The Economic Dimensions of Sustainable Intensification – Linkages to Environmental & Human Well-being

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Outline

- Motivation
- Modeling sustainable development: the objective function
- Population capital and resources
- Renewable resources and sustainable development
- The bioeconomy
- Policy challenges
- Implication for applied economics

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In search of sustainable development [Sus Dev]

- Sustainable development: a paradox?....oxymoron
  - Sustainable – Capacity to endure; unchanging
    - Static
    - Synonyms include “maintain", "support", or "endure”.
  - Development – Change for the better
    - Dynamic
- Sus Dev is a challenge of bridging conflicts: how to keep the essential while minimizing nonessentials
- It applies to economics and biological systems

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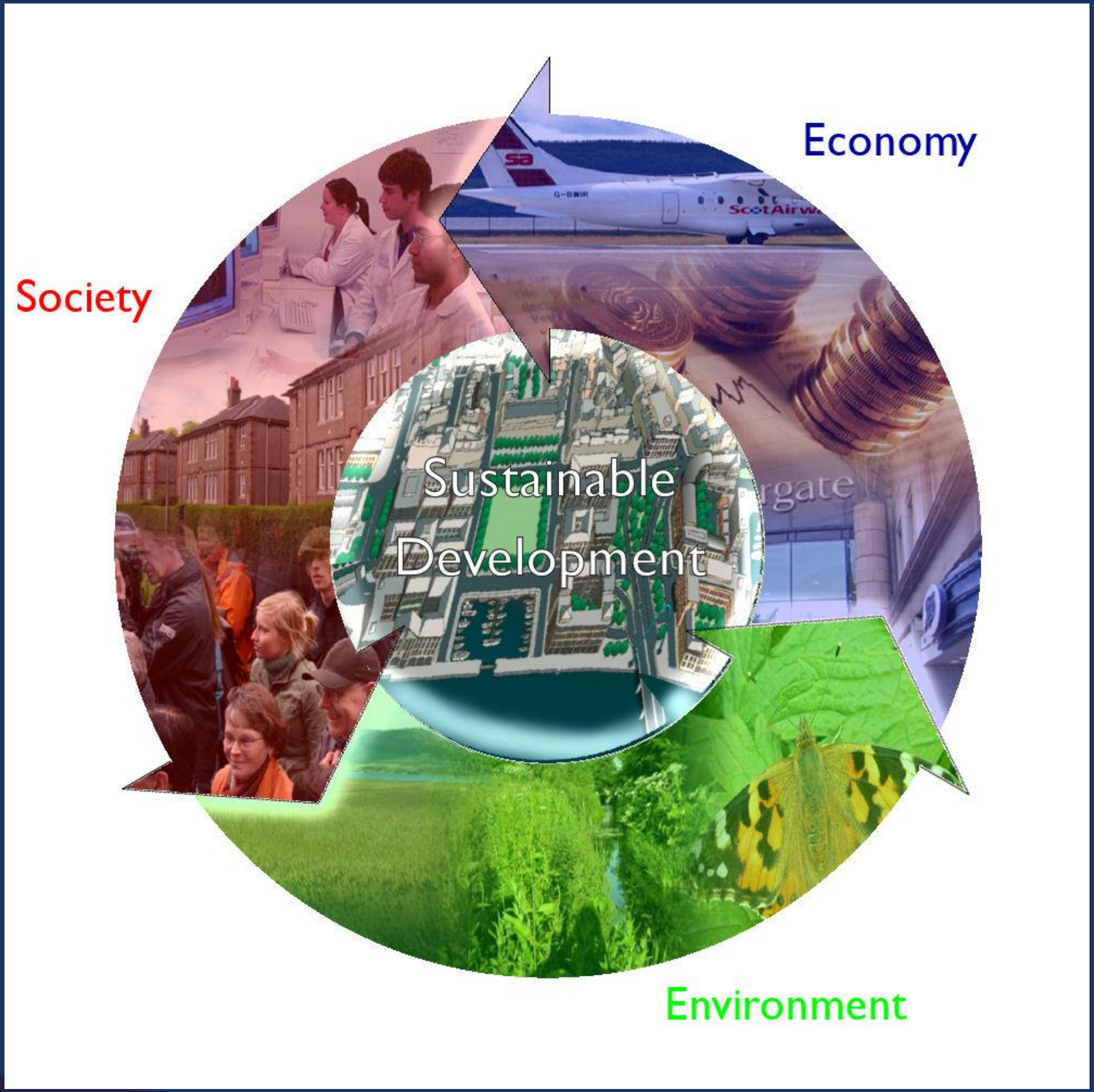
Multiple dimensions of sustainability

