Growth and Sustainability
Based on Perman et al., chapters 3 and 4
And on Pezzey, introduction to the "Economics of Sustainability"

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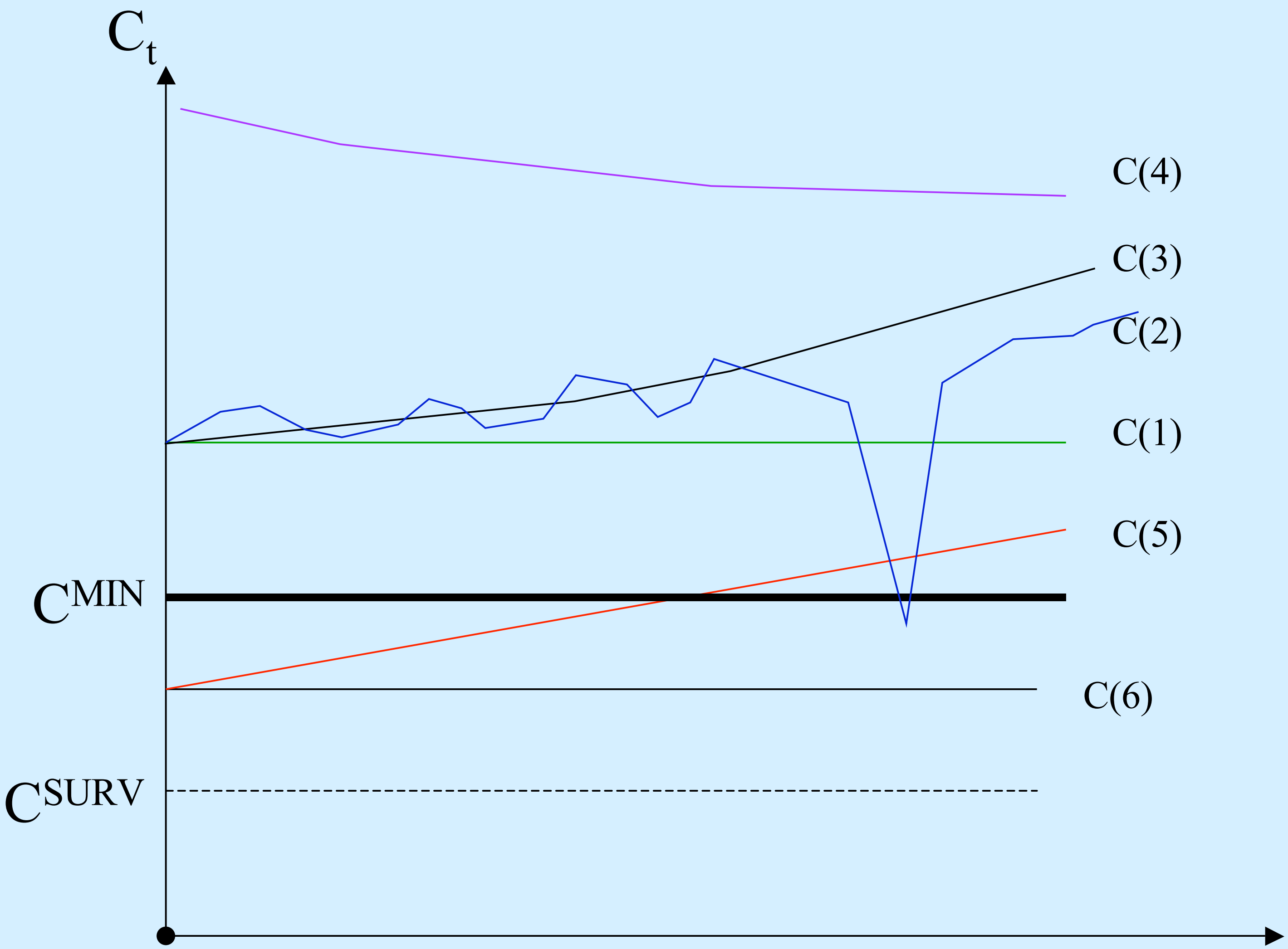
Three sustainability criteria:

- Non-declining consumption
- Survivability constraint
- Minimum standard of living constraint

Figure 4.1 Consumption paths over time.



