The role of relative prices in discounting

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Stern Review

- Climate Change the biggest externality in human history.
- 5-20% of future GDP
- Enormous uncertainties in calculation:
- Feedback from cloudformation
- Feedback from methane release
- Feedback from ice-melting (Albedo)
- *Guess which is biggest uncertainty?*

Stern Review

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- 5-20% of future GDP
- Enormous uncertainties in calculation:
- Feedback from cloudformation
- Feedback from methan release
- Feedback from ice-melting (Albedo)
- **DISCOUNT RATE!**

Discounting and relative prices in future environmental damages

Michael Hoel & Thomas Sterner

Climatic Change

An even Sterner Review

Thomas Sterner Martin Persson

Review of Env Economics & Policy

Conventional Discounting

- If some cost or benefit component at a future date t is of the magnitude V_t and the discount rate is r, the present value is
- $$(1+r)^{-t} V_t$$

The effect is big

- 1 billion in 400 years = 3 $ today (5%).
- in 500 years would be 2 cents.
- With 6% would be .02 cents.
- Difference between 5 / 6 % is a factor 100

PROBLEM ?

- 1$ in bank today = 2$ in 6 years
- so $2 cost in 6 years ~=~ cost of $1 today

- How big in 240 years?

- Can economy grow one million million*?

Many Issues

- Can growth continue forever?
- Psychological aspects
- Hyperbolic and Gamma Discounting
- Risk
- Other considerations in U

- RELATIVE PRICES

Correct value of future project

- $V_t = V_o(1+r)^{-t}(1+p)^t$
- The effect of relative prices can be as big as discounting!
- If p is big enough?

Labour

- 100 years ago 10% of the population in Tolouse had a maid.
- Incomes are growing 5%/year

Labour

- 100 years ago 10% of the population in Tolouse had a maid.
- Incomes grow 3-5%/year

- How many people have a maid today?

Why can’t we all have maids?

Why can't we all have maids?

- $P_{maid} = f\,(\text{Income})$

FOOD

- World Agriculture is 24% GDP

- Assume we loose 1% of World Agriculture. How big is loss?
- Roughly 0.01*0.24 = 0. 24% GDP

FOOD

- World Agriculture is 24% GDP

- Assume we loose 95% of World Agriculture. How big is loss?
- Roughly 0.95*0.24 = 23 % GDP

-95% FOOD

- **-23%?**

What is wrong?

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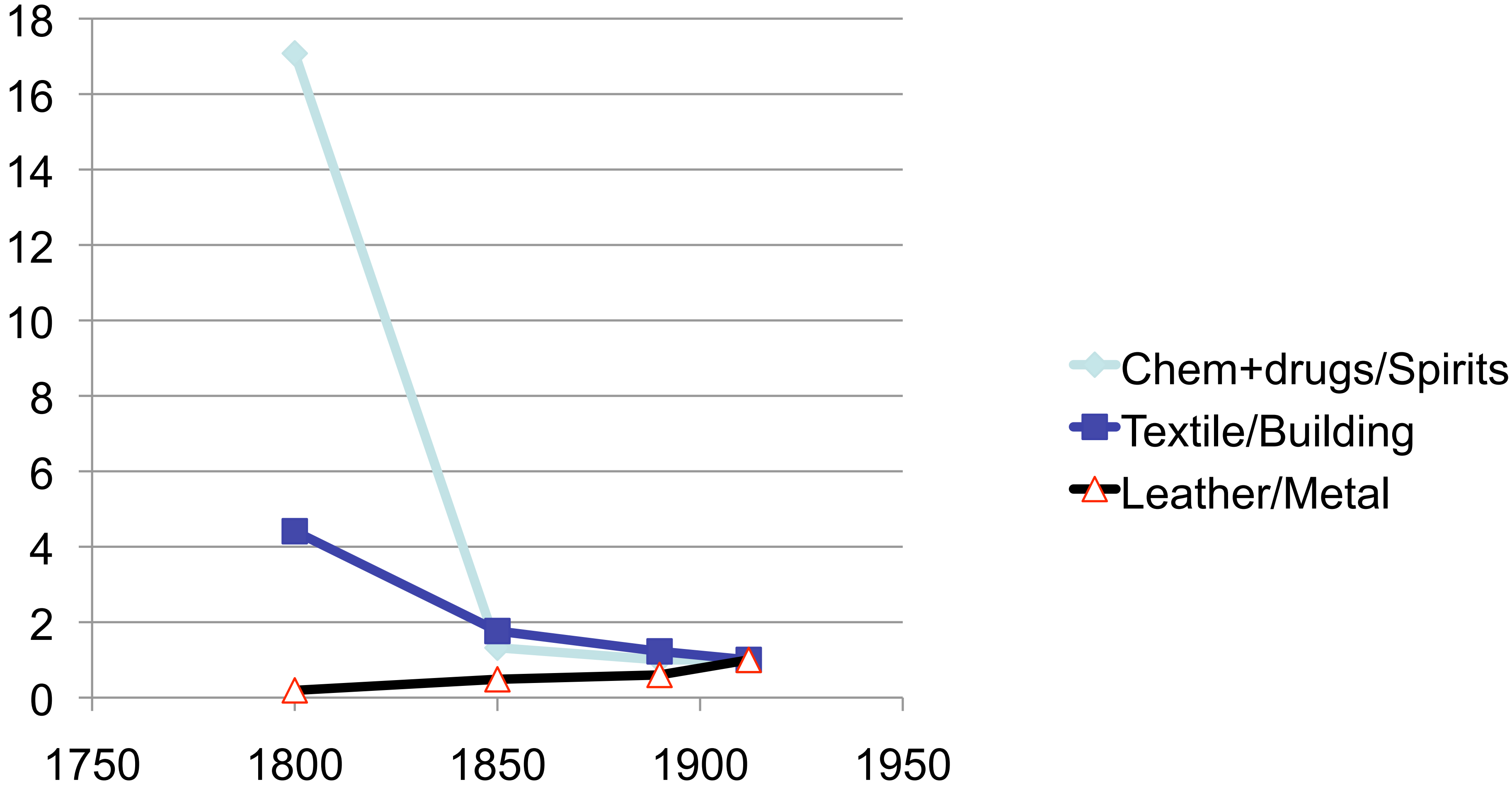
- Relative Prices of food…

What is wrong?

- Relative Prices of food…

- will change so fast
- That the 95% loss will be worth >> 23% GDP.