- Sus Dev is desirable, but interpretations vary
- Agreeing to pursue it represents a political compromise
- Over time a vocabulary to discuss sustainability was introduced, emphasizing the three pillars:
  - Economy
  - Society
  - Environment
- It is used to provide criteria for policy assessment
- We present an economic framework for Sus Dev relying on major tools developed by Applied economists
- A starting point for analysis is the Brundtland Commission.


Economy
Society
Sustainable
Development
Environment

Brundtland Commission:
March 20, 1987

- *"**Sustainable development** is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*
- This definition and economics are both anthropocentric:
  - Assume that humans are the most significant species
  - Human Utility maximization is the premier criteria
  - Other species are significant only if they provide utility to humans (pets, food) or affect productivity (fish, livestock)
  - Some environmental groups may take another perspective
    - leads to conflicts between **sustainability** and **sustainable development**
- This definition represents a constrained optimization problem—ideal for economic analysis

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Intensification

- Intensification is the transition to production systems that produce more with less input and environmental effects.
- It is a measurement challenge.
  - Is it in kilograms or dollars?
  - How do you incorporate multiple outputs?
  - What about health effects?
  - How do you compare the saving of various inputs?
  - What is the baseline?
- These questions won’t be answered here, but:
  - These questions must be answered in any research on intensification.

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Intensification and Sustainable Development

- We will argue that intensification is a crucial element of sustainable development.
- It is consistent with the desire to reduce footprint, sustain environmental amenities, and reduce pollution while improving human well-being.
- However, it is rare to find intensification strategies that are first order stochastic dominant in all dimensions (namely, use a lower level of all inputs but increase output).
- Intensification strategies often require some sort of sacrifice.
- They are more desirable if they require more human capital and less natural capital.

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Economic Models of Sustainable Development

- Maximize expected net present value of utility from consumption, environmental quality, and health subject to dynamics of:
  - Human capital
  - Physical capital
  - Social Capital
  - Natural Capital
- Natural capital affects both health and environmental amenities.

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Decision Variables and Sustainable Development

- Inputs, outputs, and pollution
- Consumption and investment
- Prices of goods and assets, including human capital and natural capital.
- Translated to policies that depend on economic conditions.
  - pollution taxes, regulation, tradable permits
  - investment in research

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Added Dimension of Sustainable Development

- Issues of income distribution
  - Maximize minimum income
  - Transfer payments
- Issues of resilience
  - Insurance
  - Redundancy
- Issues of information
  - Adaptive learning

Natural and Social capital

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Expansion of economic Sus Dev models

- Economic models of Sus Dev need to explicitly incorporate biophysical processes and the environment
  - Economic models capable of doing this exist
  - Applied economists have developed frameworks to model technologies that incorporate pollution generation for production and address various types of innovations
- Economic models of sustainability need to better address dynamics of natural resources

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Modeling technology to analyze Sus Dev

- Introducing technology adoption choices in the midst of production economics
    - Sustainable development addresses choices between discrete technologies (organic vs. GM)
    - Need to introduce discrete choices and adoption to production economics
- A key to modeling technology is knowing the production, pollution, and risk generation functions.

