Economics & Biodiversity

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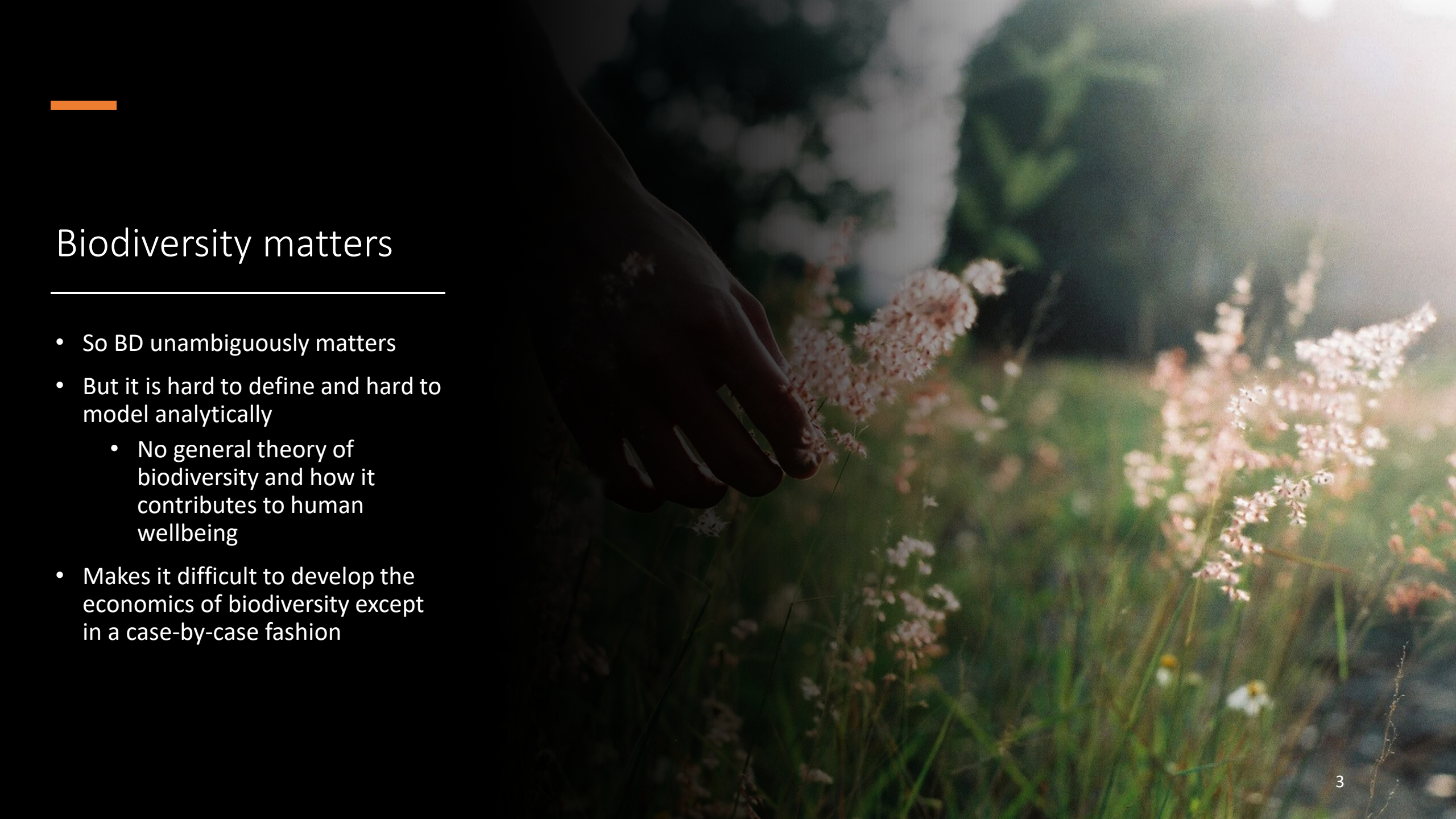
Based on Heal, *The Economic Case for Protecting Biodiversity*, NBER WP 27963 and Flammer, Giroux and Heal, *Biodiversity Finance*, NBER WP 31022. See also Heal, *Endangered Economies: How the Neglect of Nature Threatens Our Prosperity.*

Biodiversity is crucially important

- Without BD we would not have come into existence
- Without BD we could not continue in existence
- Compare Earth with Venus & Mars both uninhabitable.
  - Venus too hot, Mars too cold, neither has an atmosphere we could live with
- Why the difference? Earth has a 10,000m thick biosphere containing plants and animals that moderates the temperature and stabilizes atmospheric composition

Biodiversity matters

- So BD unambiguously matters
- But it is hard to define and hard to model analytically
  - No general theory of biodiversity and how it contributes to human wellbeing
- Makes it difficult to develop the economics of biodiversity except in a case-by-case fashion



Biodiversity as an asset

Most productive way of thinking about BD is as a set of assets that generate a flow of services over time