Six concepts of sustainability: a sustainable state is one in which …

- Utility/consumption is non-declining over time (econ)
- Production opportunities are maintained for the future (econ)
- Natural capital stock is non-declining over time (econ)
- A sustainable yield of resource services is maintained (ecol)
- Ecosystem resilience is maintained (ecol)
- Consensus-building and institutional development occurs

Is optimization of intertemporal utility consistent with sustainability?

Optimal growth: no natural resources

Goal: Find consumption and investment path that maximizes discounted utility from consumption, based on available technology

Assumptions:

- Exponential (time-consistent) discounting
- Capital is reproducible through investment
- Positive, but diminishing marginal returns to investment

Optimal growth; no natural resources cont.

Results:

- More investment occurs early on while marginal payoffs are high relative to consumption
- Consumption levels off asymptotically
- The asymptotic level of consumption (steady-state) depends on the discount rate; higher rates lead to lower levels.

Optimal growth with non-renewable resources

- Assumptions:
- Rate of capital growth depends on both man-made and natural capital (3.23a)
- Amount of natural capital is reduced by the amount used in production each year (3.23b)
- The total amount of natural capital used over time can be no more than the total amount available (3.23c)
- No explicit assumptions about substitutability

Optimal growth with non-renewable resources, cont.

- Results:
- Optimal path involves increasing then decreasing consumption
- With a Rawlsian constraint (maximize the utility of the worst off generation), the optimal consumption path can be constant consumption forever (Solow 1974a)
- This results depends on man-made and natural capital being substitutes

