Optimal Global Dynamic Carbon Abatement

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How do income differences shape optimal global climate policy?

Outline

- **Previous work**
- Simple Model
- Stock public bad case
- FUND Model
- Results
- Conclusion

Previous Work

- Privately provided public goods
  - Chichilnisky and Heal (1994) [also Chichilnisky and Heal (2000), Shiell (2003), Sheeran (2006)]
- Optimal taxation
  - Sandmo (2006)
- Equity weights
  - Azar and Sterner (1996) [also Azar (1999), Fankhauser, Tol and Pearce (1997), Hope (2008), Anthoff, Hepburn and Tol (2009), Anthoff and Tol (2010)]
- Real World
  - DEFRA studies
  - European Commission projects: NEEDS (New Energy Externalities Development for Sustainability)
  - Stern Review (?)

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Simple Model

- Two agents: r & p (rich and poor)

Gross Income: $\overline{Y}_r$ & $\overline{Y}_p$

Mitigation: x_r & x_p

Mitigation Costs: $C_r(x_r)$ & $C_p(x_p)$

Benefits: $B_r(x_r + x_p)$ & $B_p(x_r + x_p)$

Net Income:

$$y_r(x_r, x_p) = \overline{Y}_r - C_r(x_r) + B_r(x_r + x_p)$$
$$y_p(x_r, x_p) = \overline{Y}_p - C_p(x_p) + B_p(x_r + x_p)$$

Simple Model

- Utility: $U(y) = \ln y$

Welfare: $W = U(y_r) + U(y_p)$

$$\max_{x_r, x_p} U[y_r(x_r, x_p)] + U[y_p(x_r, x_p)]$$

$$\max_{x_r, x_p, T} U[y_r(x_r, x_p) - T] + U[y_p(x_r, x_p) + T]$$

Simple Model

- FOCs with transfer

$$
\begin{array}{ccc}
C_r'(x_r^*) & = & B_r'\left(x_r^* + x_p^*\right) + B_p'\left(x_r^* + x_p^*\right) \\
= & & = \\
C_p'\left(x_p^*\right) & = & B_r'\left(x_r^* + x_p^*\right) + B_p'\left(x_r^* + x_p^*\right)
\end{array}
$$

$$T = \frac{1}{2}\left(y_r^* - y_p^*\right)$$

Simple Model

- FOCs without transfer

$$C'_r(x^*_r) = \overbrace{\frac{y^*_r}{y^*_p}}^{>1} B'_r(x^*_r + x^*_p) + \frac{y^*_r}{y^*_p} B'_p(x^*_r + x^*_p)$$

$$\neq$$

$$C'_p(x^*_p) = \frac{y^*_p}{y^*_r} B'_r(x^*_r + x^*_p) + \underbrace{\frac{y^*_p}{y^*_r}}_{<1} B'_p(x^*_r + x^*_p)$$

Simple Model

- FOCs without transfer

$$C_r'(x_r^*) = \overbrace{\frac{y_r^*}{y_p^*}}^{>1} B_r'(x_r^* + x_p^*) + \overbrace{\frac{y_r^*}{y_p^*}}^{>1} B_p'(x_r^* + x_p^*)$$

$$\neq$$

$$C_p'(x_p^*) = \underbrace{\frac{y_p^*}{y_r^*}}_{<1} B_r'(x_r^* + x_p^*) + \underbrace{\frac{y_p^*}{y_r^*}}_{<1} B_p'(x_r^* + x_p^*)$$