Relative prices, US fed gov 1800-1921



Relative prices

- The price of ”spirits” relative to ”chemicals” rose 1700 %
- Similar for metals.
- P(flour) / P(wheat) falls
- Or ”nails” in relation to ”iron”

- P (labour), results of mechanisation

Future Ecosystem Scarcities

- Water
- Soil
- Wild (non-cultivated) fish
- Biodiversity
- Glaciers and snow
- Wildlife, protected areas
- Fuelwood, pasture, silence (?)

OK: Why discount?

- We are impatient
- We will be richer
- Rich people dont know the value of money

$$r(t) = \rho + \alpha g_C(t)$$

Assume an intertemporal welfare function

$$W = \int_0^T e^{-\rho t} U(C(t))dt$$

The tradeoffs between consumption at different points of time are given partly by the “utility discount rate” ρ

partly by the utility function *U*.

The appropriate discount rate is the sum of these two reasons

$$r = \rho - \frac{\frac{d}{dt}U'(C(t))}{U'(C(t))}$$

With Constant elasticity of utility function → classical Ramsey Rule

$$U(C) = \frac{1}{1-\alpha} C^{1-\alpha}$$

$$r(t) = \rho + \alpha g_C(t)$$

Ramsey and growth

- If ρ= 0.01, α =1.5 and g = 2.5% r = 4.75%.
- Constant iff growth is constant.
- Increases with growth
- If growth falls, future discount rates will fall over time. Azar & Sterner (1996): limits to growth → falling discount rates and higher damage from carbon emissions.

Compare Nordhaus 5 $/ton

The marginal cost of CO_2 emissions

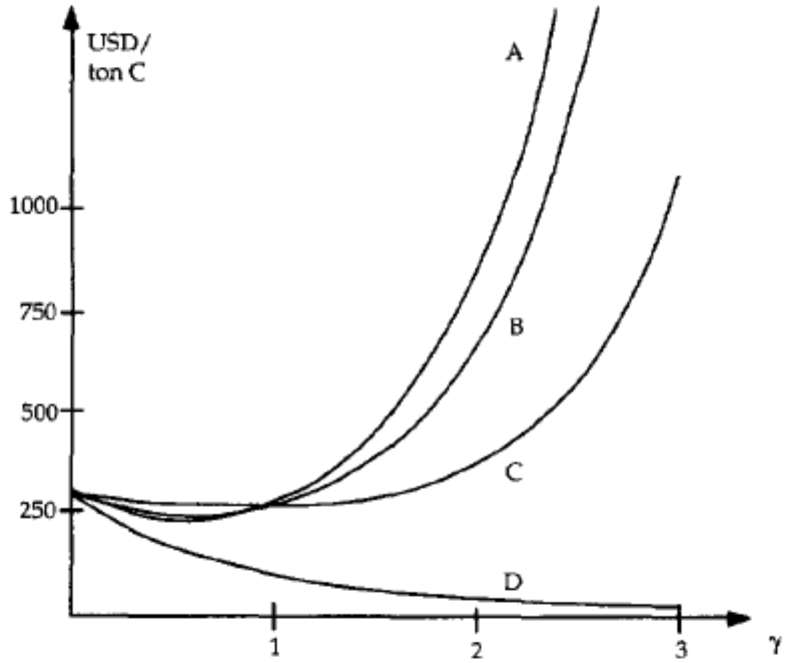


Fig. 3. The *generalized* cost of a unit emission of CO_2 is plotted as a function of γ in four cases. In plot A, B and C, the inequality situation is worsened, unchanged, and improved, respectively. In plot D, income distribution is not considered. The higher the value for γ, the higher is the discount rate, but also the inequality aversion.

Results

- Nordhaus 5
- We got 10 –150 for gamma 3→0,5
- Falls with gamma !
- But--
- With inequality we got 250-1000
- Higher values for higher gamma!

- However we did assume Ymax = 10Y

Are there Limits to Growth?

- Clearly YES:
- A finite planet
- The amount of cement, carbon, steel and water that we can use is limited!

Are there Limits to Growth?

- Clearly YES:
- A finite planet
- The amount of cement, carbon, steel and water that we can use is limited!
- Clearly NO:
- Human imagination is limitless
- The quality of concerts and computer games knows no bounds!

Our best image of the future

- Continued growth…
- Rich get even richer.
- Poor will eventually also get richer but gap not eliminated.
- Much of growth in manufactured goods that use little resources. More mobiles, culture, computation, communication…
- Less transport, corals, clean water?

We need two sectors:
C which grows; E (which does not)

$$W = \int_0^\infty e^{-\rho t} U(C, E)\, dt$$

The appropriate discount rate *r* is then

$$r = \rho + \frac{-\frac{d}{dt} U_C(C, E)}{U_C(C, E)}$$

Relative price of ”environment”

Value of environmental good is given by

$$U_E / U_C$$

The relative change in this price, *p*, is

$$p = \frac{\frac{d}{dt}\left(\frac{U_E}{U_C}\right)}{\left(\frac{U_E}{U_C}\right)}$$

To simplify: select utility function that combines contant elasticity of utility above with constant elasticity of substitution between E and C

$$U(C,E) = \frac{1}{1-\alpha}\left[(1-\gamma)C^{1-\frac{1}{\sigma}} + \gamma E^{1-\frac{1}{\sigma}}\right]^{\frac{(1-\alpha)\sigma}{\sigma-1}}$$

The relative price effect

$$p = \frac{\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{U_E}{U_C}\right)}{\left(\frac{U_E}{U_C}\right)} = \frac{1}{\sigma}(g_C - g_E).$$

Formula for discounting

- not only is there a relative price effect
- but the discounting formula itself changes

Discounting in 2 sector model

$$r = \rho + \left[(1-\gamma^*)\alpha + \gamma^* \frac{1}{\sigma}\right] g_C + \left[\gamma^* \left(\alpha - \frac{1}{\sigma}\right)\right] g_E$$

Where γ* is ”utility share” of the environment

$$\gamma^* = \frac{\gamma E^{1-\frac{1}{\sigma}}}{(1-\gamma)C^{1-\frac{1}{\sigma}} + \gamma E^{1-\frac{1}{\sigma}}} = \frac{U_E E}{U_E E + U_C C} = \frac{\frac{U_E}{U_C} E}{\left(\frac{U_E}{U_C} E\right) + C}$$