These assets are typically referred to as elements of natural capital

And the services from them as ecosystem services

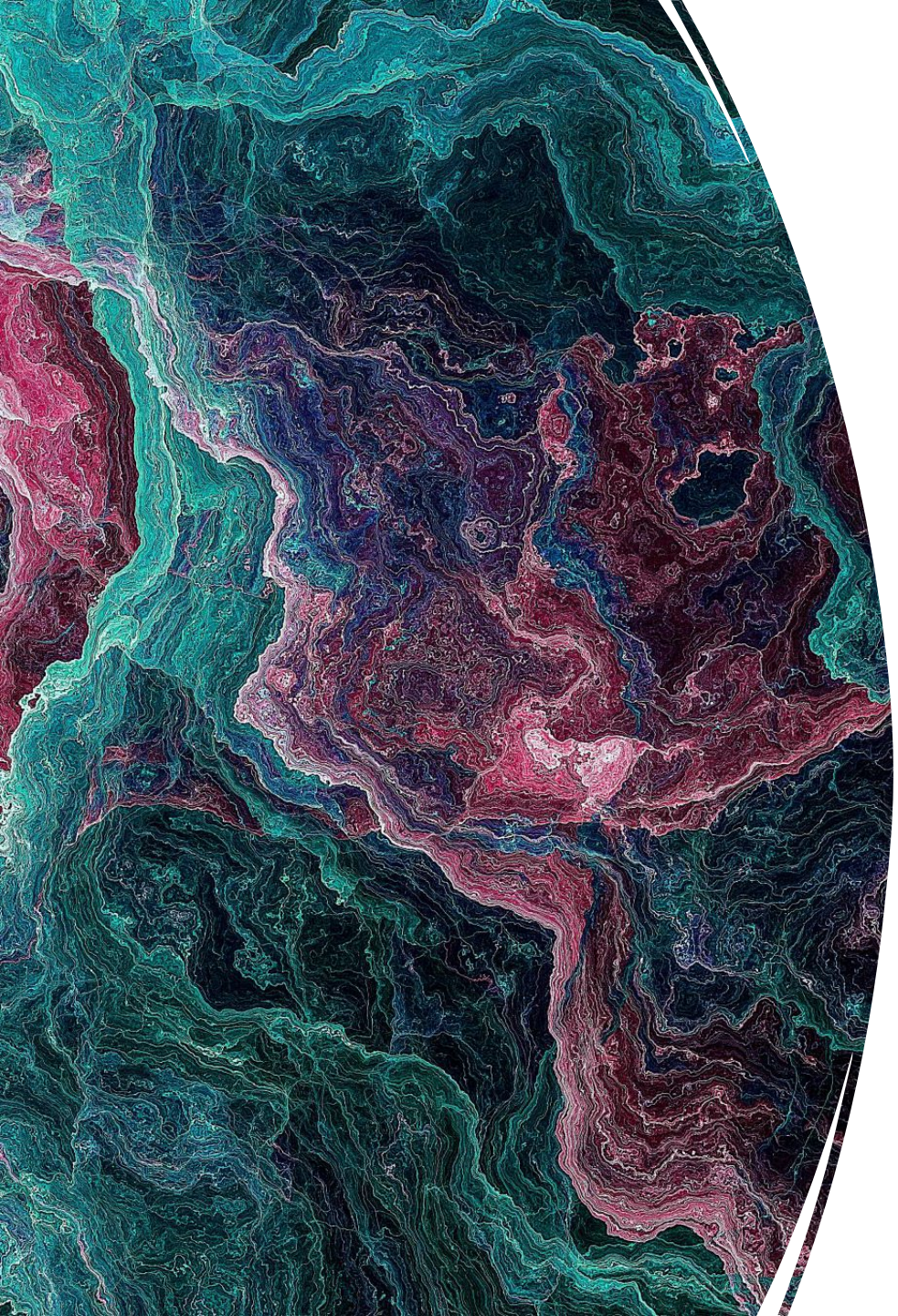
- Items of natural capital are the components of ecosystems

So we have a model of BD as a collection of assets yielding a flow of services over time

Enables us to employ a range of techniques and concepts from finance – e.g. value the asset as the PDV of the flow of services

BD & Natural Capital

- We are used to thinking of many types of capital – built capital, human capital, intellectual capital, social capital, …….
- Natural capital is another type of capital
  - Capital is an asset that yields a flow of services over time
- Soil, forest, rivers, climate, species, …. are all examples of natural capital
  - All are part of nature and yield a flow of services over time