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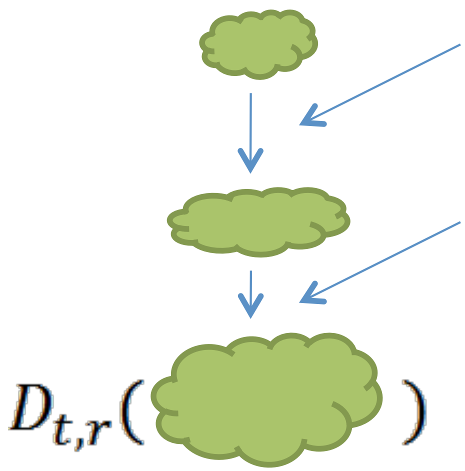
$$W = \sum_{t=0}^{T} \delta^t \sum_r U(\boldsymbol{y}_{t,r}) P_{t,r}$$

$$\delta = \frac{1}{1+\rho}$$

$$U(y) = \begin{cases} y^{1-\eta}/(1-\eta) & \text{for } \eta \neq 1 \\ \ln y & \text{for } \eta = 1 \end{cases}$$

$$\boldsymbol{y}_{t,r} = \frac{Y_{t,r} - C_{t,r}(\boldsymbol{x}_{t,r})}{P_{t,r}}$$