Comparing discount formulas

$$r = \rho + \left[(1 - \gamma *)\alpha + \gamma * \frac{1}{\sigma} \right] g_C + \left[\gamma * \left(\alpha - \frac{1}{\sigma} \right) \right] g_E$$

$$r(t) = \rho + \alpha g_C(t)$$

Comparison of discountrates

g_c = 2,5%, rho = 1%, g_E = 0%,

α	σ	Convent *r*	***2sector R***		
0.5	0.5	2.25	**3.35**		
0.5	1	2.25	**2.37**		
0.5	1.5	2.25	**2.28**		
1	0.5	3.5	**4.24**		
1	1	3.5	**3.50**		
1	1.5	3.5	**3.44**		
1.5	0.5	4.75	**5.12**		
1.5	1	4.75	**4.62**		
1.5	1.5	4.75	**4.60**		

Comparison of discountrates

g_c = 2,5%, rho = 1%, g_E = 0%,

α	σ	Convent *r*	***2sector R***	*Price p*	TOT *R*
0.5	0.5	2.25	**3.35**	-5.00	-1.65
0.5	1	2.25	**2.37**	-2.50	-0.12
0.5	1.5	2.25	**2.28**	-1.67	0.61
1	0.5	3.5	**4.24**	-5.00	-0.76
1	1	3.5	**3.50**	-2.50	1.00
1	1.5	3.5	**3.44**	-1.67	1.77
1.5	0.5	4.75	**5.12**	-5.00	0.12
1.5	1	4.75	**4.62**	-2.50	2.13
1.5	1.5	4.75	**4.60**	-1.67	2.94

Conclusions

- Relative prices CRUCIAL in long run CBA
- Discounting itself complex in 2 sector model
- Important policy conclusions for Climate
- Next step: integrated GE Climate model

Introducing relative prices into DICE

- Stern has been criticised for low r. δ=0,1 η=1 and per capita g =1,3. Total 1.4
- Nordhaus reproduced Stern-type results with DICE and low r
- We reproduce Stern (or intermediate) results with Nordhaus values (high r)
- By including a small part of non-market sector and changing relative prices.

An even Sterner Review

Thomas Sterner & Martin Persson

1. Comment on r, η and δ
2. And on non market damages
3. Introduce Relative Prices into Debate

2 Changes to DICE

- The original model maximizes total discounted utility using a CRRA function
- $U(C) = C^{1-\alpha} / (1-\alpha)$
- To include the effect of changing relative prices we use a constant elasticity of substitution function of two goods:
- $U(C)= [(1-\gamma)C^{1-1/\sigma} + \gamma E^{1-1/\sigma}]^{(1-\alpha)\sigma/(\sigma-1)}/(1-\alpha)$

Environmental Damages

- First we assume a share of environmental services in current consumption of 10%.
- We assume damage to environmental amenities will be quadratic in temperature
- At 2,5 °C damage ~ 2% current GDP
- $E(t) = E_0 / [1+ aT(t)^2]$
- *So E is actually falling due to climate ch.*
- *We assume elasticity of Substitution is .5*

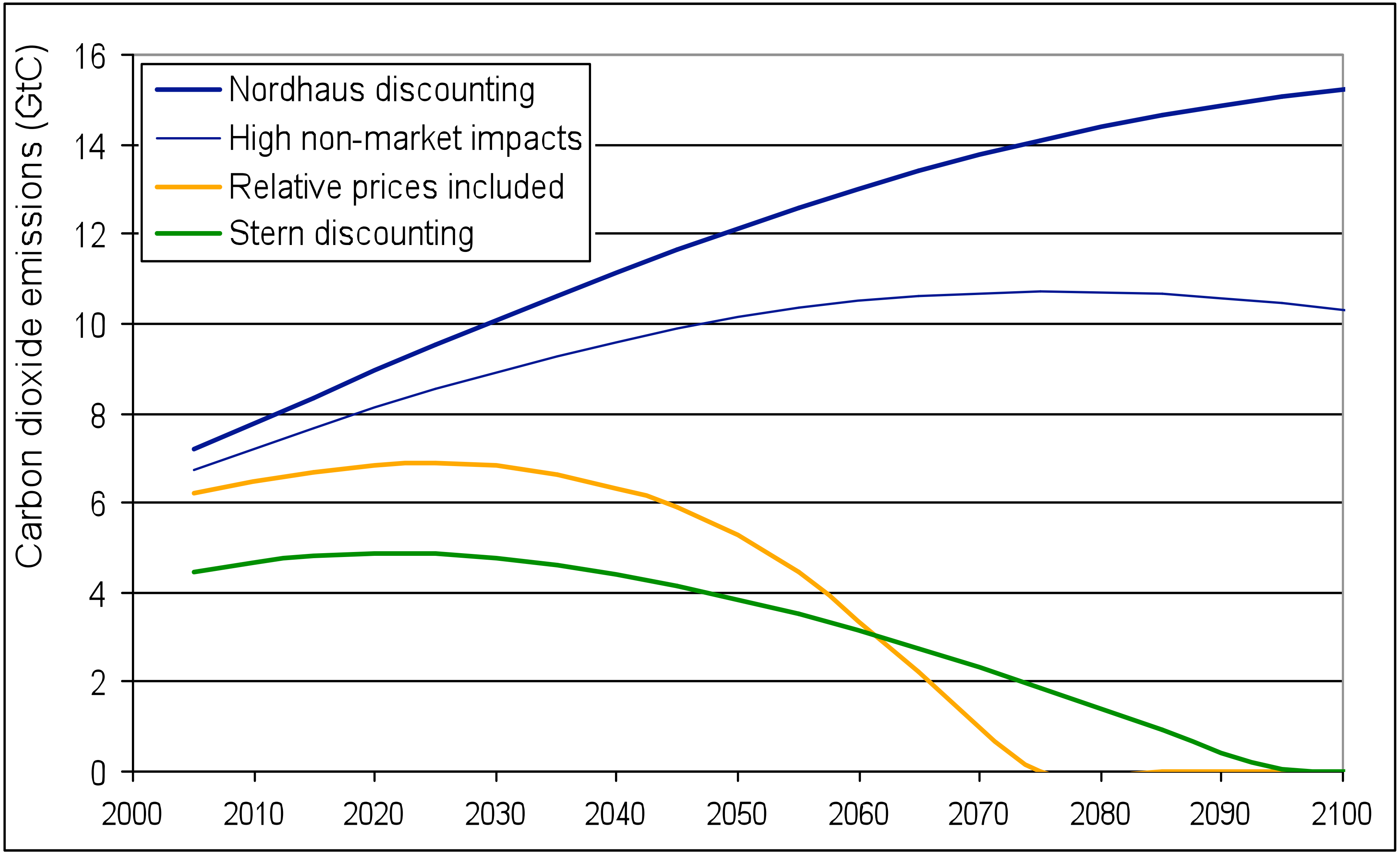


Figure 2: *Optimal carbon dioxide emission paths in the DICE model for four different cases: the original model (Nordhaus discounting), the original model with high non-market impacts(High non-market impacts), the original model with low discount rate (Stern discounting) and a run where the changes in relative prices between market and non-market (environmental) goods is taken into account (Relative prices included). See text for explanation.*

Thank you very much

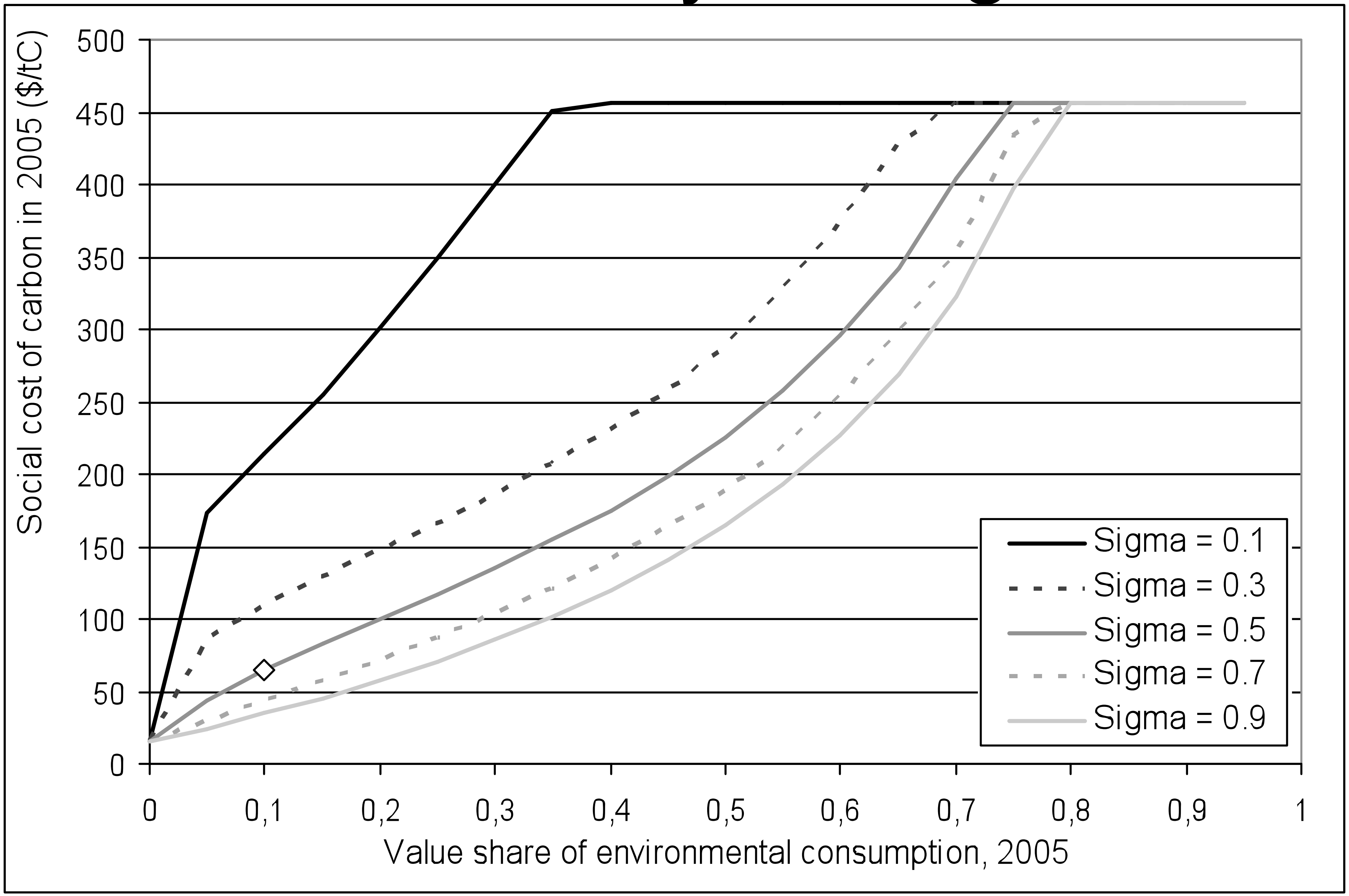
- More issues:

- Sensitivity,
- Relative income

Relative Income Hypothesis

- If U(c,z) and certainty then opt r lower (OJS, TS)
- CG OJS TS:
- If U(c, g_c) and uncertainty then optimal r is lowered because habit formation reduces the wealth effect. However habits also reduce precautionary effect (however less)
- So Net effect still → lower discount rate

Sensitivity testing



Warning:
Next 10 slides: details of r,p & R

- Discount rates will be the same if

- $\gamma^* = 0$ (Sector E plays no role for U)
- $g_C = g_E$ (Sectors E and C identical)

- $\alpha\ \sigma = 1$

2 sector discount will be lower if

- $g_C > g_E$ (Sector E grows slowly)

and

- $\alpha \sigma > 1$ (ie if substitutability is good and utility curvature very high).