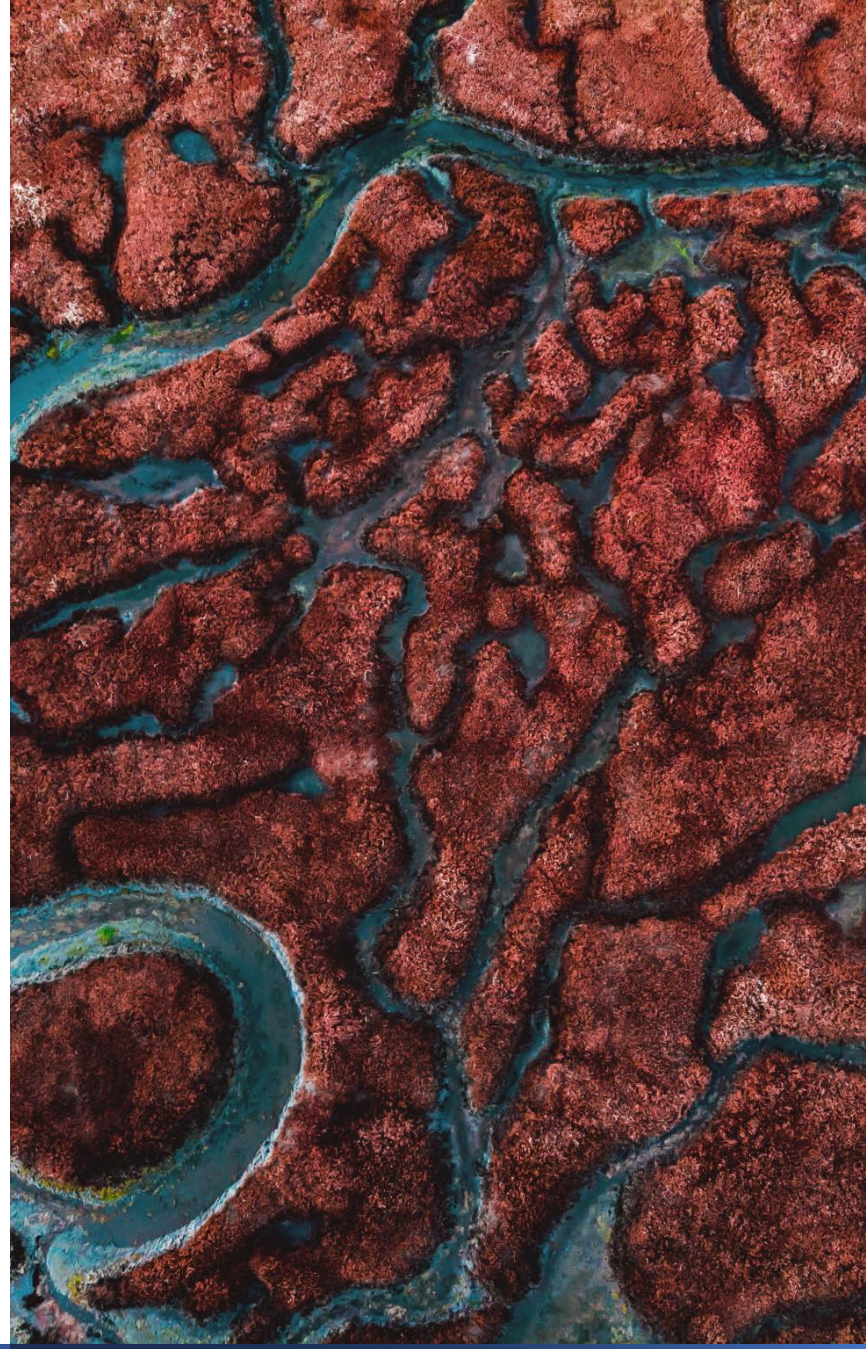


Biodiversity as capital

Examples

BD as capital assets

- Soil & crops
- Rivers & hydro power
- Oceans & fisheries
- Genetic diversity & bioprospecting
- Forests & CCS
- Wetlands & water purification
- Watersheds & drinking water
- Insects, birds & pollination
- Genetic diversity



Soil

- Soil is alive – its fertility comes from billions of micro-organisms
- These contribute to its fertility
- Fertile soil is clearly an asset and is valued as such by the market – farms sell for a price that depends on the fertility of their land
- Soil is an asset, whose value depends on its biodiversity

Hydro Power

- A hydro power station is clearly an asset – and is a mix of natural and built capital
  - Three Gorges Dam is the largest power station in the world – 22 Gw
- Physical capital element is obvious – the natural capital is the flow of water in the river and the geomorphology and climate system that generates the flow
- Rainfall depends on biodiversity – on vegetation via evapotranspiration
  - So vegetation ⇔ rainfall
  - Rainforests generate their own rainfall via evapotranspiration
  - Animals and insects essential to the health of the forest
- Hydropower depends on biodiversity
  - Norway gets 90+% of electricity from hydropower

Fisheries

Oceans are a critical food source, the main source of protein in a number of countries

And a major source of employment in coastal communities

Fish populations are currently collapsing from over-exploitation

Clearly fisheries are an asset

Bioprospecting

- Pharma companies find novel molecular structures by studying plants & insects that are chemically active
  - Defending against attacks, repairing damage, attacking prey
- Over one third by value of pharma products sold in the US were originally derived from plants or animals
  - Aspirin occurs in the willow tree – known to traditional healers for its pain-relieving properties
  - Several recent anti-cancer drugs derived from plants

Forests & CCS

- Forests capture & store CO2 – are probably the most important & cost-effective method of removing CO2 from the air
- ClimeWorks and Carbon Engineering charge $1000 to remove and sequester a ton of CO2 – forests can do this for < $5
- Forests have a vast range of co-benefits
  - Forests are not just trees – the insects and animals in them are crucial in pollination and seed dispersal
- Value of forests in CCS role $50-100tn

Watersheds

- NYC has high-quality water in abundance, with no processing – “organic water”
- Because of the Catskills watershed in the Hudson valley
  - Rain flows through the soil which purifies it and smooths the flow so that the flow is more even than the rainfall
- NYC has invested $3bn in the watershed, improving sewage systems, encouraging organic agriculture, etc and as a result has cheap high-quality water

Pollination

- Many of our food crops need pollinating
  - High-volume crops like corn, soy, rice & wheat have been bred to be self-pollinating, but everything else needs pollinating – all fruit and vegetables
- Pollinators are dying out – *insect apocalypse*
- Loss of food output in absence of pollinators estimated at $217bn.
- Allowing for consumer surplus sends this > $500bn for an asset value of roughly $14tn