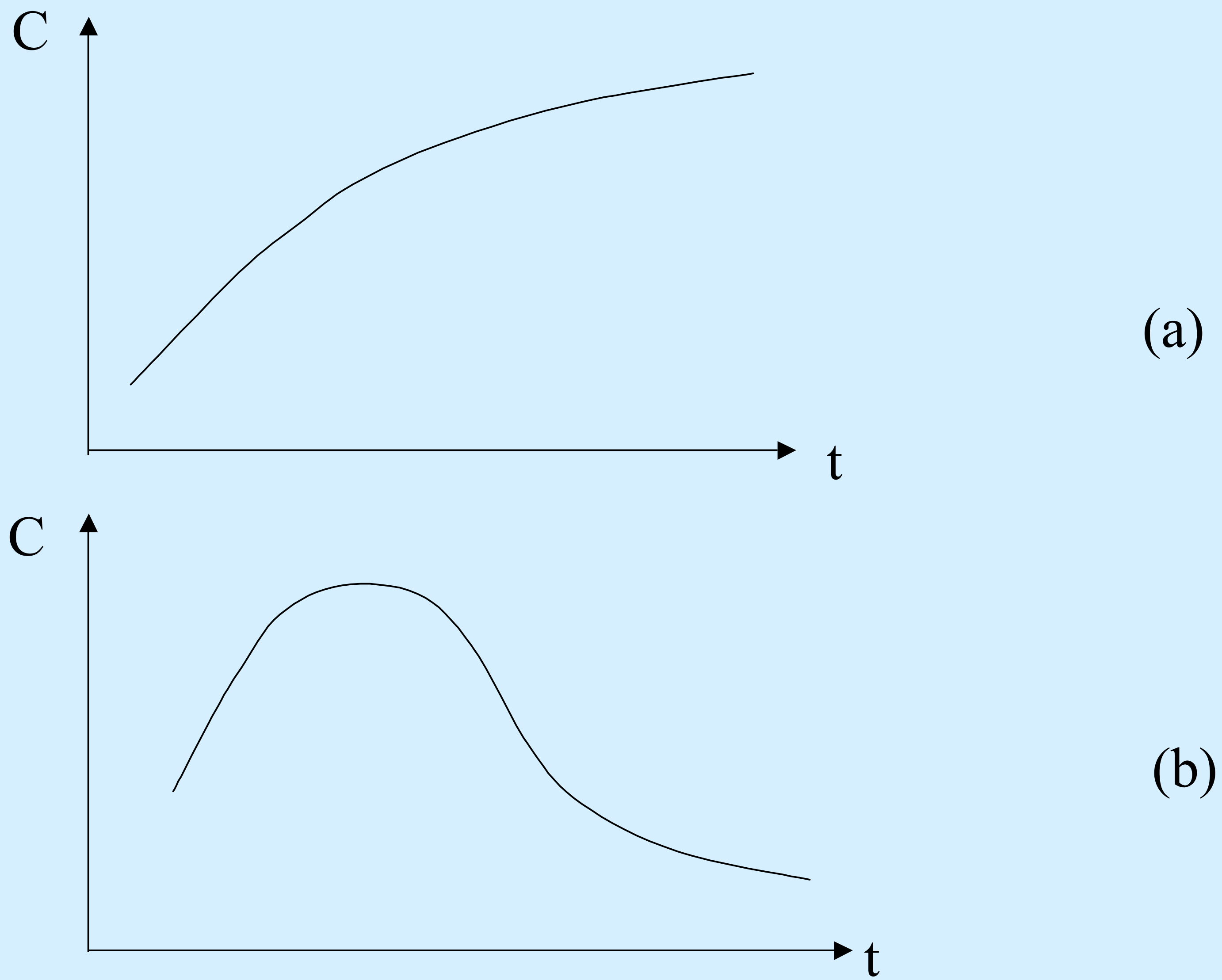


Figure 3.6 Optimal consumption growth paths

Are economists' conceptions of sustainability feasible?

- Answer depend on the substitution possibilities between man-made and natural capital
- For perfect substitutability, sustainability is trivial
- For partial substitutability, sustainability is feasible
- For non-substitutability, sustainability is not feasible (but note this is true only for non-renewable resources!)

Figure 4.2 Production functions with capital and natural resource inputs.