- NB that normally if $\sigma \neq 1$ and $\alpha\sigma \neq 1$ then r in the 2 sector model will change over time

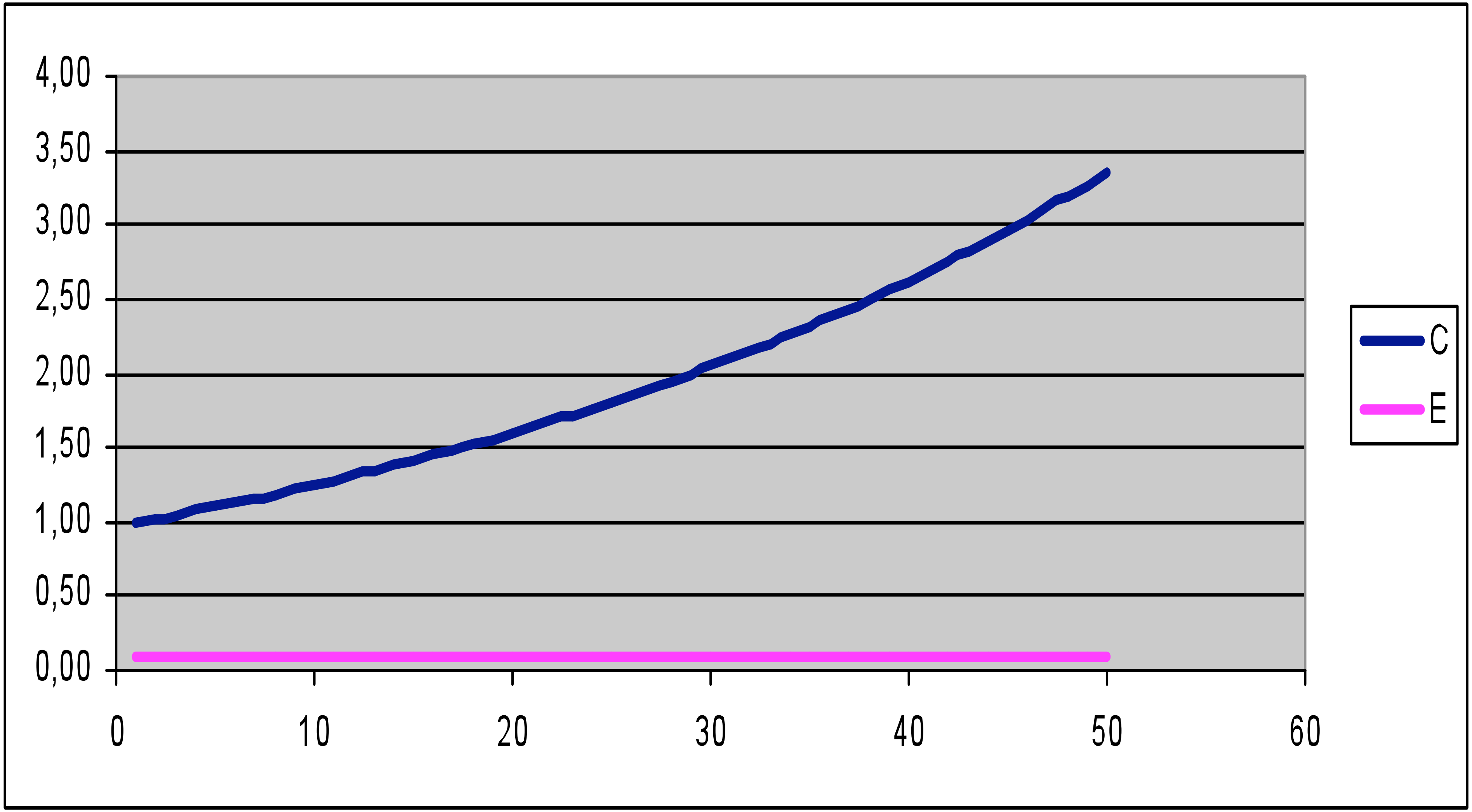
The TOTAL discount factor

Using R to denote the combined effect of discounting and relative price increase of environmental goods,

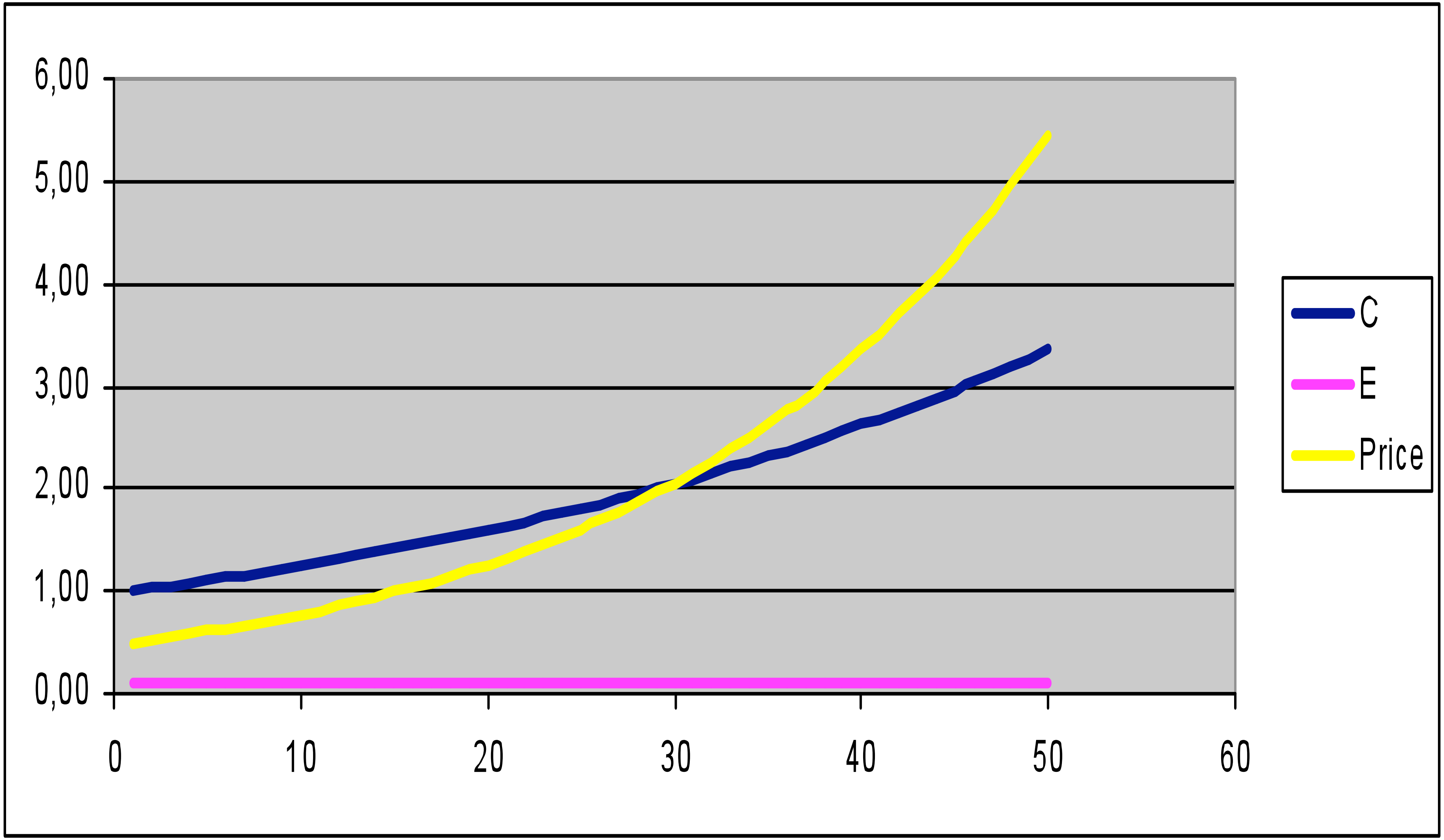
i.e. $R=r-p$,

$$R = \rho + \left[\left(1-\gamma^*\right)\left(\alpha - \frac{1}{\sigma}\right) \right] g_C + \left[\gamma^* \alpha + (1-\gamma^*)\frac{1}{\sigma} \right] g_E$$