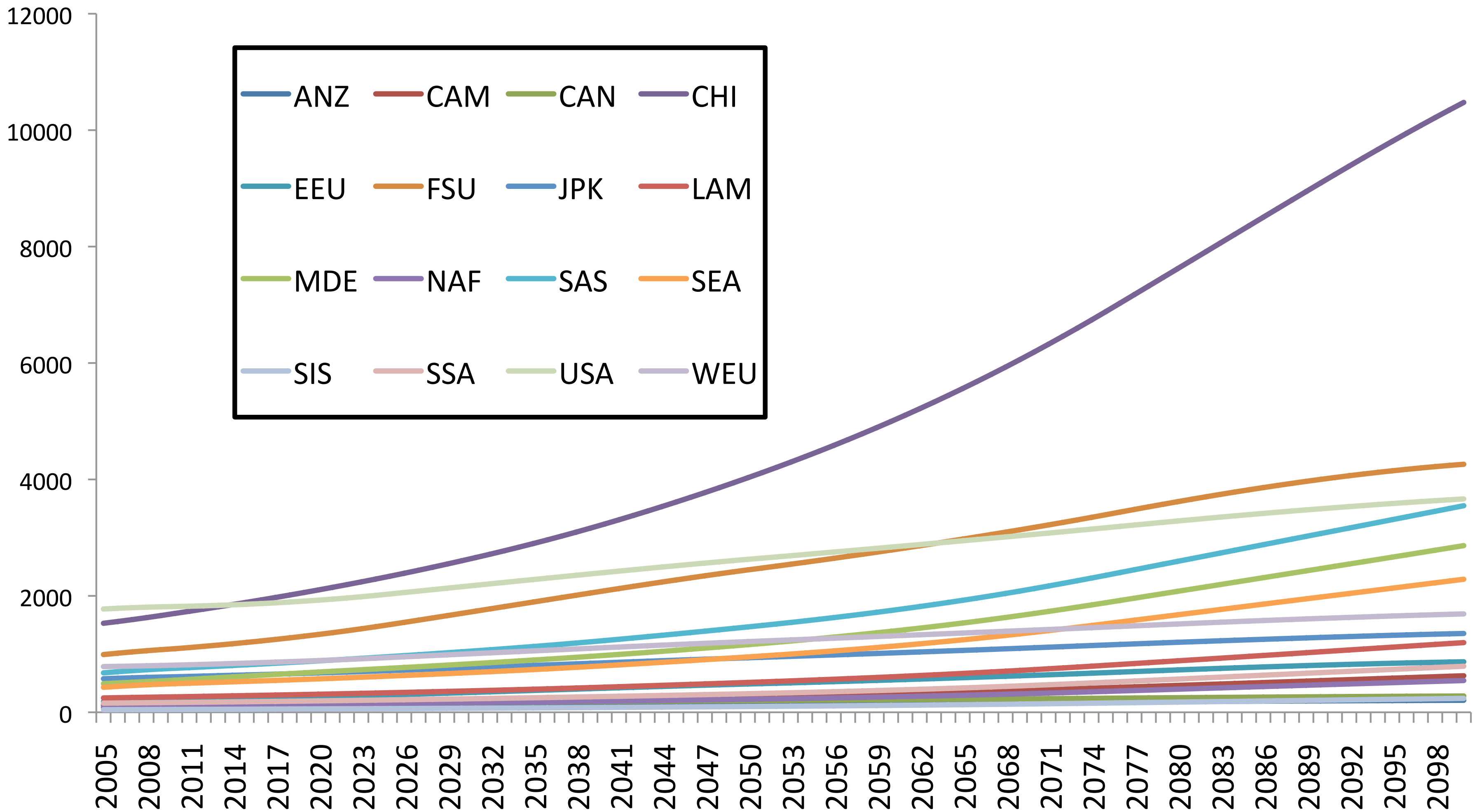


	USA		CHI		AFR		...
2010	6 Gt C	+	5 Gt C	+	1 Gt C	+	...
2011	7 Gt C	+	6 Gt C	+	1 Gt C	+	...
2012	8 Gt C	+	7 Gt C	+	2 Gt C	+	...
...	...		...		...		...

$$y_{t,r} = \frac{Y_{t,r} - C_{t,r}(x_{t,r}) - D_{t,r}(S_t)}{P_{t,r}}$$

$$S_{t+1} = g\left(S_t, \sum_r x_{t,r}\right)$$

$$W = \sum_{t=0}^{T} \delta^t \sum_{r} U(y_{t,r}) P_{t,r}$$



Two Cases

- With lump sum transfers
  - (Negishi weights trick)
- Without lump sum transfers

Bellman Equations & FOC

$$V_t(\boldsymbol{S}_t) = \max_{\{x_t\}} \sum_r U(\boldsymbol{y}_{t,r}) P_{t,r} + \delta V_{t+1}(\boldsymbol{S}_{t+1})$$

$$\frac{\partial}{\partial \boldsymbol{x}_{t,i}} \left(\sum_r U(\boldsymbol{y}_{t,r}) P_{t,r} + \delta V_{t+1}(\boldsymbol{S}_{t+1}) \right) = 0 \quad \forall t, i$$

Optimal Taxes - Transfers

Marginal Abatement Cost
or
Carbon Tax

Ramsey Discount Factor

Marginal Damage Cost

$$MAC(t,i) = \sum_{s=t}^{T} \sum_{r} \frac{1}{(1+\rho+\eta g_t)^t} MD_{s,r}(t)$$

Same for all Regions

Social Cost of Carbon

Optimal Taxes – No Transfers

Marginal Abatement Cost
or
Carbon Tax

Marginal Damage Cost

$$MAC(t,i) = [y(t,i)]^{\eta} \sum_{s=t}^{T} \delta^{s-t} \sum_{r} \left(\frac{1}{y_{s,r}}\right)^{\eta} MD_{s,r}(t)$$

Higher for rich regions
Lower for poor regions

Same for all regions

Optimal Taxes – No Transfers

Marginal Abatement Cost
or
Carbon Tax

Ramsey Discount Factor

Marginal Damage Cost

$$MAC(t,i) = \sum_{r} \left[\frac{y(t,i)}{y_{t,r}}\right]^{\eta} \sum_{s=t}^{T} \frac{1}{(1+\rho+\eta g_{t,r})^{t}} MD_{s,r}(t)$$

Distributional / Equity Weight

Social Cost of Carbon for one Region

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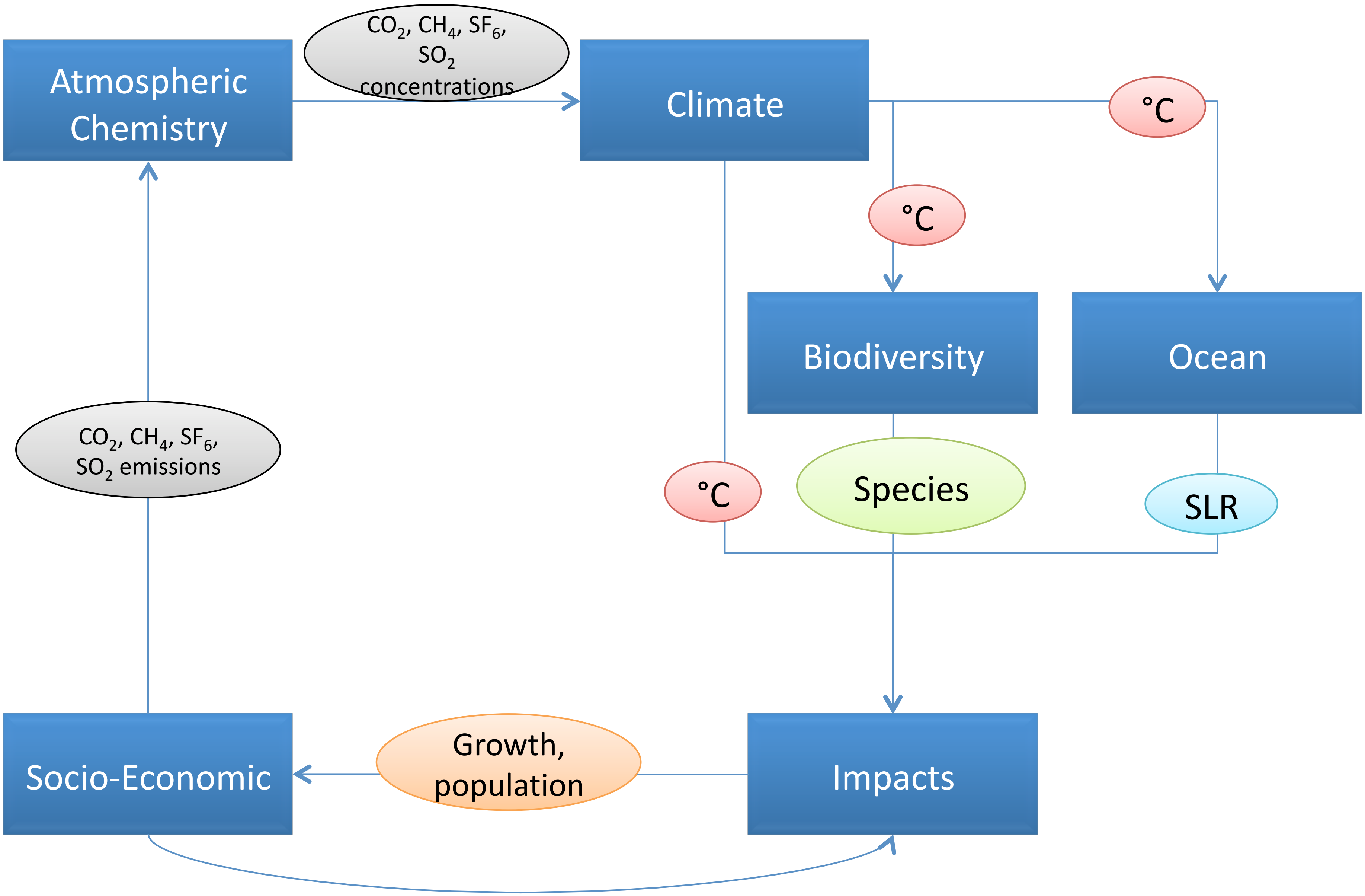
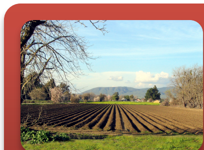
FUND



Atmospheric Chemistry
CO_2, CH_4, SF_6, SO_2 concentrations
Climate
°C
°C
Biodiversity
Ocean
CO_2, CH_4, SF_6, SO_2 emissions
°C
Species
SLR
Socio-Economic
Growth, population
Impacts

Impacts

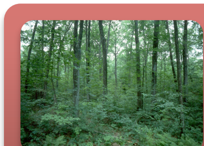
Market



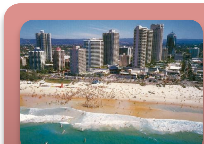
Agriculture

Energy consumption

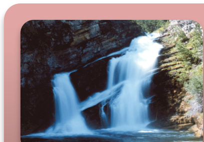
- Cooling
- Heating



Forests



Sea level rise – market



Water

Non-Market

Ecosystems

Health

- Cardiovascular
- Respiratory
- Dengue fever
- Schistosomiasis
- Malaria
- Diarrhea