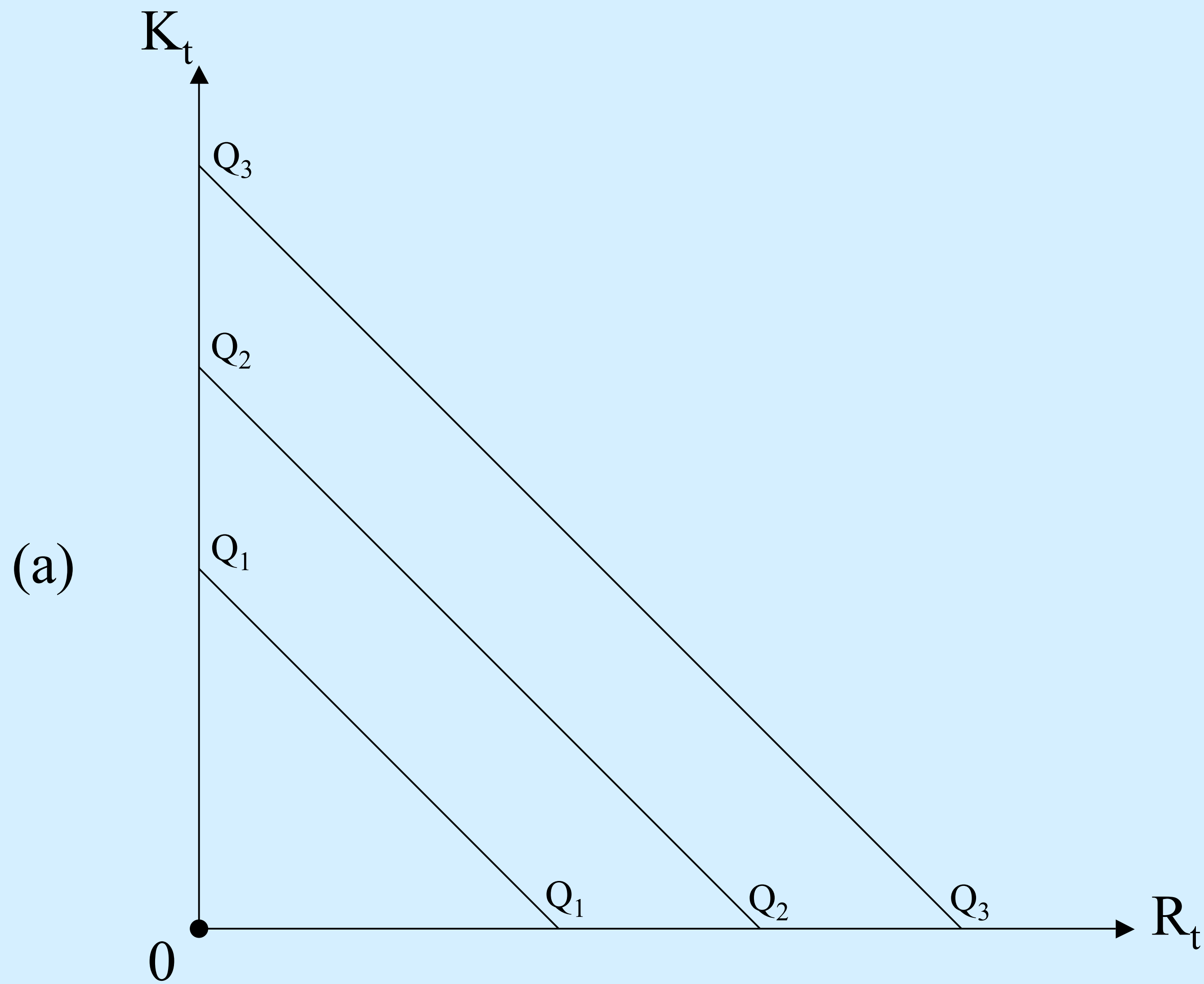


Figure 4.2 (Part (c))