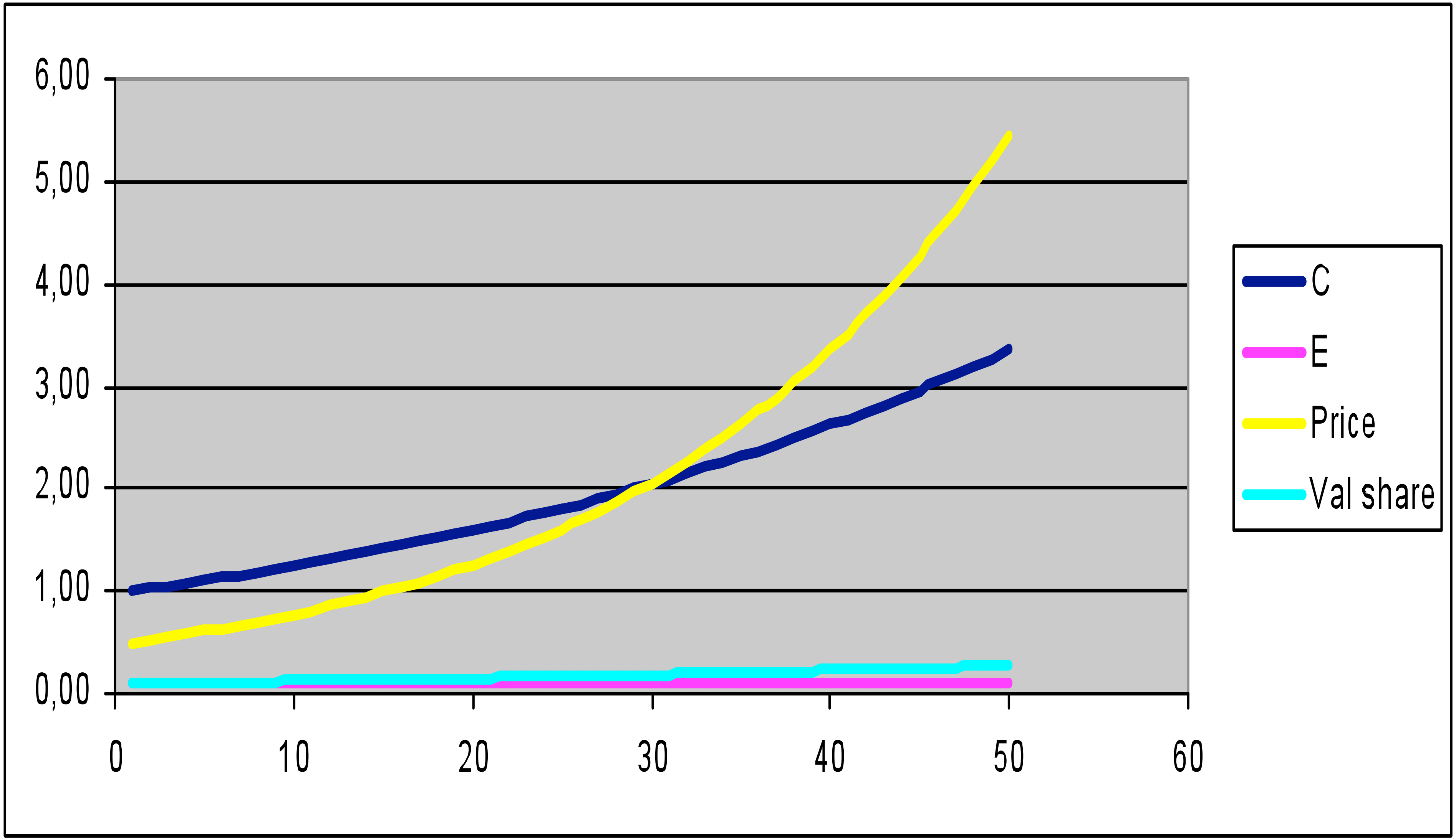
2 sectors, C&E with different rates σ=0,5



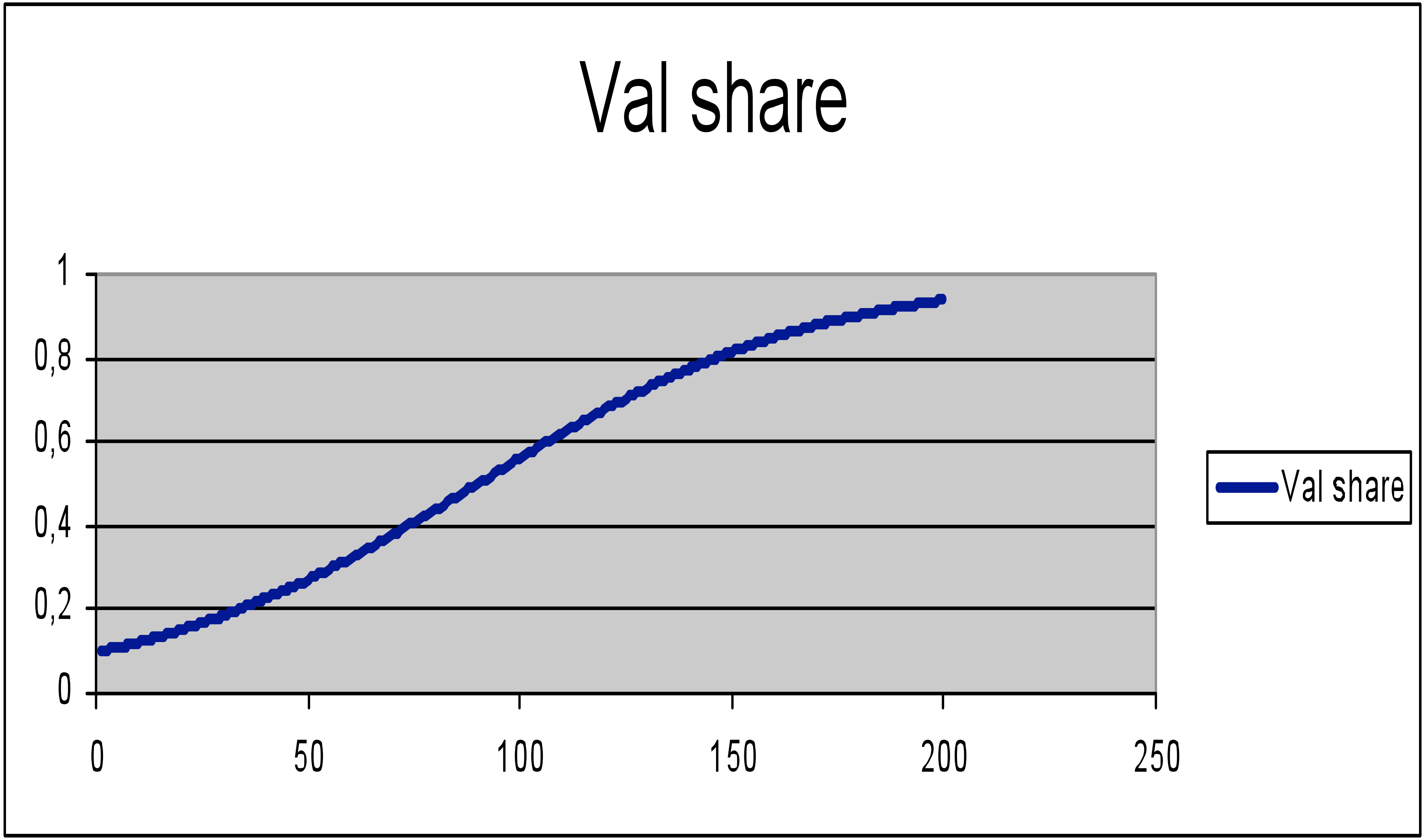
C gets bigger but the price of E goes up FASTER



So the value share of E rises

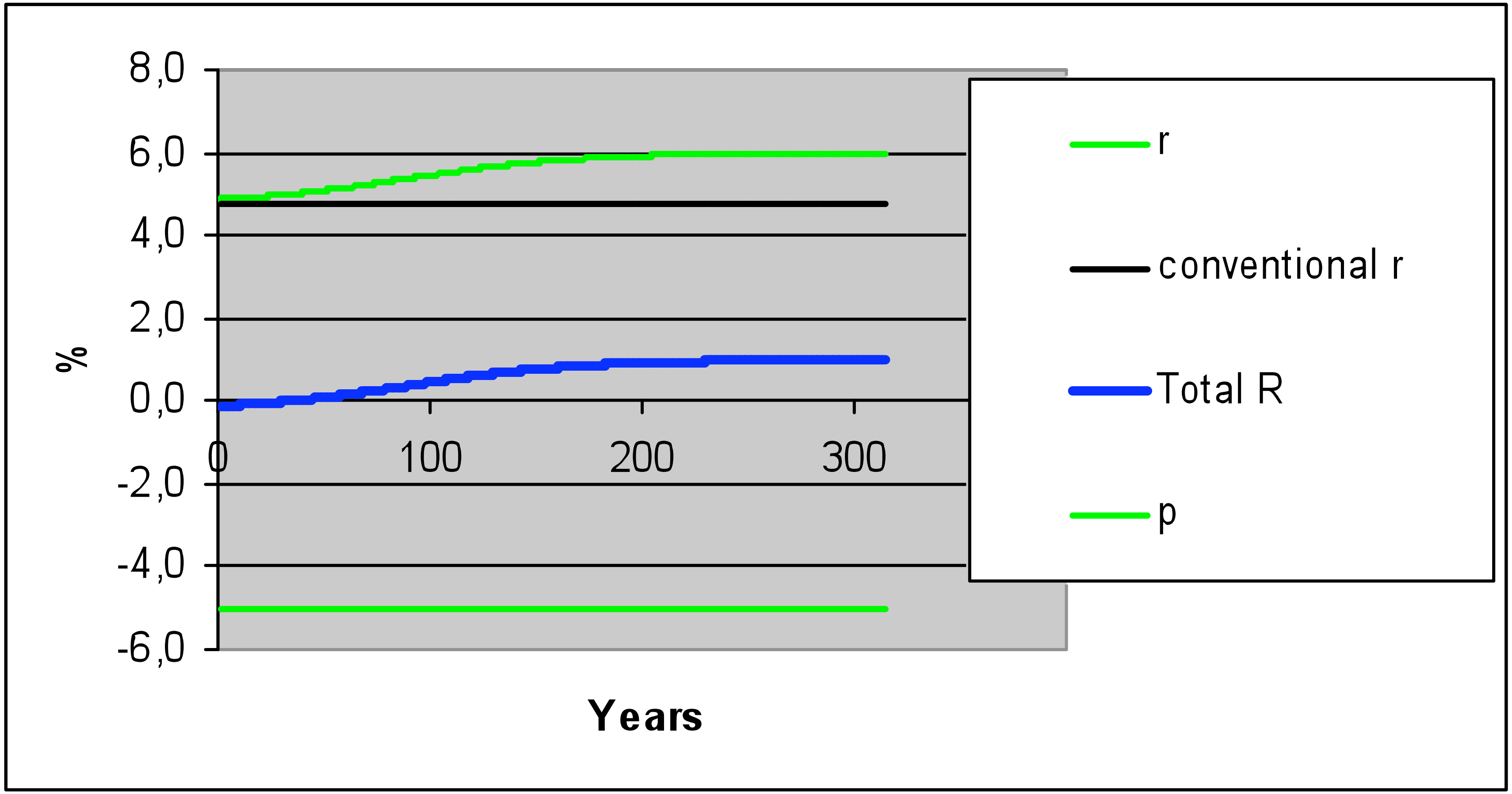


After some time E dominates



Therefore variation in discount rate

$\rho=0.01,\ \sigma=0.5,\ \alpha=1.5,\ \gamma^*_0=0,1\ g_C=2.5\%$



More opinions on Climate costs

- Not reasonable to base r, in this case, on short term markets for equity or bonds
- Ethics: Reasonable to use low delta
- On top of this more non-market damages and changing relative prices!
- RISK: Uncertain outcomes with uncertain parameters in uncertain model + uncertain valuation → FAT tails
- Separate valuation of disaster risks?