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Incorporating input use efficiency
(a term used by engineers, scientists, and practitioners)

- **Input use efficiency** is the fraction of input actually utilized in production (cars have about a 30 % fuel efficiency)
  - Distinguish between applied and effective input
  - Input use efficiency depends on technology and location
  - Residues (unused inputs) may be polluting
  - Adoption will likely increase yield
  - Optimal if extra gains > fixed costs
  - Not optimal everywhere
- **Damage control** (a related concept)
  - *Actual Output = Potential Output – Damage*
  - Damage depends on technology and location
  - May increase over time (i.e. resistance)

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Input use Efficiency: A Key Element in Intensification

- Intensification strategy by definition increases input use efficiency of socially scarce resources (market value + externalities) and reduces pollution per unit of output.
- Frequently requires extra investment and cost.
- Most desirable when it relies on human capital and abundant and environmentally benign inputs to substitute for scarce and hazardous inputs.
- Increased input use efficiency is associated with increased precision, which is also a key ingredient of intensification.

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Irrigation: increasing input use efficiency

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The link between coal and air quality

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Importance of complementarity among inputs

- Technologies are introduced in packages
  - The Green Revolution included new varieties, fertilizers, and irrigation practices in some cases.
- Complementary inputs working in tandem may lead to massive increases in yields
  - Ghana produces 1 ton corn-hectare while the US produces 10 tons-but Ghana can reform:
    - Adding fertilizer will double yield
    - Pest control will do the same
    - Improved varieties will have a similar effect, increasing yields from 1 to 8 tons/hectare

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Innovation

- **Innovation** is the product of efforts and investment
  - **Induced innovation**—technology advancement is the outcome of economic choices

- The educational industrial process leads to many innovations in the US
  - Similar factors can be used elsewhere

- Understanding technology generation will allow for policies triggering innovation.

Recognizing variability in Sus Dev analysis

- Introducing technological and institutional solutions in response to disruptions
  - Adoption
  - Adaptation
  - Expanded trade
- Different solutions recognizing heterogeneity and variation over space and time
- How will alternative solutions affect resilience?

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Modeling natural resource dynamics

- Nonrenewable resources (including environmental amenities' capacity to absorb harm).
- Recognizing irreversibility
- Renewable resources
- Considering alternative strategies of resource depletion and buildup.
- Renewable resources can be exhaustible.
- We can distinguish between renewable systems based on harvesting and on farming.
- Sustainable development intensifies farming systems.

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Renewable Resources (Cont'd.)

- Two types of living systems: Harvesting (hunting) vs. Husbandry (farming)

Harvesting	Husbandry
Hunting	Animal husbandry
Fishing	Aquaculture

- Farming includes
  - Breeding
  - Raising (feeding, disease and pest protection)
  - Harvesting
- Farming system has cheaper harvesting but incurs cost of breeding and raising

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Evolution of harvesting systems

- Gradual improvement of plant systems:
  - Better raising (fertilizers, pest control strategies, advanced irrigation, farm machinery, precision farming, etc.)
  - Better breeding (Selective breeding—biotechnology)
- The species involved in the transitions are modified
  - The modern cow is bred to be a docile milk machine and could not survive in wilderness
- Farming allowed the survival of wild populations— co-existence of agriculture and wilderness

Main elements to attain Sus Dev

- **Conservation** – reduces consumption of energy and nonrenewables. Can be achieved by:
  - Improving input use efficiency
  - Adoption of precision systems
  - Triggered by policies
- **Recycling**
  - Allow sustainable use of minerals
- Use of **renewable energy sources**, e.g solar, wind, etc.
- The **bioeconomy** (discussed in more detail on the following slide)

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The bioeconomy defined

- The **bioeconomy** is defined as:

“The part of the economy that utilizes new biological knowledge for commercial and industrial purposes, and for improving human welfare”

- Enriquez-Cabot 1998

- It produces foods, fuels, fibers, pharmaceuticals, chemicals, and even computer memory
- It is a natural resource based industrial system
  - Traditional technologies – fermentation (wine, etc.)
  - New technologies – modern molecular biology (DNA), information technology