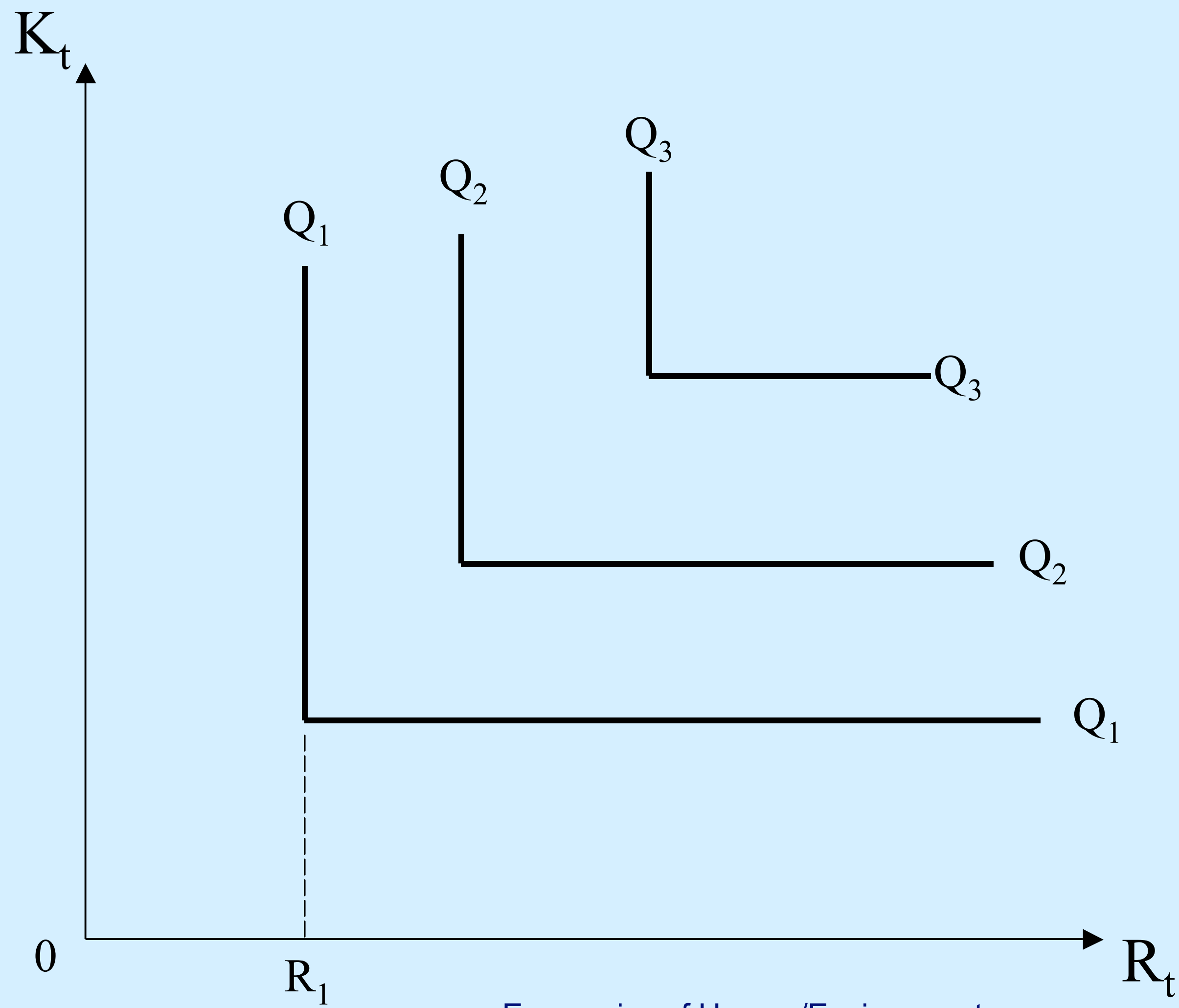