Genetic diversity

- Genetic variation between species and within species
- Variation within a species allowed our ancestors to breed plants & animals selectively and massively increase productivity – genetic variability is an asset
- Valuable as crop insurance – case of grassy stunt virus and Asian rice crop
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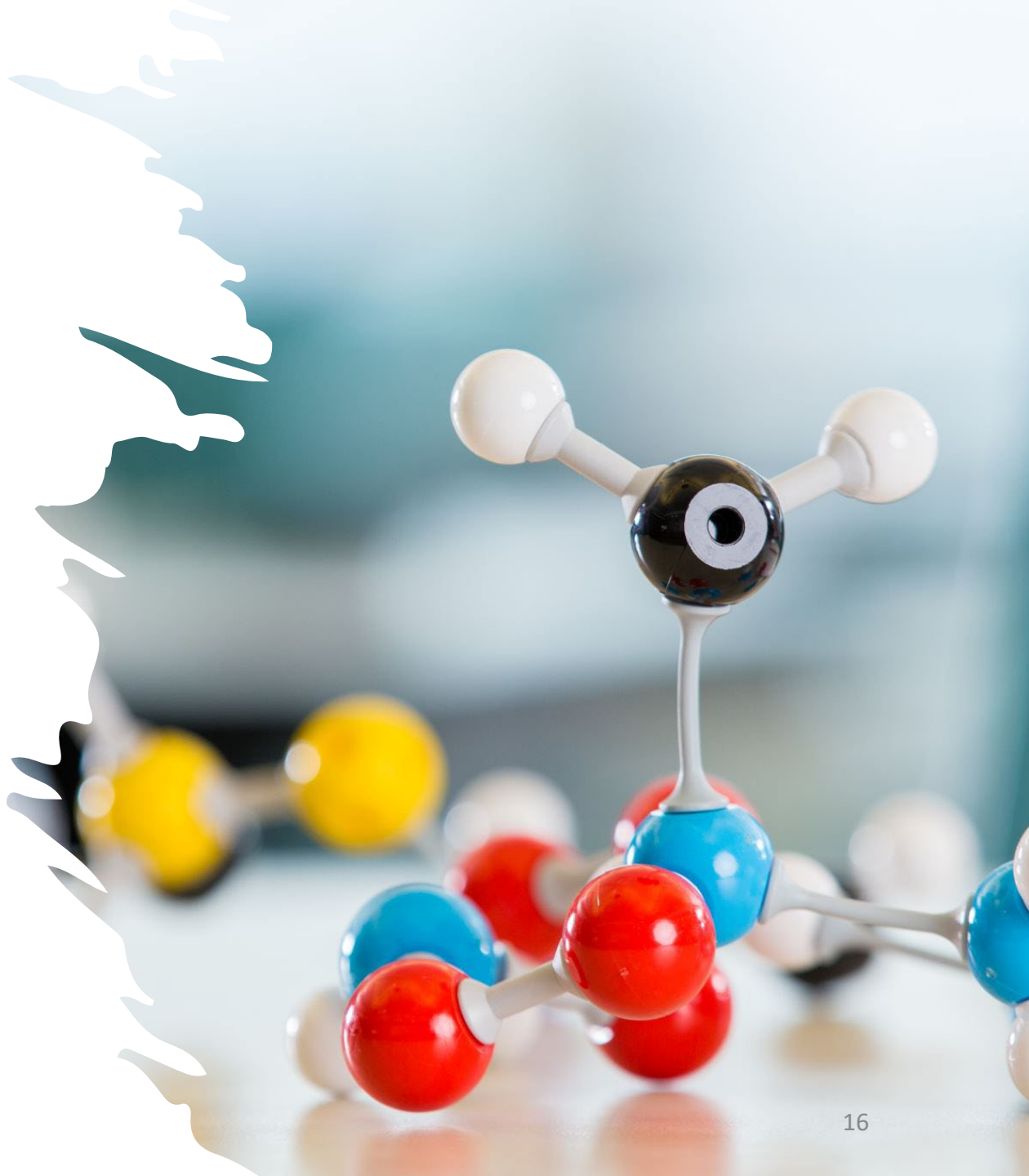
Genetic diversity

- Diversity between species is what facilitates bioprospecting
- Gives us a wide range of genetic and molecular structures to work with in designing pharmaceuticals



Economic attributes of biodiversity

What makes it hard to analyze

Attributes

- Natural capital can last for ever – forests will absorb CO2 as long as they exist, Catskills watershed has managed NYC's water supply as long as the city has existed and will continue for ever – no depreciation. Long time horizon.
- Destruction is irreversible. Generally, can't recreate natural capital once it's destroyed. Extinction is forever.
  - Deforestation is irreversible as it leads to chemical changes in soil and also to changes in local climate
  - Destruction of US NE cod population – regulation has not allowed cod populations to rebound

Attributes

Ecosystem services are generally public goods

- Knowledge of molecular structures from bioprospecting – knowledge a classic public good
- Climate stability from forests and sequestration of CO2
- Pollinator services are a public good

We don’t have a good model of how policies affect outcomes

- Central banks have reasonably widely-accepted models of how QE affects the macroeconomy
- For biodiversity conservation, many weak models of how policies affect human welfare

Implications – time horizon

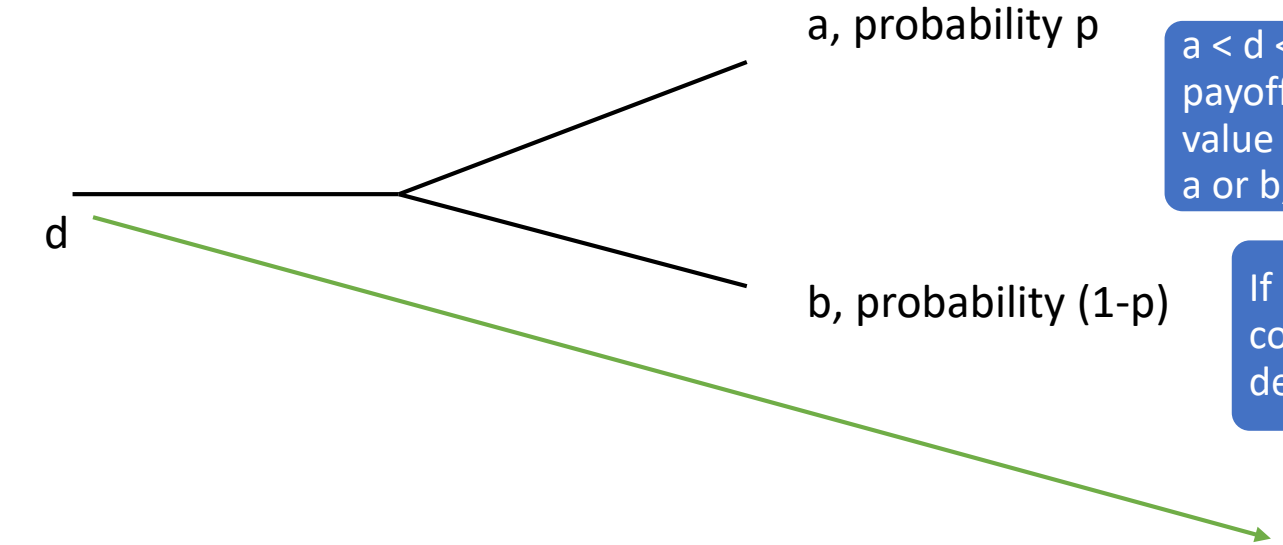
- **Long time horizon** means choice of discount rate is crucial. Benefits 100+ years ahead are annihilated by conventional discount rates and so much of the value of the asset is lost
- To value conserving an extra increment of BD we need to use the consumption discount rate not the pure rate of time preference
- $\frac{dln\{U_c e^{-\delta t}\}}{dt}$ not δ. This is $\rho = \delta + \eta \frac{\dot{C}}{C}$ where $\eta = -c \frac{U_{cc}}{U_c}$
- But suppose $U = U(C, E)$ where E is state of environment or measure of biodiversity