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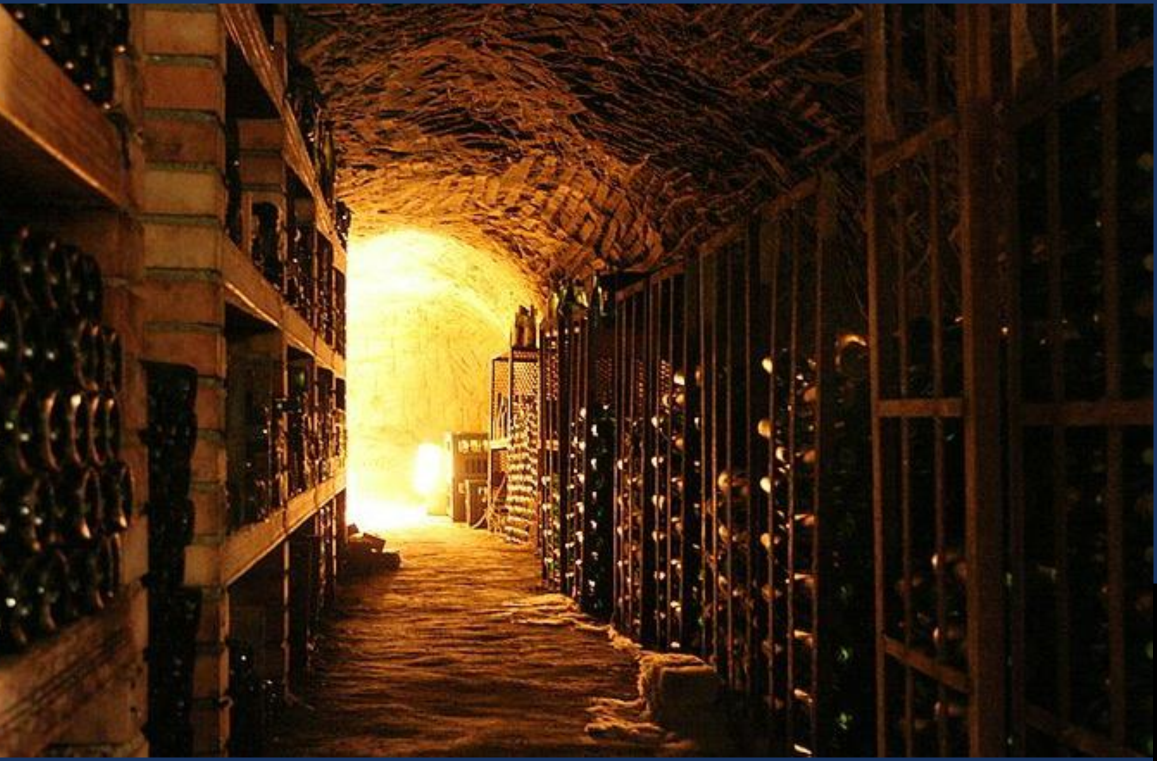
The old and new bioeconomy



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The bioeconomy leads to major changes

- Replaces nonrenewables with renewables
- Is associated with a new mode of R&D
- Increases value of natural resources and income from agriculture
- Provides new agribusiness opportunities and may create rural jobs in processing and production of new products (cosmetics, oils, coloring)
- Challenges food and energy systems
- Its future depends on polices and institutions

The bioeconomy is associated with transition

- From nonrenewables to renewables (biofuel, green chemistry)
- From harvesting to husbandry (using some biotechnology)
- Improvement of husbandry systems
  - Better breeding and raising (biotechnology)
- Development of new value added industries (many in rural areas)
  - Refineries to fuels and fine chemicals
  - Processing of new bio base product close to source

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Direct and indirect effects of the bioeconomy

- Reducing reliance on nonrenewables
- Increasing overall and farm sector welfare (?)
- Reducing externalities (?)
- Challenges
  - Outputs of the bioeconomy may be renewable but rely on nonrenewab inputs (fertilizers)
    - Fixing nitrogen is a major challenge and a $50 billion opportunity
  - Overall GHG's and other externalities of new products may be greater than those of the products they replace
  - Some bioeconomy activities will reallocate resources away from food production