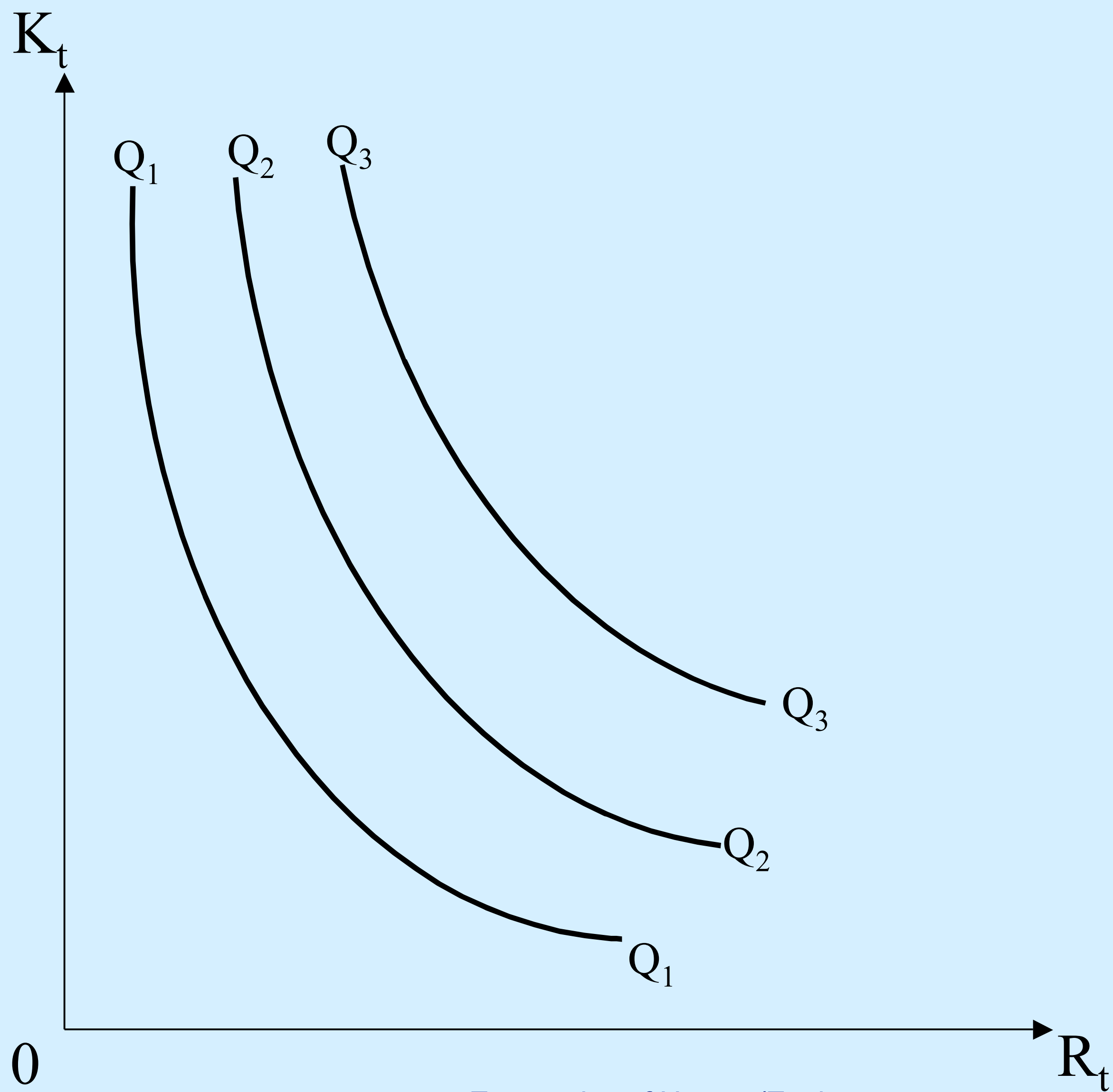