Implications

- Then $\rho_E = \delta + \eta_{EE}\frac{\dot{E}}{E} + \eta_{EC}\frac{\dot{C}}{C}$ as the rate of change of U_E depends on level of C
- For CES utility $\eta_{EE} > 0$ and η_{EC} is positive or negative as the elasticity of substitution is >1 or <1. Likely that $\frac{\dot{E}}{E} < 0, \frac{\dot{C}}{C} > 0$ so it is possible that $\rho_E < \delta$
- Choosing δ is controversial – several paradigms
  - Look to the market
  - Objective, benign planner
  - Social choice

Implications - irreversibility

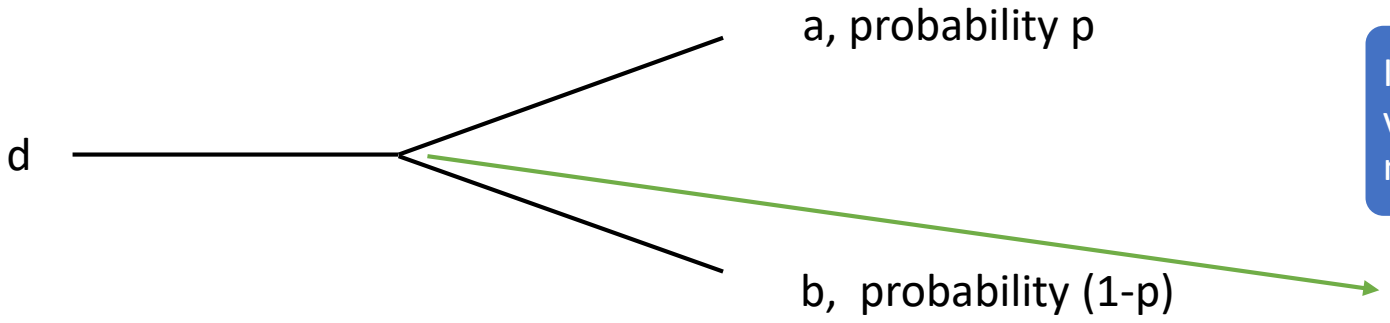
- The combination of irreversibility, uncertainty and the possibility of learning raise the threshold for policy choice that damages biodiversity
- Implies the existence of a quasi-option value associated with the conservation of BD



a < d < b. Develop land at t = 0 for payoff of d or leave in which case value as biodiversity reserve is either a or b, known only at t = 1.

If decision is made at t = 0 then one compares d with p.a + (1-p).b and develops iff d > p.a + (1-p).b.

Return is max{d, p.a + (1-p).b}



If decision is delayed till t = 1 then value a or b is known. Develop if a, not if b.

Return is max{d,b} >= max{d, p.a+(1-p).b}

t = 0 t = 1

Public goods

Well-known that markets don’t allocate public goods efficiently.

Why? Because an extra unit of the good benefits everyone. With the standard individualistic utility function, I will be willing to pay for the benefits to me but won’t consider the benefits to everyone else.

Hence under-provision from a social perspective

How to resolve this problem?

Two approaches

Incentive mechanism design. When I increase the amount of the public good, I benefit everyone else but am not rewarded for this – I generate a positive externality for everyone

Internalize this by paying me for the benefits I generate for others – the Clarke-Groves-Vickery mechanism

Problems with this mechanism – government expenditure exceeds revenues

Two approaches

Suppose instead of the usual individualistic utility function people place value on the wellbeing of others

Then they will value the benefits they convey to others by supporting the public good

With sufficient interpersonal solidarity or empathy public goods will be provided efficiently

Bundling public & private goods

Safaris in S or E Africa are big business. What guests pay for is transport and accommodation in tents - may pay $20,000+ for a week

They are willing to pay so much to stay in a tent because of the presence of biodiversity – lion, elephants, leopards, rhinos, hippos,etc

The organizers are not just selling tented accommodation – they are selling that bundled with access to biodiversity

The BD – a public good - raises the willingness to pay for the accommodation – so bundling a public good with a private raises the WTP for the private and can be good business

Bundling public & private goods

- The safari business is an illustration of this proposition – that it can be profitable for the seller of a private good to provide and bundle with it a public good
- If the seller is a discriminating monopolist, it can lead to an efficient outcome

