

# Accounting for Climate Change

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# Sustainable development

Sustainable development is

... development that meets the needs of the present without compromising the ability of the future to meet their own need.

(Our Common Future, 1987)

# Interpretation

Sustainable development is  
development that sustains social  
welfare!

# What is social welfare?

- An individual's wellbeing in one period is determined by
  - consumption
    - ordinary consumption
    - amenities
    - health
- a measure of this concept of wellbeing in one period is called utility ( $U$ )
- Social welfare ( $W$ ) = present value of the future stream of utility

# Social welfare

$$W_0 = U(C^0) + \frac{U(C^1)}{(1+\delta)} + \frac{U(C^2)}{(1+\delta)^2} + \dots$$

$C^0$  consumption in year 0, the first period,

$C^1$  consumption in year 1, etc

$\delta$  utility discount rate

# Ramsay equation

$$r = \delta + g\eta$$

$r$  consumption discount rate

$\delta$  utility discount rate

$g$  consumption growth rate

$\eta$  elasticity of the marginal utility of consumption

# Sustainable development

Social welfare must not decrease over time

$$W_{t+1} - W_t \geq 0$$

for all  $t = 0, 1, 2, \dots$

# What determines the social welfare?

- Stocks of assets
  - man made capital stocks – buildings, machines, infrastructure
  - man made knowledge - human capital
  - natural capital
- Technology
  - human capital
- Institutions
  - rules of the game

# Resource allocation mechanism

Prediction of future consumption through  
resource allocation mechanisms

$$C^t = \alpha_C(K^0_1, K^0_2, \dots, K^0_n, t)$$

$$K^t = \alpha_K((K^0_1, K^0_2, \dots, K^0_n, t)$$

# The Value Function

$$\begin{aligned} W^t &= \sum_{s=t}^{\infty} \frac{U(C^s)}{(1+\delta)^{s-t}} = \\ &= \sum_{s=t}^{\infty} \frac{U(\alpha(K_1^t, K_2^t, \dots, K_n^t, t))}{(1+\delta)^{s-t}} = \\ &= V(K_1^t, K_2^t, \dots, K_n^t, t) \end{aligned}$$

# Sustainable development

- Productive resources must be given to future generations in such amounts that their social welfare is not less than ours
- Thus, total investment in all assets (genuine investment) must be positive
- If investment is negative in some sectors, it must be sufficiently positive in others to guarantee that genuine investment is positive

# Accounting prices

1. How do we aggregate changes in the stock of salmon, stock of vehicles, stocks of buildings?  
**By using accounting prices as weights!**
2. The accounting price is the change in the social welfare from a marginal change in the stock today
3. The accounting price may be equal to or may differ from the corresponding market price
4. There is a huge literature on estimating accounting prices

# Accounting price

$$P_i^t = \frac{\partial W^t}{\partial K_i^t}$$

# Sustainable development

$$W^{t+1} - W^t = \sum_{i=1}^n p_i^t (K_i^{t+1} - K_i^t) + v_t$$

$\sum_{i=1}^n p_i^t (K_i^{t+1} - K_i^t)$ : *Genuine investment (World Bank)*

$v_t$ : *Drift Term (Dasgupta, Mäler)*

# Population Change

## Social Welfare Function

$$W_t = \frac{\sum_{s=t}^{\infty} \frac{U\left(\frac{C_s}{N_s}\right)}{(1+\delta)^{s-t}}}{\sum_{s=t}^{\infty} \frac{N_s}{(1+\delta)^{s-t}}}$$