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Bioeconomy and environmental and food challenges

- In order to assess and improve environmental effects:
  - Conduct Life cycle analyses (LCAs) to assess overall external effects
  - Establish policies that make agents pay social costs of the externalities they create
- Need constant increase in food productivity as well as mechanisms to protect the poor from food price inflation

GMOs

- Our study suggest that GMOs increased
  - Corn production by 10%+ annually
  - Soybean output by 15%+ annually
  - Increased inventories
- And decreased
  - Corn prices 20%+ annually
  - Soybean prices 25%+ annually
- Allowing biotech corn and soybean across the world would close to counter the impacts of biofuels
- Having GMO wheat and rice globally would make fuel affordable again
- So regulations and bans have a price besides slowing the introduction of new traits

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Agriculture is much more than food

- Traditional agricultural problem: low farm incomes suggested a need for new sources of income, and the bioeconomy provides it.
  - It increases the product mix of farming systems
  - It is also likely to shift jobs (in refining, processing, quality control, etc.) to rural areas
- But food comes first – need policies to assure food availability and affordability
  - The bioeconomy requires expanding the region of agricultural production and the productivity of agricultural systems, in particular food commodities

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Biofuel

- Sugarcane and corn are economically viable first generation biofuels
  - In case of corn, GHG reduction is small but increases balance of trade
  - Sugar ethanol has desirable GHG effects
    - Sugar in Brazil can grow to 40-60 tons/hectare, increasing from 8 today and replacing 20% of gasoline globally
- Other first generation fuels are less promising
- Some second generation ideas are promising, but require commercial testing
  - Has a large potential to provide liquid fuel without compromising food supply too greatly

Green chemistry

- Move from petroleum-based chemicals to plant-based chemicals
  - Biodegradable plastics
  - Food additives
  - Cosmetics
  - Fine chemicals for industrial use (lubricant and fuels)
- New products produced in safe ways

Strategies for Sus Dev and Intensification

- Conservation is one form of intensification.
- Damage control GMOs are another form.
- While biofuel replaced nonrenewable with renewable resources, intensification improved the economic viability and sustainability of biofuel.
  - The same is true of green chemistry.
- Transition to alternative strategies is an ongoing process requiring continuous learning and improvement.

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Policy challenges

- Integrate agricultural, environmental, energy, and other resource policies with the aim of reducing inefficiency and attaining environmental objectives

- Provide incentives and policies to adopt technologies and induce behavioral changes—consistent with Sus Dev

- Develop global trade and other international agreements to enhance efficiency and Sus Dev

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Sus Dev depends on Science requires:

- Support for R&D and build up of human capital
  - – Low support for research in energy
  - – Decline in public research slows productivity growth in agriculture
  - – Educational industrial complex essential for biotechnologies
  - – Public research complementing private research
- Challenge of science communication
- Political economy of technology and certification

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Sus Dev is not "sustainability"

- Sustainability has become an attractive brand and label
- There is money in certifying "sustainability"
- But not every Sustainable practice is economically viable
  - Not what seems sustainable is sustainable (interdependence)
- A major contribution of economics is the capacity to control against unsound policies
- Research and outreach on sustainable development requires multidisciplinary discipline- but may lead to tensions

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Thank You

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Related concepts

- **Carrying capacity**: the amount of activity a resource base can sustain (how many people with a standard of life equivalent to the average U.S. resident can the globe support? What if we use Costa Rican standards?)
  - *For economists, carrying capacity depends on technology and institutions.*
- **Resilience** is the capacity of an ecosystem to respond to a disturbance by resisting damage and recovering quickly
  - The ability to withstand changes that may lead to species extinction, etc.
- Economic analysis of sustainability needs to be able to address these concepts
- The starting point for analysis of Sus Dev is the Brundtland Commission report that coined this term

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