Figure 4.2 (Part (b))



The Hartwick Rule: ensuring constant consumption

If the following conditions are met:

- Man-made and natural capital are substitutes
- Man-made capital contributes more to output than natural capital
- Resource allocation is intertemporally efficient
- Total resource rents (difference between marginal extraction cost and sales price) are invested in production of man-made capital

Then, constant consumption is obtained

Weak vs. strong sustainability

- Both have the goal of constant consumption over time
- “Weak” sustainablists assume Hartwick substitutability conditions are met
- “Strong” sustainablists assume that, at least in some important aspects, substitution is not possible

Weak vs. strong sustainability cont.

- Natural capital includes non-renewable and renewable resources, including ecosystem services. Strong sustainability requires non-declining stocks of natural capital.
- Man-made capital includes physical, human, and intellectual capital, and therefore embeds technological progress. Weak sustainability requires that the sum of natural and man-made capital be non-declining.

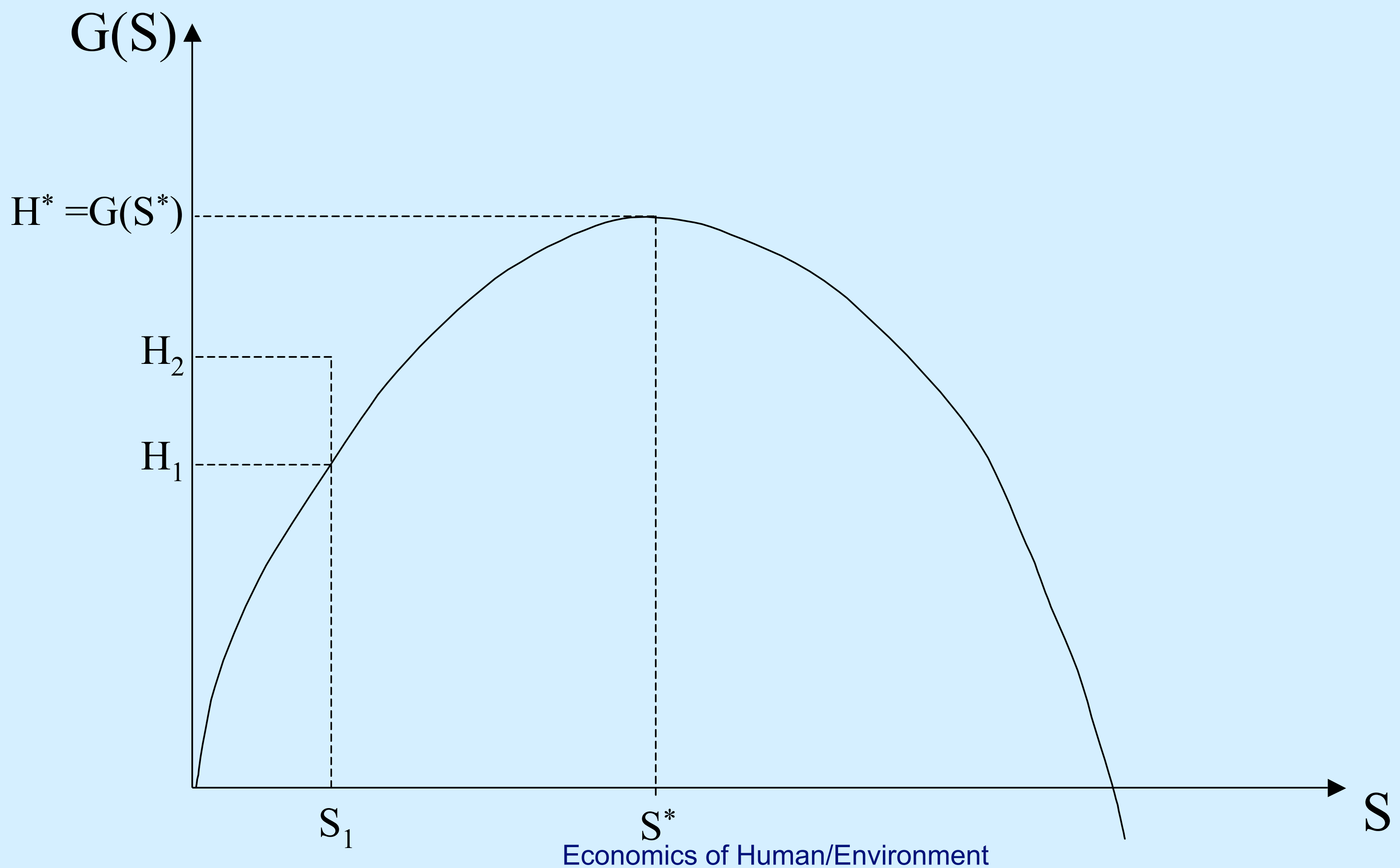
Past evidence and future concerns

- Past evidence indicates that man-made capital can often substitute for natural, often due to technological progress (the “Weitzman” perspective
- However, evidence indicates that man-made capital cannot provide life-sustaining ecosystem services on a large scale (the “Kahn” perspective)
- If the goal is to sustain stocks of natural capital, it must be measured--very difficult in an environment where prices send the wrong signals

Ecological perspectives: sustainable yield

- Sustainable yield is the amount of harvest of a renewable resource that will not diminish the stock of the resources
- With a simple logistic growth function, there are many sustainable yields
- Maximum s.y. occurs at moderate stock levels
- Economic models dictate MSY only under special circumstances (our friend discounting!)
- We will talk about critical depensation later

Figure 4.3 Sustainable harvests.



Resilience

- Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems (SES). "Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:

- * The amount of change the system can undergo and still retain the same controls on function and structure
- * The degree to which the system is capable of self-organization
- * The ability to build and increase the capacity for learning and adaptation
- For lots more interesting information and links to really interesting people, see the Resilience Alliance: http://www.resalliance.org/ev_en.php

The steady-state economy (Daly)

- Requires a constant stock of capital and population (similar to demands of sustainability models)
- Efficiency improvements are gained through same stock with a lower level of throughput, or by a greater number of services from the same stock
- Entropy laws prevent sustained efficiency improvements
- Steady state is needed, but not infinitely sustainable
- Weitzman and Daly will never agree!