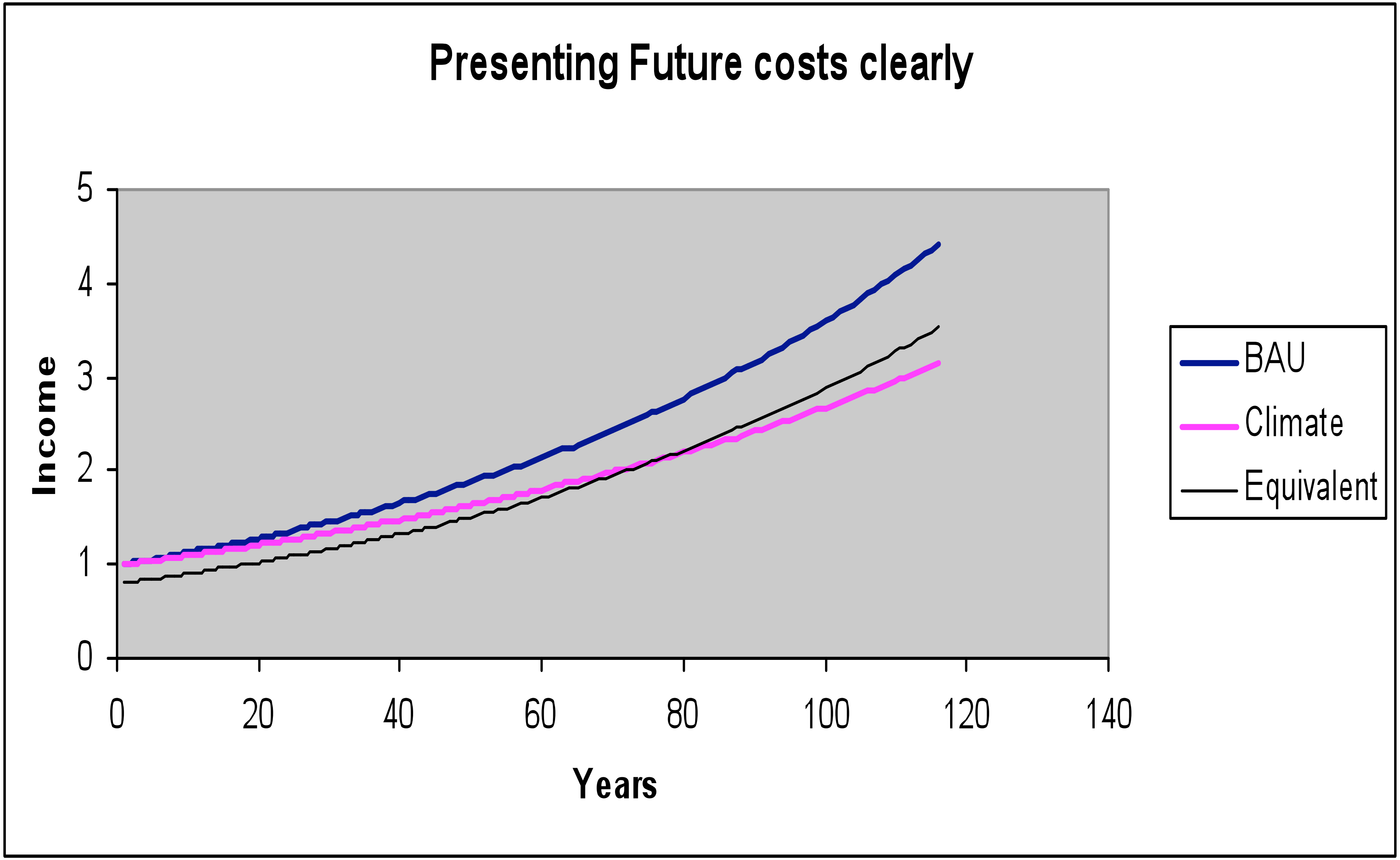
Sign of Derivatives of *r*, *p*, and *R*

	R	p	$R = r - p$
g_C	$+$	$+$	$-$ if $\alpha\sigma < 1$ $+$ if $\alpha\sigma > 1$
g_E	$-$ if $\alpha\sigma < 1$ $+$ if $\alpha\sigma > 1$	$-$	$+$
α	Depends on γ^*, g_C and g_E ($+$ if $g_C > 0$ and $g_E \geq 0$)	0	Depends on γ^*, g_C and g_E ($+$ if $g_C > 0$ and $g_E \geq 0$)
σ	$-$ (if $g_C > g_E$)	$-$ (if $g_C > g_E$)	$+$ (if $g_C > g_E$)

Double counting ?

- Is someone lost:
- Are we double counting when we first work out special discount formula that builds on the marginal utility of *quantities* of E and C and then also add in a relative price change?
- No: Our discount rate for the two sector model is specifically formulated in terms of rate of change of U_C !

5-20% For now and forever…



Discount rates will be the same if

- $\gamma^* = 0$ (Sector E plays no role for U)
- $g_C = g_E$ (Sectors E and C identical)

- $\alpha \sigma = 1$
- (For instance if $\alpha = \sigma = 1$ then utility is logarithmic and substitution between E and C is good (1% change in price leads to 1% change in cons).

Costa & Kahn, The Rising Price of Nonmarket goods, AEA Papers &P

TABLE 1—THE VALUE OF LIFE IN 2002 DOLLARS, 1900–2000

Year	Value of life
1900	$427,000 (predicted)
1920	895,000 (predicted)
1940	1,377,000
1950	2,426,000
1960	2,884,000
1970	5,176,000
1980	7,393,000
2000	12,053,000 (predicted)

More opinions on Stern & Nordhaus

- Not reasonable to base r, in this case, on short term markets for equity or bonds
- LONG run should be used. Other phenomena such as lack of aid and lack of progressive taxes
- In 1970s ”everyone” recomended welfare weighting (Dasgupta, Marglin, Sen, Little & Mirrlees (1974) Drèze and Stern. Eta = 1 is already quite high. Sometimes 2 was recommended but
- In practical CBA it is **not** used ie **η=0** !
- It would be strange to use **η=0 for all current issues and η=2 only for decisions about the future.**