PROPOSITION 1: *If utility functions are strictly concave and the cost function strictly convex, then a profit-maximizing producer who provides a private and a public good and can practice first-order price discrimination will provide an economically efficient combination of the public and private goods.*

No good models

- We know that BD affects human welfare but don’t have a compelling model of how this occurs
- Several different models of this relationship, each giving a different map from policy choices to welfare outcomes
- How to act given this uncertainty – we have a “multiple priors” situation
- Growing literature suggests two dominant approaches

No good models

- MaxMin Expected Utility – evaluate each policy alternative according to the model that makes it look worst (Gilboa-Schmeidler)
- Evaluate choices by a non-linear weighted average of outcomes according to the the alternative models (Klibanoff Marinacci Mukherji)
- Both involve some degree of focus on worst-case outcomes not unlike the precautionary principle

Monetizing BD

- In practical terms the biggest problem is that BD though valuable is hard to monetize
- Partly because it is a public good and because of the uncertainties associate with it
- And partly because its benefits are intangible in many cases
- Bundling is an attempt to monetize
- BD is in some ways like the climate – hard to monetize the benefits of a stable climate

BD is being destroyed

- US bird population declined by 3bn or 30% from 1970 to 2010
- Loss of habitat the main cause
- Massive drop in insect populations around the world – with use of insecticides a major cause here
- WWF reports in 2022 average 69% decline in populations of mammals, fish, birds, reptiles & amphibians since 1970

Dynamics of Biodiversity

- Highly complex
- Multiple regimes
- Tipping points – associated with irreversible changes

Two approaches to conservation

- *Government policies* such as conservation areas/habitat protection, endangered species act (Bird Directive in EU), limiting trade in endangered species, taxing activities that harm BD (developing wilderness, using pesticides), etc.
- *Private financing* of BD conservation
- To date government policies have dominated but private financing is beginning to play a role
- What is the potential for expansion?

Financing BD conservation

Despite the difficulty of monetization, we are seeing a growth in private financing of BD conservation

Socially responsible investors are interested in supporting BD and willing to sacrifice some return for this

Monetization generally relies on ecotourism or carbon credits – effectively free riding on climate policies

Monetizing climate

A cap-&-trade system effectively monetizes a public good – market puts a price on the traded commodity

- Though not really a market price as it is determined largely by the cap

If offsetting is allowed into the market this extends to price beyond the traded commodity

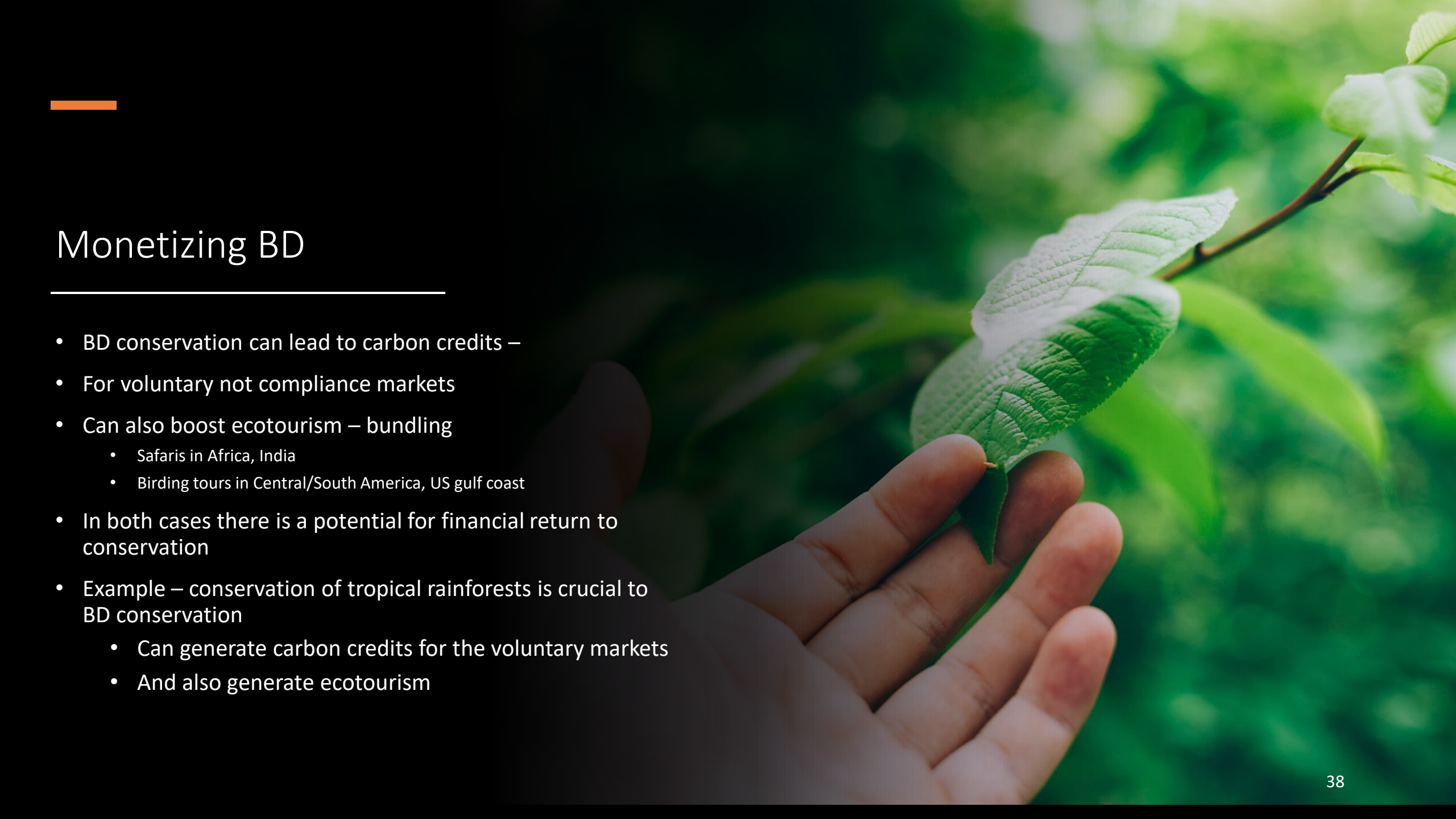
- The California C&T carbon market allows forestry offsets and so establishes a price for forest carbon