Reasons for caution

- Ecological considerations indicate that our understanding of ecological causes and consequences is highly uncertain
- The “precautionary principle” is a conservative decision strategy in this case: actions should not be undertaken unless they are demonstrated to not be likely to cause harm
- Safe minimum standards are another cautious strategy

What can such models tell us?

- Very abstract theoretical models generally only provide qualitative explanations and predictions
- Generally do not produce an immediately applicable policy prescription
- Model deductions are completely dependent on initial assumptions
- Sustainability is more likely if the Hartwick rule is adopted
- The free market is not likely to produce a sustainable level of capital accumulation, in part due to market failure, in part due to discounting

Pezzey, intro to “Economics of Sustainability”

Chapter serves several roles:

- Focuses more specifically on economic definitions of sustainabilty and details of the weak vs. strong debate
- Focuses more on intergenerational equity than Perman et al.
- Provides a nice history of the evolution of this literature
- Provides a nice overview of more litereature in the field, for those who might want to follow up

Possible article categorizations:

- Attention paid to intergenerational equity
- Tradeoffs inherent between environmental, economic, and social sustainability
- Focus on social welfare vs. some more specific metric
- Assumptions regarding resource substitutability
- Assumptions regarding technical progress
- Renewable vs. non-renewable resources
- Trade considerations
- Consideration of uncertainty
- Fixed or evolving preferences

Responses to "Limits to Growth"

- Models assume finite non-renewable resources which are production inputs
- Man-made capital may be substitutable
- Technological progress may be possible

Lessons from Limits to Growth responses

- Grim picture if non-renewable resource is essential for production
- Bright picture if you assume technological progress -> substitutability
- Solow’s analysis motivates Hartwick’s rule: constant consumption is possible if resource rents are invested in man-made capital substitutes
- Constant consumption is only possible if man-made and natural resources are substitutes (“Weak sustainability”)
- PV maximization does _not_ lead to constant consumption: “If one takes the view that market investment heavious is driven by a conventional PV objective, then Harwick’s investment rule in effect requires massive government intervention in captial markets” (Pezzey, page xvi).
- (Revisit last week’s assignment in light of this quote?)

Verbal/Philosophical contributions

- Tradeoffs between economic, social, and ecological sustainability
- Daly's "steady-state economy" principles:
  - Harvest rates equal regeneration rates
  - Emissions rates equal assimilative capacities
  - (non?) Renewable energy sources should not be depleted at a rate greater than development of substitutes
- Question: interpret Daly in terms of weak/strong sustainability

More contributions

- Note Pezzey has done more work on relative consumption and cites other papers in this area. This review is quite comprehensive …
- Toman suggest safe minimum standard as a way of bringing together economists and environmental philosophers. (I agree, but again it depends on WHICH economists.)
- Beckerman rejects strong sustainability (but believes in resource substitution

Intergenerational equity considerations

- Howarth and Norgaard demonstrate, using an OLG model, that intertemporal resource endowments lead to different--but all economically efficient--consumption profiles
  - (Implications for Phil's question about markets and Chris's question about endowments--what are possible policy implications (Susan)?)
- They also demonstrate that even with intergenerational altrusim, intergenerational transfers may not be PV maximizing (and results depend on discounting--no surprise)
- Pezzey points out that PV optimality implicitly assigns all resource rights to the current generation
- Is there a "Hartwick Rule" equivalent that endows resources to future generations?

Empirical sustainability work

- Challenges include calculating natural capital, depletion rates, investment rates, substitutability
- Pearce and Atkinson's work looks at savings and resource depletion rates
- Two big problems: how to estimate technical progress, and it is impossble to calculate correct prices (which are needed for resource rents)
- Note Franceschi and Kahn (last year) also has some empirical content

More empirics

- No surprise, Weizman concludes that taking into account technical change, our economy is sustainable.
- Propos finds that when trade is accounted for, resource-importing nations are less sustainable
- Hanley et al. estimate 7 measures for Scotland and find mix results for weak sustainability, and marginally sustainable according to the “strong” criteria
- Question: is a strongly sustainable economy also weakly sustainable?