# Population changes

- If exogenous population growth rate is constant

and

- If there are constant returns to scale

then

the value function will be a function of capital per capita, and

the sustainability criteria becomes

$$W^{t+1} - W^t = \sum_{i=1}^n p_i^t (k_i^{t+1} - k_i^t) + v_t$$

**Table 1: Genuine Investment and Components as Percentage of GDP**

Country	Domestic Net Investment	Education Expenditure	Natural resource depletion				Genuine investment
			Damage from CO <sub>2</sub> emissions	Energy depletion	Mineral depletion	Net forest depletion	
Bangladesh 1973-2001	7.89	1.53	0.25	0.61	0.00	1.41	7.14
India 1970-2001	11.74	3.29	1.17	2.89	0.46	1.05	9.47
Nepal 1970-2001	14.82	2.65	0.20	0.00	0.30	3.67	13.31
Pakistan 1970-2001	10.92	2.02	0.75	2.60	0.00	0.84	8.75
China 1982-2001	30.06	1.96	2.48	6.11	0.50	0.22	22.72
SubSaharan Africa 1974-82; 1986-2001	3.49	4.78	0.81	7.31	1.71	0.52	-2.09
Middle East & North Africa 1976-89; 1991-2001	14.72	4.70	0.80	25.54	0.12	0.06	-7.00
United Kingdom 1971-2001	3.70	5.21	0.32	1.20	0.00	0.00	7.38
United States 1970-2001	5.73	5.62	0.42	1.95	0.05	0.00	8.94

# Accounting price for climate

- Climate is a global public good
  - the public good
- The accounting price for the stock of green house gases equals the marginal damage from emissions!
- There is a bewildering number of different estimates of this marginal damage
- They vary from almost zero to over hundred dollars per ton CO<sub>2</sub>
- A recent estimate would be US \$ 40 per ton CO<sub>2</sub>

# Accounting price for climate – several countries

- For sustainable development in one country, estimate the value of the impact on the local, national damage from increases in the global emissions!
- This corresponds for France to  $p^F E^{\text{tot}}$
- Unfortunately this estimate is not available for all countries. Only  $p^{\text{tot}} E^F$  is available. But
- $p^F E^{\text{tot}} \neq p^{\text{tot}} E^F$  unless all countries are included
- World Bank's estimates of global damage are only the latter  $p^{\text{tot}} E^F$ !

$$p_t^F dQ_t^{\text{tot}}$$

# Accounting for climate change

- Climate is a global public good
  - A change of that good affects citizens of France
  - That change must be included, valued with the French accounting price for climate – not a global accounting price
- French emissions contribute to a change of the global public good
  - The value of that change is measured by the “global” accounting price of climate
    - that is the global total of changes in climate damages
- Only if all countries are identical will there be no difference between these two viewpoints!

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# Accounting for climate

## A simple climate model

$$\frac{dK_{\tau}}{d\tau} = f(K_{\tau}, E_{\tau}, N_{\tau}) - C_{\tau}$$

$$U_{\tau} = N_{\tau} \varphi \left( \frac{C_{\tau}}{N_{\tau}}, T_{\tau} \right)$$

$$W_t = \frac{\sum_{\tau=t}^{\infty} \frac{N_{\tau} \varphi \left( \frac{C_{\tau}}{N_{\tau}}, T_{\tau} \right)}{(1 + \delta)^{\delta(\tau-t)}}}{\sum_{\tau=t}^{\infty} \frac{N_{\tau}}{(1 + \delta)^{\tau-t}}}$$

# Accounting price for climate

$$\frac{\partial W_t}{\partial Q_t} = \frac{\sum_{\tau=t}^{\infty} \left[ N_{\tau} \frac{\frac{\partial U}{\partial C_{\tau}} \frac{\partial C_{\tau}}{\partial Q_t} + \frac{\partial U}{\partial T_{\tau}} \frac{\partial T_{\tau}}{\partial Q_t}}{(1 + \delta)^{\tau-t}} \right]}{\sum_{\tau=t}^{\infty} \frac{N_{\tau}}{(1 + \delta)^{\tau-t}}}$$

$$M D_{\tau} = \frac{\partial U}{\partial C_{\tau}} \frac{\partial C_{\tau}}{\partial Q_t} + \frac{\partial U}{\partial T_{\tau}} \frac{\partial T_{\tau}}{\partial Q_t}$$

$$dQ_t = E_t - vQ_t$$

# A final example

- Botswana and Namibia similar:
  - Both very dry countries – water is very valuable
  - Both have diamonds
  - Botswana has cattle, and tourism
  - Namibia has forests, fisheries, and tourism
- Both have similar development of GDP per capita

# A final example

- Wealth per capita has been going up in Botswana but going down in Namibia

Why?

- Botswana has a legislation that requires that rent on natural capital must be reinvested in other forms of capital!
  - human capital – education
  - investment in small enterprises
- In Namibia, the rent on natural capital has been consumed!
  - partly through expenditures for having an army in Congo

# Final conclusion

Wealth matters more than income!

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