Monetizing climate

- Distinguish compliance and voluntary markets
- California, EU ETSs are compliance markets – compliance legally required
- Offsets bought by most corporations are voluntary and do not meet standards required to trade on compliance markets

Monetizing BD

- BD conservation can lead to carbon credits –
- For voluntary not compliance markets
- Can also boost ecotourism – bundling
  - Safaris in Africa, India
  - Birding tours in Central/South America, US gulf coast
- In both cases there is a potential for financial return to conservation
- Example – conservation of tropical rainforests is crucial to BD conservation
  - Can generate carbon credits for the voluntary markets
  - And also generate ecotourism



Natural capital asset types	Monetization mechanisms of ecosystem services
A. Land	
Agriculture: soil and pollinators	Agricultural productivity; price of farmland; certification as "biodiversity-friendly" agricultural products (higher prices); carbon credits; fire suppression; water quality
Forests	Ecotourism (hotel nights, tour guide services); carbon credits (carbon capture and storage); biodiversity credits; health; recreational value; bioprospecting for medicine; certification as "biodiversity-friendly" wood (higher prices); hydropower (pay for success)
Urban parks and other green infrastructures in urban areas	Value of real estate (proximity to park, green roofs provide heat isolation); prevention of flooding; carbon credits (carbon capture and storage); recreational value (e.g., birdwatching tours, sports activities, etc.)
Natural parks & wildlife protection	Ecotourism (hotel nights, tour guide services); value of real estate around the park; biodiversity credits
Genetic resources	Protection against diseases (humans, plants, food, animals); bioprospecting for medicine; biodiversity credits

Biodiversity deals

Pure private finance or

Blended finance

Aim of blended finance is to de-risk investments

Three ways of de-risking

Seniority - Waterfall structure where fraction of first losses is taken by philanthropic/governmental/MDB investors, private investors senior

Preferred rate of return – LPs must receive z% before GP gets any share

Development finance institutions may guarantee investors certain rate of return

De-Risking

Aim is always to act as a catalyst in attracting private finance

Case Study: Biodiversity Investment Manager

We have access to data from major anonymous fund manager that has arranged BD investment deals

33 deals from 2020 to 2022

Average maturity 8 years

	All (N = 33)		Blended finance (N = 14)		Pure private capital (N = 19)	
	# Deals	Percent	# Deals	Percent	# Deals	Percent
Land	16	48.5%	8	57.1%	8	42.1%
Agriculture: soil and pollinators	8	24.2%	3	21.4%	5	26.3%
Forests	6	18.2%	3	21.4%	3	15.8%
Natural parks & wildlife protection	1	3.0%	1	7.1%	0	0.0%
Genetic resources	1	3.0%	1	7.1%	0	0.0%
Sea	17	51.5%	6	42.9%	11	57.9%
Watersheds	1	3.0%	0	0.0%	1	5.3%
Coastal ecosystems	3	9.1%	0	0.0%	3	15.8%
Fisheries	10	30.3%	4	28.6%	6	31.6%
Oceans (incl. coral reef)	3	9.1%	2	14.3%	1	5.3%
Total	33	100.0%	14	100.0%	19	100.0%

Notes. This figure plots the number of biodiversity finance deals of BIM by countries. Darker-shaded areas indicate a greater number of deals.

Table 6. Biodiversity finance deals by type of financing

	All (N = 33)		Blended finance (N = 14)		Pure private capital (N = 19)	
	# deals	Percent	# deals	Percent	# deals	Percent
Equity	11	33.3%	4	28.6%	7	36.8%
Equity + Debt	8	24.2%	4	28.6%	4	21.1%
Equity + Debt with profit sharing	1	3.0%	0	0.0%	1	5.3%
Equity + VERPA	2	6.1%	2	14.3%	0	0.0%
Debt	1	3.0%	1	7.1%	0	0.0%
Debt with profit sharing	6	18.2%	3	21.4%	3	15.8%
VERPA	4	12.1%	0	0.0%	4	21.1%
Total	33	100.0%	14	100.0%	19	100.0%

Notes. This table reports the number and percentages of biodiversity finance deals by type of financing. The statistics are reported for all BIM deals (first two columns), and separately for blended finance deals (middle two columns) and deals financed by pure private capital (last two columns). VERPA refers to voluntary emission reduction purchase agreements.

	All			Blended finance			Pure private capital			Difference in means
	N	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.	*p*-value
A. Deal size and financing										
Maturity (years)	33	7.94	3.03	14	7.93	2.70	19	7.95	3.32	0.986
Deal size ($ million)	33	22.84	17.47	14	29.15	18.39	19	18.19	15.63	0.074*
Ticket size ($ million)	33	6.62	3.86	14	7.24	3.99	19	6.17	3.79	0.443
Equity ($ million)	33	3.21	4.00	14	3.44	4.45	19	3.04	3.74	0.781
Debt ($ million)	33	2.79	4.20	14	3.65	4.34	19	2.16	4.08	0.320
VERPA ($ million)	33	0.62	1.62	14	0.14	0.53	19	0.97	2.03	0.147
% Equity	33	0.52	0.44	14	0.50	0.44	19	0.53	0.46	0.881
% Debt	33	0.35	0.42	14	0.47	0.46	19	0.26	0.39	0.172
% VERPA	33	0.13	0.33	14	0.03	0.11	19	0.21	0.42	0.124
B. Financial performance and risk										
Project return (target IRR)	33	13.52%	3.68%	14	11.88%	2.86%	19	14.72%	3.81%	0.026**
Project risk (deviation from target IRR)	20	7.18%	5.22%	8	6.94%	6.13%	12	7.34%	4.81%	0.872
Project return / project risk	20	2.51	1.32	8	2.44	1.54	12	2.56	1.22	0.846
C. Environmental and social impact										
Total impact area (ha, expected)	17	73,408	167,115	9	114,798	226,016	8	26,844	27,805	0.098*
GHG emissions reduction (1,000 tCO2e, expected)	18	5,665	8,649	8	9,469	11,900	10	2,622	2,824	0.096*
# Beneficiaries (expected)	13	11,623	11,779	6	19,133	13,812	7	5,185	3,710	0.025**
# New jobs created (expected)	15	1,846	4,273	6	3,358	6,693	9	838	1,050	0.279
Certification (1/0 dummy)	33	0.79	0.42	14	0.79	0.43	19	0.79	0.42	0.980

Differences

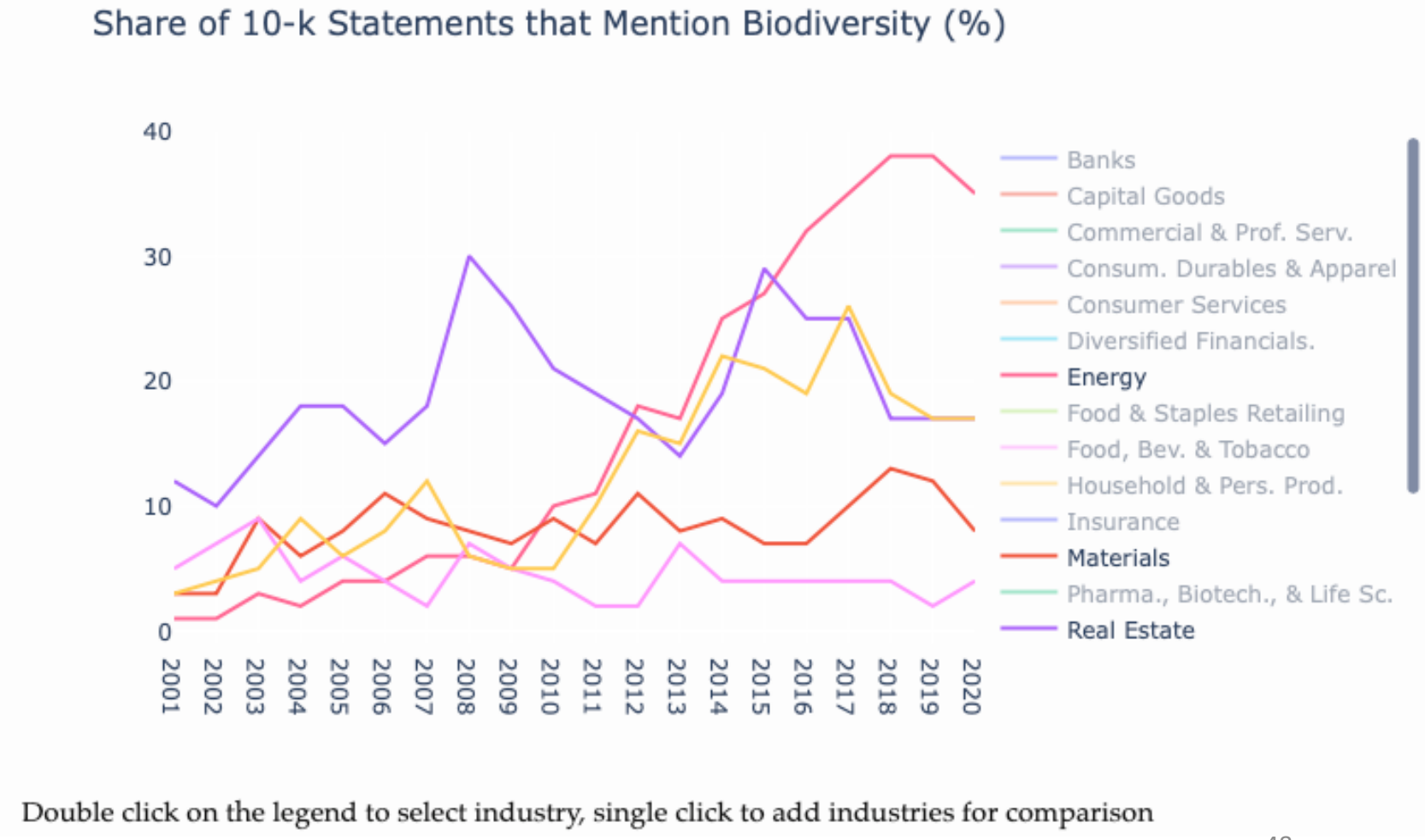
- Blended finance deals involved more $
- Involved larger impacts in terms of GHGs, area affected and # people affected
- BUT private finance deals had a higher expected ROR

Growing corporate concern for BD

Shown: Energy, Utilities, Real Estate, Materials, Transportation.

From www.biodiversityrisk.org
By Giglio et al.

Industry Biodiversity Risk Exposure



Summary

BD matters to the economy and to society as a whole

Many of its services are public goods and so hard to monetize

We are seeing limited monetization of BD services

Small but growing interest in investing in BD as an asset