societies.

**ii.** Moreover, international problems are inherently more difficult to address politically than are national and sub-national environmental problems.)

C. Poorly run governments do not necessarily solve commons problems or other externality problems very well--even once the problems are recognized.

D. The sustainablility of growth in the long run depends on the continued success of proper political response to commons problems that arise as economic growth continues.

**i.** Well functioning markets and political systems tend to address a wide range of sustainable growth issues, as they become widely recognized.

**ii. Keeping alert for new problems** is an important part of the recipe for sustainable growth.

**iii.** As long as technological and public policy improvements are possible, further growth may well be sustainable ad infinitum.

## V. A picture: