Natural Processes, Human Technologies, and Macroeconomics

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Main points I

- Aggregate macroeconomics is built up from cost relationships that set prices, distributive relationships among economic actors, and their patterns of spending that determine output.
- “Technological progress” reduces apparent costs of output per capita. For example, large-scale agriculture combines energy embodied in machinery and agrochemicals with land and human labor to generate high levels of output relative to labor, or low output prices relative to the wage rate.

Main points II

- Technical change also affects distribution (Green Revolution) and patterns of demand (Google, which in operation is quite energy intensive).
- From a biophysical perspective, these changes have all been “short run,” occurring in time frames of years or decades.
- But historically, changes in technologies and tastes have had longer run implications which have not been foreseen.
- One important example is land degradation in floodplain civilizations (Indus valley, southern Mesopotamia), with extensive irrigation leading over centuries to rising water tables and highly saline or alkali soils.

Main points III

- Degradation did not “always” occur (Nile valley). But when it did, novel irrigation technology induced natural feedbacks that eventually destroyed the system. These changes were not foreseen in microeconomic calculations but ultimately upset the macroeconomy by reducing agricultural productivity in a form of “technological regress.”
- A more recent example has been increasing energy use in production processes over the past two centuries. Discuss that in some detail, and then come back to the broader theme.

Energy Productivity and Labor Productivity I

- For two centuries, there has been a strong positive association between increases in labor productivity (the basic source of per capita income growth) and energy intensity, or the ratio of energy use to labor.
- Using energy from fossil fuels inevitably creates atmospheric carbon dioxide or CO_2 (the most important GHG). It is a "produced means of destruction" of economic output.
- Its effects, however, only become apparent with a lag because it takes time for the atmospheric stock of GHG to build up.

Energy Productivity and Labor Productivity II

- The literature on economic planning concentrated on produced means of *pro*duction. It suggests that *early* investment in such technology has a big pay-off because it yields benefits over a longer time span than investment in the future. The same logic applies to early investment in GHG mitigation, to slow technological destruction.
- Mitigation is likely to cheaper in non-industrialized economies because they can use technologies already on hand in the rich countries.

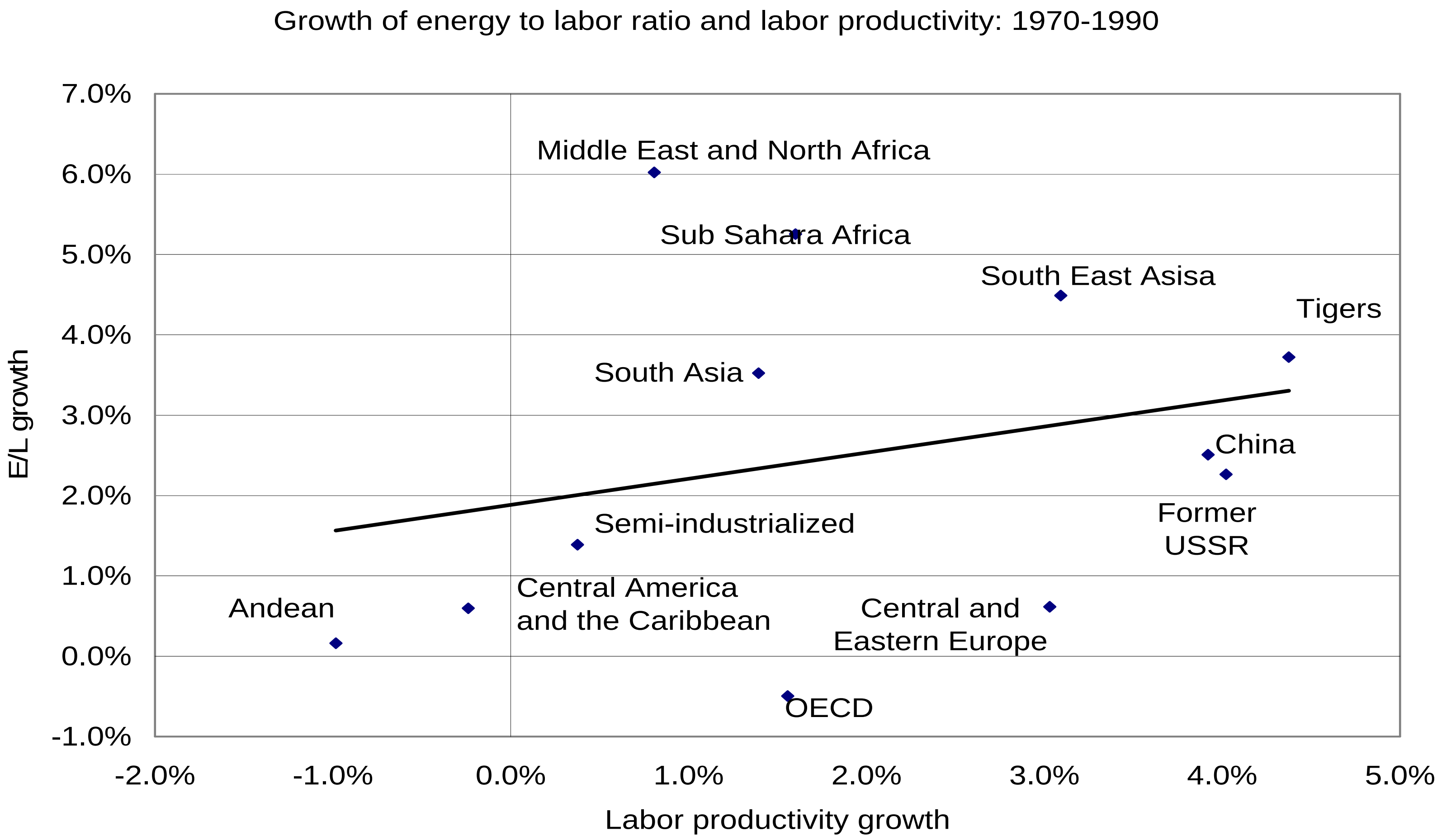
Energy Productivity and Labor Productivity III

- As discussed further below, the adverse effects of GHG creation on production are often called an “externality” which forces output to lie below the maximum level feasible along the “production possibility frontier.” Moving toward the frontier means that all economic actors – say both present and future generations in particular – can gain.
- In other words, early investment in mitigation concentrated in developing countries may lead to benefits from future generations without “excessive” costs in terms of foregone consumption for present generations.
- Let’s see how the logic works out.

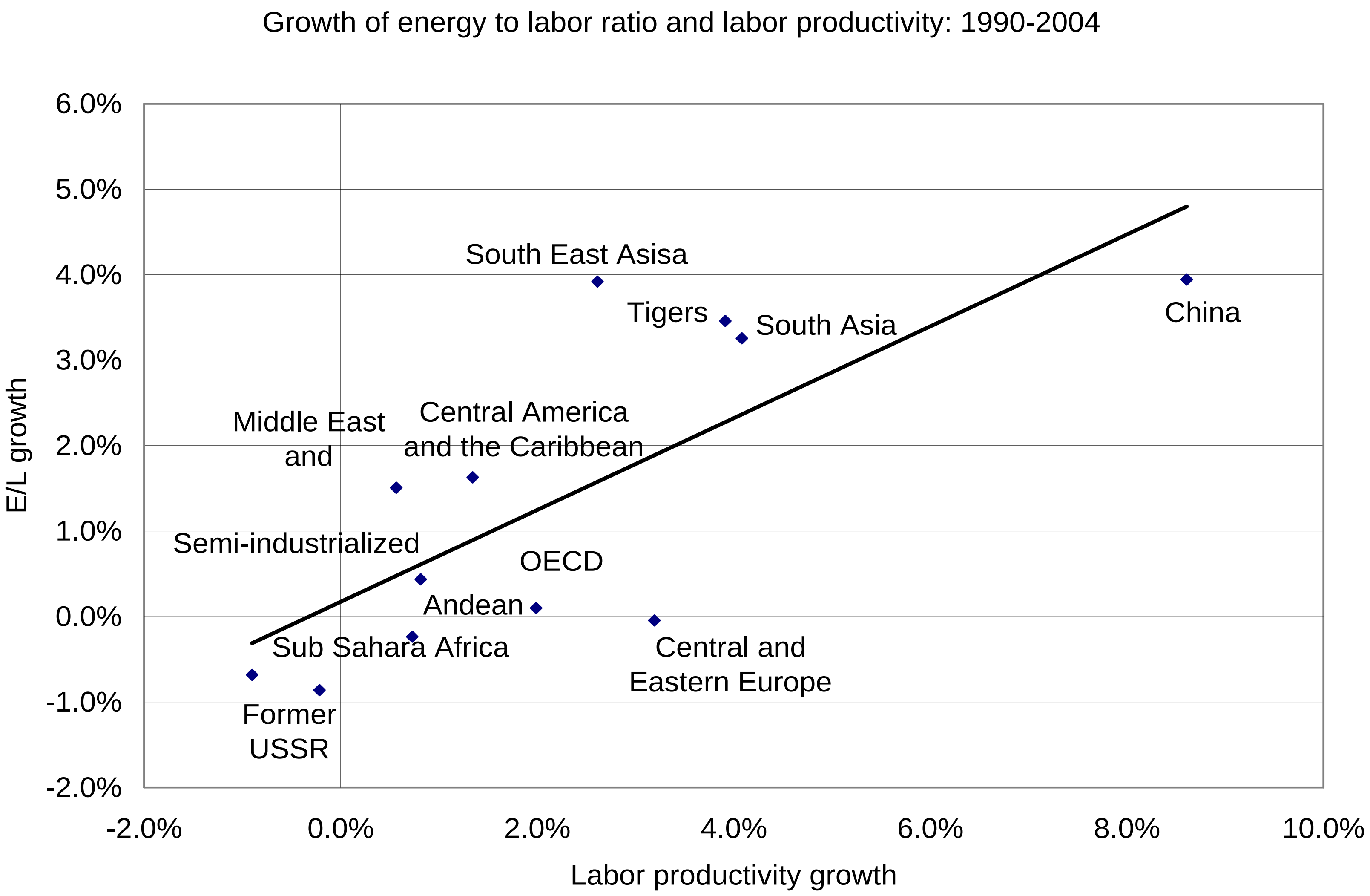
Energy Productivity and Labor Productivity IV

- There is a pretty clear positive association over 35 years between growth rates of the energy/labor ratio and labor productivity in regions of the world. The relationship got stronger after 1990.

Growth rates of labor productivity and the energy/labor ratio (1970-1990)



Growth rates of labor productivity and the energy/labor ratio (1990-2004)



Energy Productivity and Labor Productivity V

- Here are numbers on annual energy use (or use of power) in terajoules per worker-year . One terajoule is roughly equivalent to 7700 gallons of gasoline or 31 tons of coal.
- There is a wide range of uses -- from 0.01 (77 gallons of gasoline) in sub-Saharan Africa to 0.74 (5700 gallons) in Saudi Arabia. The ratio is 0.58 in the US and less than 0.3 in Western European countries, the Asian Tigers, and Japan.
- Again we see a pretty strong association between growth rates of the energy/labor ratio E/L and labor productivity.
- Growth rate of energy productivity = growth rate of labor productivity – growth rate of E/L. Less impressive.

Growth of energy productivity, labor productivity, and the energy/labor ratio

1970-1990	Selected OECD	Central and East. Europe	USSR (1989 end year)	Tigers	South East Asia	China	South Asia	Semi-Industrialized countries	Central America and the Caribbean	Andean	Middle East	SubSahara Africa
Growth Rates Energy Productivity	2.1%	2.4%	1.6%	0.6%	-1.3%	1.4%	-2.1%	-1.0%	-0.8%	-1.1%	-4.9%	-3.5%
Growth Rates Labor Productivity	1.6%	3.0%	4.0%	4.4%	3.1%	3.9%	1.4%	0.4%	-0.2%	-1.0%	0.8%	1.6%
Growth Rates E/L	-0.5%	0.6%	2.3%	3.7%	4.5%	2.5%	3.5%	1.4%	0.6%	0.2%	6.0%	5.3%
E/L beginning year (1970)	0.49	0.21	0.26	0.08	0.01	0.02	0.01	0.09	0.04	0.04	0.05	0.0048
E/L end year (1990)	0.45	0.24	0.40	0.17	0.03	0.04	0.02	0.12	0.05	0.04	0.16	0.0133

1990-2004	Selected OECD	Central and Eastern Europe	USSR (1989 end year)	Tigers	South East Asia	China	South Asia	Semi-Industrialized countries	Central America and the Caribbean	Andean	Middle East	SubSahara Africa
Growth Rates Energy Productivity	1.9%	3.2%	2.1%	0.4%	-1.3%	4.5%	0.8%	0.4%	-0.3%	1.0%	-0.9%	-0.2%
Growth Rates Labor Productivity	2.0%	3.2%	-0.2%	3.9%	2.6%	8.6%	4.1%	0.8%	1.3%	0.7%	0.6%	-0.9%
Growth Rates E/L	0.1%	0.0%	-0.9%	3.5%	3.9%	3.9%	3.3%	0.4%	1.6%	-0.2%	1.5%	-0.7%
E/L beginning year (1990)	0.45	0.24	0.41	0.17	0.03	0.04	0.02	0.12	0.05	0.04	0.16	0.01
E/L end year (2004)	0.45	0.24	0.37	0.27	0.05	0.07	0.04	0.12	0.06	0.04	0.19	0.01

Data Sources: World Bank Development Indicators 2005 database; Gronningen Center for Growth and Development

Energy Use and GHG Emission

- Now look at emissions per use of power (next slide): 65–75 metric tons per terajoule in rich countries and somewhat higher in (some) developing and transition economies.
- However the numbers for China, Kenya, Brazil, etc. suggest that there is room for reducing worldwide emissions simply by increasing poor countries' efficiency of carbon utilization. But that major benefits can only come from cutting back on energy use per capita and per unit of economic output.
- In any case, switching from the current worldwide mix of fossil fuel energy sources to using natural gas (the least carbon-intensive source) exclusively would reduce carbon emissions by only about 15%.

Carbon dioxide emission and energy consumption in 2004

	World	US	UK	Sweden	France	Japan
Total CO_2 Emission (thousands of metric tons)	27,245,758	6,049,435	587,261	53,033	373,693	1,257,963
Total Energy Consumption (thousands of terajoules)	361,849.00	81,762.00	8,926.00	671.00	5,667.00	17,094.00
Employment	2,836,437	140,702	28,008	4,311	24,963	63,290
Population	6,411,145	293,028	60,271	8,986	60,991	127,480
Energy Consumption/Labor	0.13	0.58	0.32	0.16	0.23	0.27
CO_2 Emission/Energy Consumption	75.3	74.0	65.8	79.0	65.94	74
CO_2 Emissions/Population	4.25	20.6	9.7	5.9	6.1	9.9

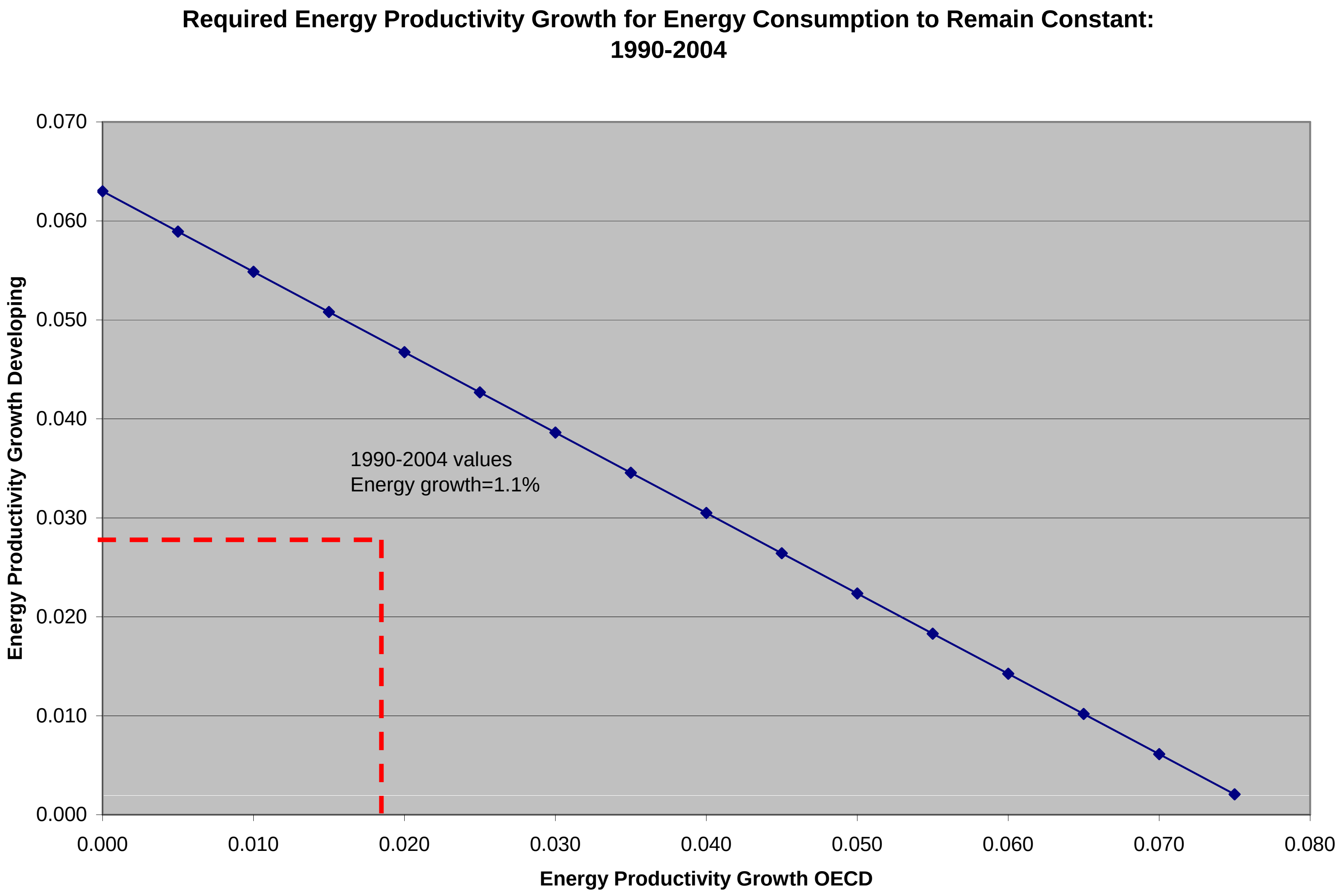
	China	India	Argentina	Brazil	Venezuela	South Africa	Kenya	Saudi Arabia	Poland	Russia
Total CO2 Emission (thousands of metric tons)	5,012,377	1,342,962	141,786	331,795	172,623	437,032	10,588	308,393	307,238	1,524,993
Total Energy Consumption (thousands of terajoules)	51,339	14,890	2,358	4,880	2,295	4,939	119	5,715	3,745	24,355
Employment	752,000	394,612	14,329	71,058	8,855	19,092	15,110	7,675	13,855	66,407
Population	1,295,734	1,065,071	38,984	183,169	24,765	44,448	33,973	25,796	38,580	143,508
Energy Consumption/Labor	0.07	0.04	0.16	0.07	0.26	0.26	0.01	0.74	0.27	0.37
Carbon Emission/Energy Consumption	97.6	74.0	65.8	79.0	65.94	74	89.0	74.0	73.7	74.7
Carbon Emissions/Population	3.87	1.3	3.6	1.8	7.0	9.8	0.31	12.0	8.0	10.6

Data Sources: Gronningen Center for Growth and Development; 2004 Energy Statistics Yearbook, United Naions; Carbon Dioxide Information Analysis Center, United States Department of Energy

Rich and Poor Country Trade-offs I

- In 1990–2004, energy productivity rose at 1.9% per year in the rich OECD economies and at 2.8% in the rest of the world because of high productivity growth rates in some of the larger economies (red dashed lines in the next slide).
- The blue line is an isocline showing combinations of energy productivity growth rates that would have been needed to hold the growth rate of total energy use to zero.
- For example this goal could be achieved with energy productivity growth rates of about 3.5% in both developed and developing countries. This target would imply a growth rate in the energy/labor ratio of about -1.5% in rich countries and -1% in poor countries.

Energy productivity growth rates required to hold overall growth of energy use to zero, 1990-2004



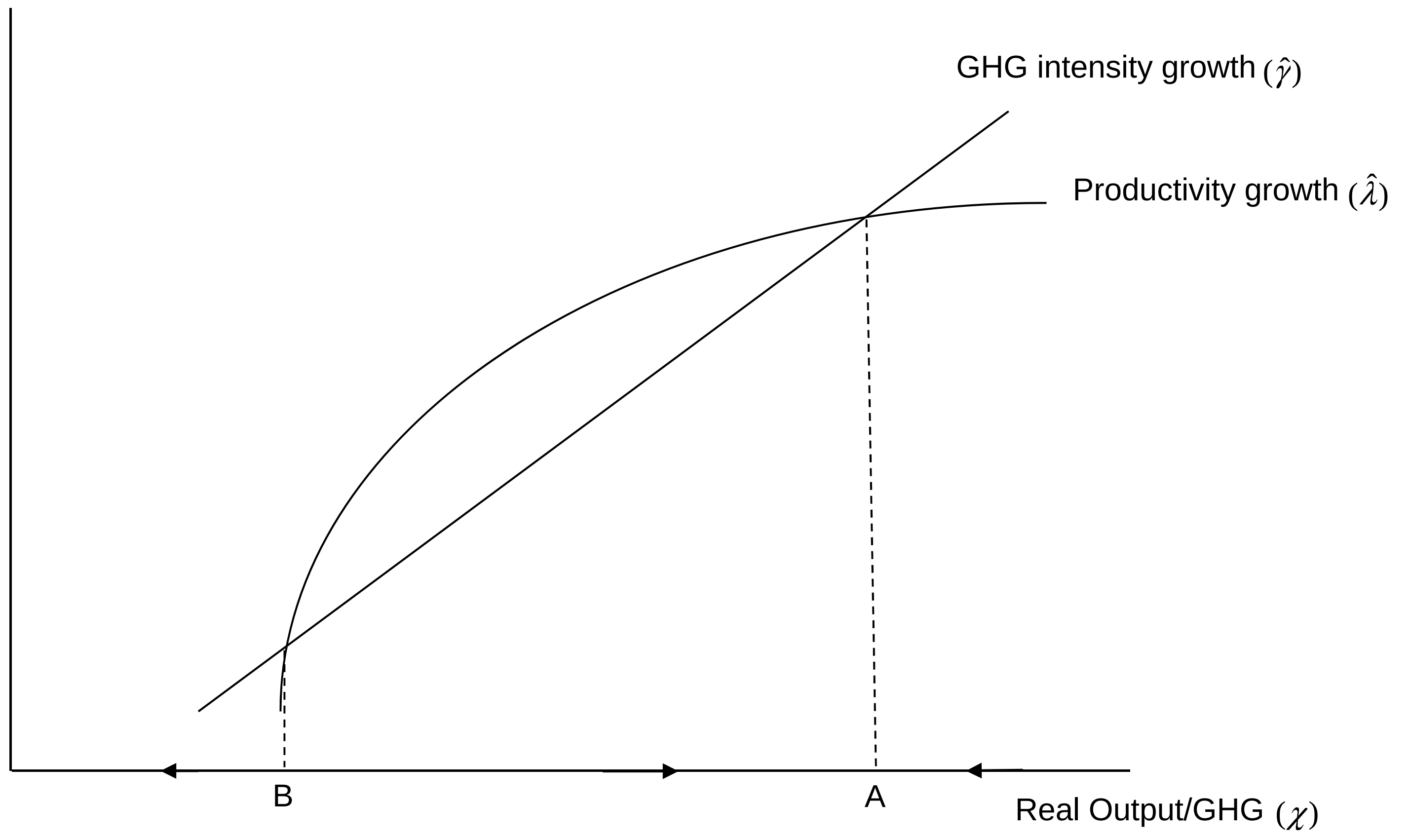
Rich and Poor Country Trade-offs II

- Compared to the historical data summarized above, the rates of change in energy/labor ratios required to achieve zero energy use growth look extremely optimistic. The required changes in growth rates are on the order of 100 percent of the historical growth rates themselves.

Medium Term Issues I

- Now let $\lambda = X/L$ be labor productivity, $\gamma = G/L$ be GHG concentration per unit of labor (intensity), and $\chi = \lambda/\gamma = X/G$ be output per unit of GHG.
- Next slide shows trade-offs *if* the system is stable: Growth rate of GHG intensity rises as χ goes up.
- At the same time, labor productivity growth rate decreases (at an increasing rate) as χ goes down or G/X goes up.
- There is a “steady state” value A of χ for which growth rates of labor productivity and GHG intensity are equal. Eventually labor force growth would have to fall to zero if total GHG were to stabilize.

Stable "medium term" greenhouse gas accumulation dynamics



Medium Term Issues II

- At present, growth rates of γ and λ are about 0.5% and 2% respectively so that $\chi = \lambda/\gamma$ is rising, or χ lies to the left of point A.
- However, A itself may be shifting toward the left as the intensity growth rate schedule shifts upward and the productivity growth schedule shifts down.
- What are the implications for investment planning?

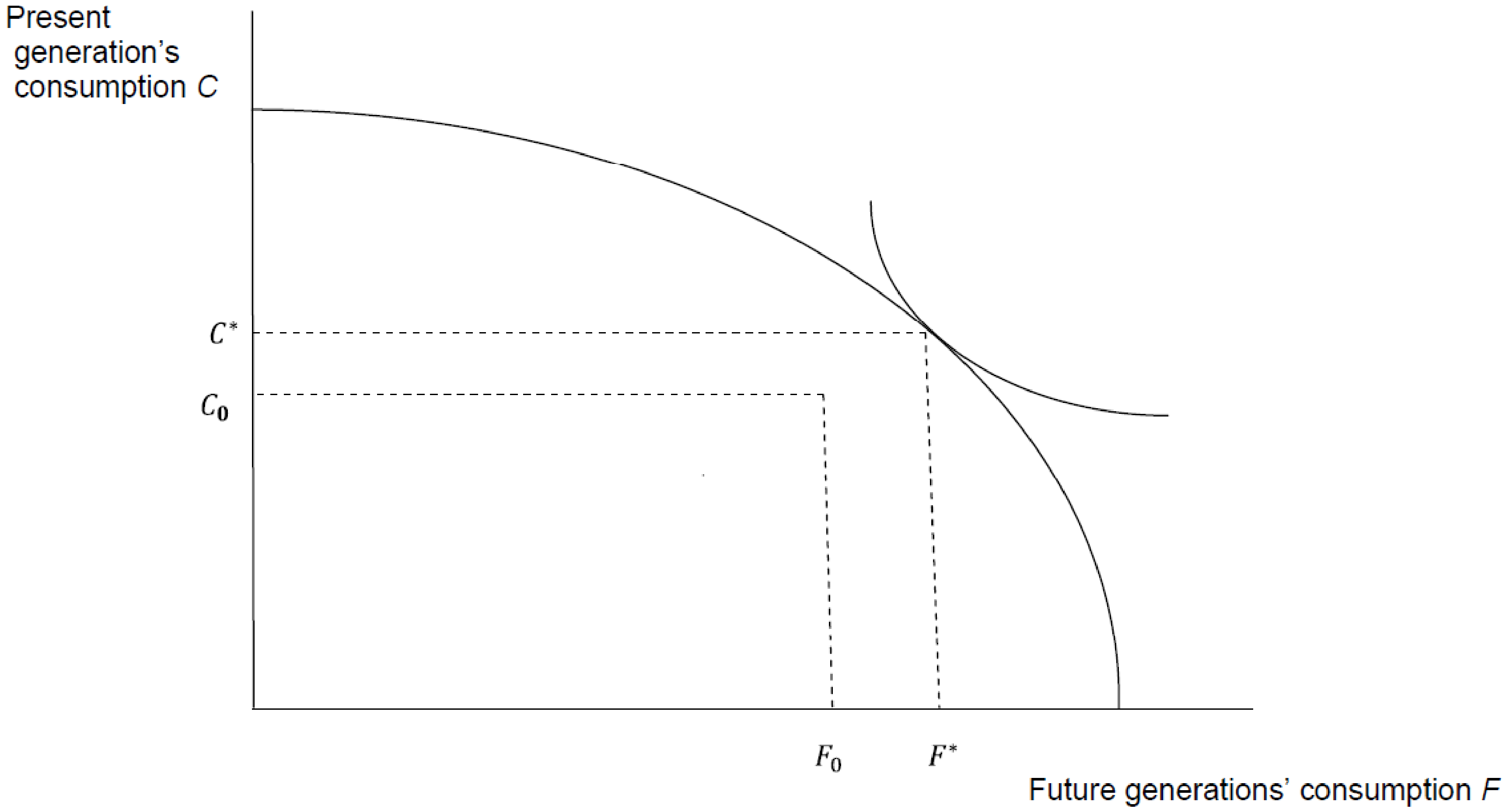
Medium Term Issues III

- That is, we have already argued that it makes sense to pursue mitigation earlier than later, and that achieving mitigation may be less costly in poor countries than in rich ones. In both cases, slower growth of energy intensity (the energy/labor ratio) is likely to be required.
- Another consideration, raised by Duncan Foley and noted above, involves the GHG “externality.”

Medium Term Issues IV

- In the next slide, the economy operates at a point (F_0 , C_0) within its production possibility frontier between future consumption F and present consumption C. Relaxing the externality allows the system to move toward (or closer to) an "optimal" allocation such as (F^*, C^*).

Stylized description of removing the GHG externality (following Foley)



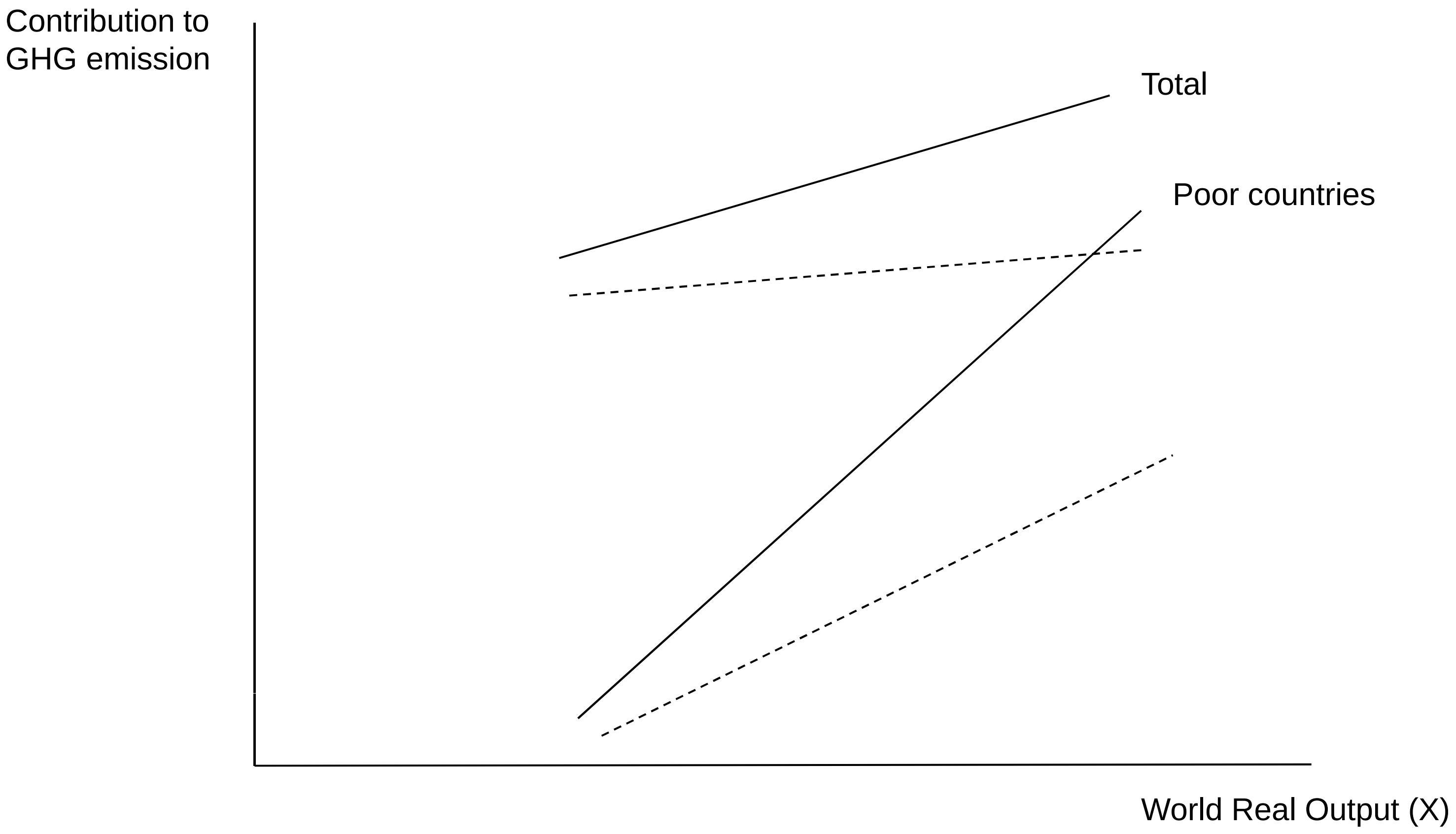
Medium Term Issues V

- How could such a shift be attained? A final conflicting factor is preference for present over future consumption.
- When that effect is taken into account, an “optimal” plan as calculated by Foley, Rezai, and Taylor has the following features:
- Mitigation outlays are front-loaded, amounting to 1-2% 0f GDP in early decades of the plan, and stabilizing thereafter.

Medium Term Issues VI

- Depending on parameters consumption in the first decade of the plan may be slightly above or below the “business as usual” (BAU) level. Over the entire time horizon, consumption utility in an optimal plan exceeds its level under BAU.
- We did not consider regional allocations. Hypothetically, under BAU poor countries would contribute an increasing share of total emissions (solid lines in next slide). The dashed lines show a mitigation scenario in which the poor country contribution drops off notably on the assumption that decreasing returns to mitigation are less onerous in economies which use relatively low levels of energy in production, often under conditions of low efficiency.

Hypothetical contributions to GHG emission



Summing up I

- Not all biophysical processes will be macroeconomically visible, with effects in the range of 1% of GDP or more.
- Besides global warming, problems of sufficient magnitude over the next decades might include water scarcity, land degradation (including loss of tropical rain forests) and scarcity of other key resources (peak oil?).
- In dealing with them, the principles discussed here would continue to apply, i.e. mitigation of produced means of destruction, searching for regions or production sectors in which at the margin mitigation would be cheap, and balancing intergenerational trade-offs.

Summing up II

- The great risk is that there are as yet unrecognized biophysical processes which may be macroeconomically destabilizing. Global warming may have been recognized in time, but there are certain to be many “unknown unknowns” in the future.