Sea level rise – non market

http://www.fund-model.org

List of papers, documentation and source code

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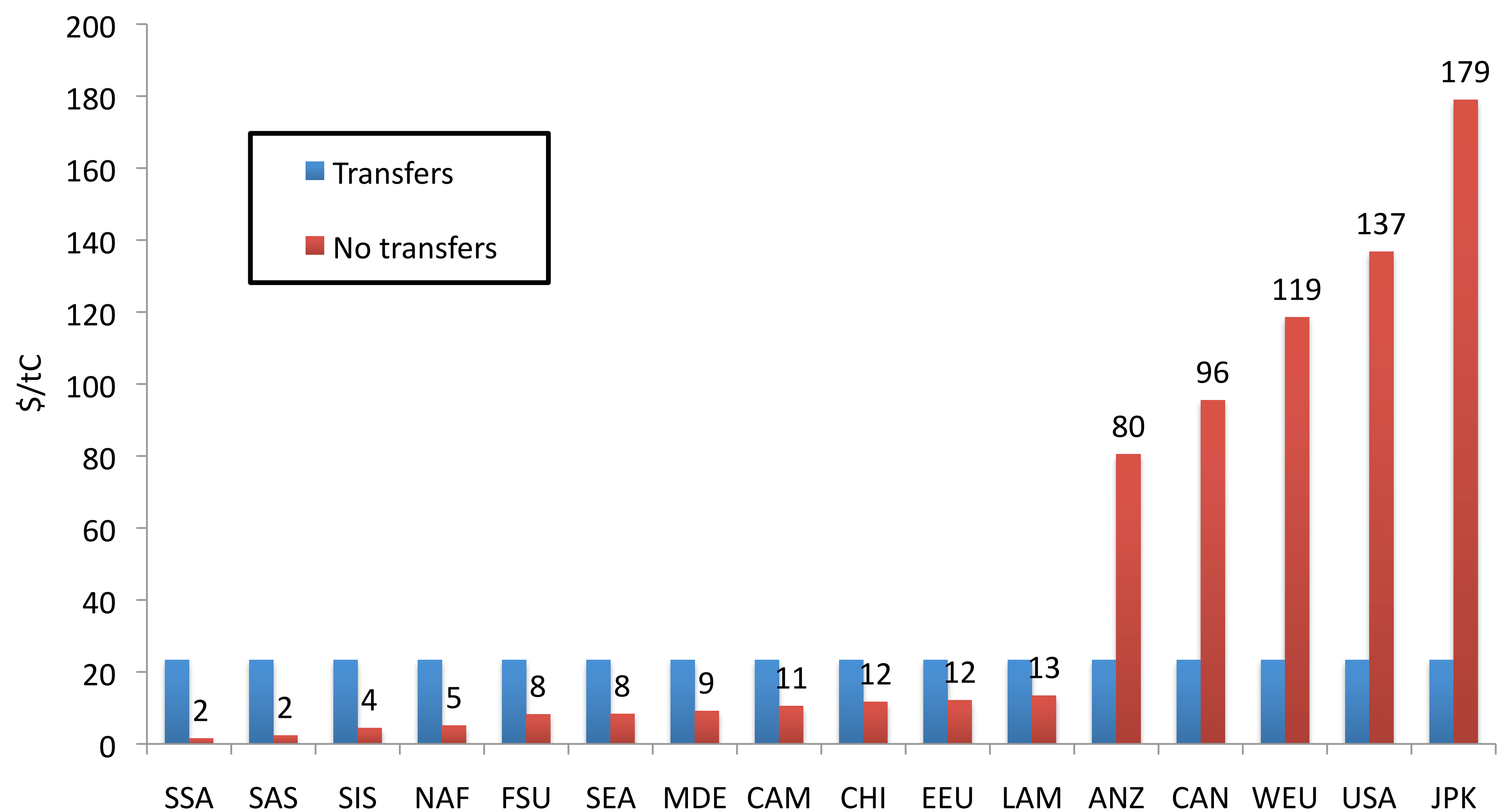
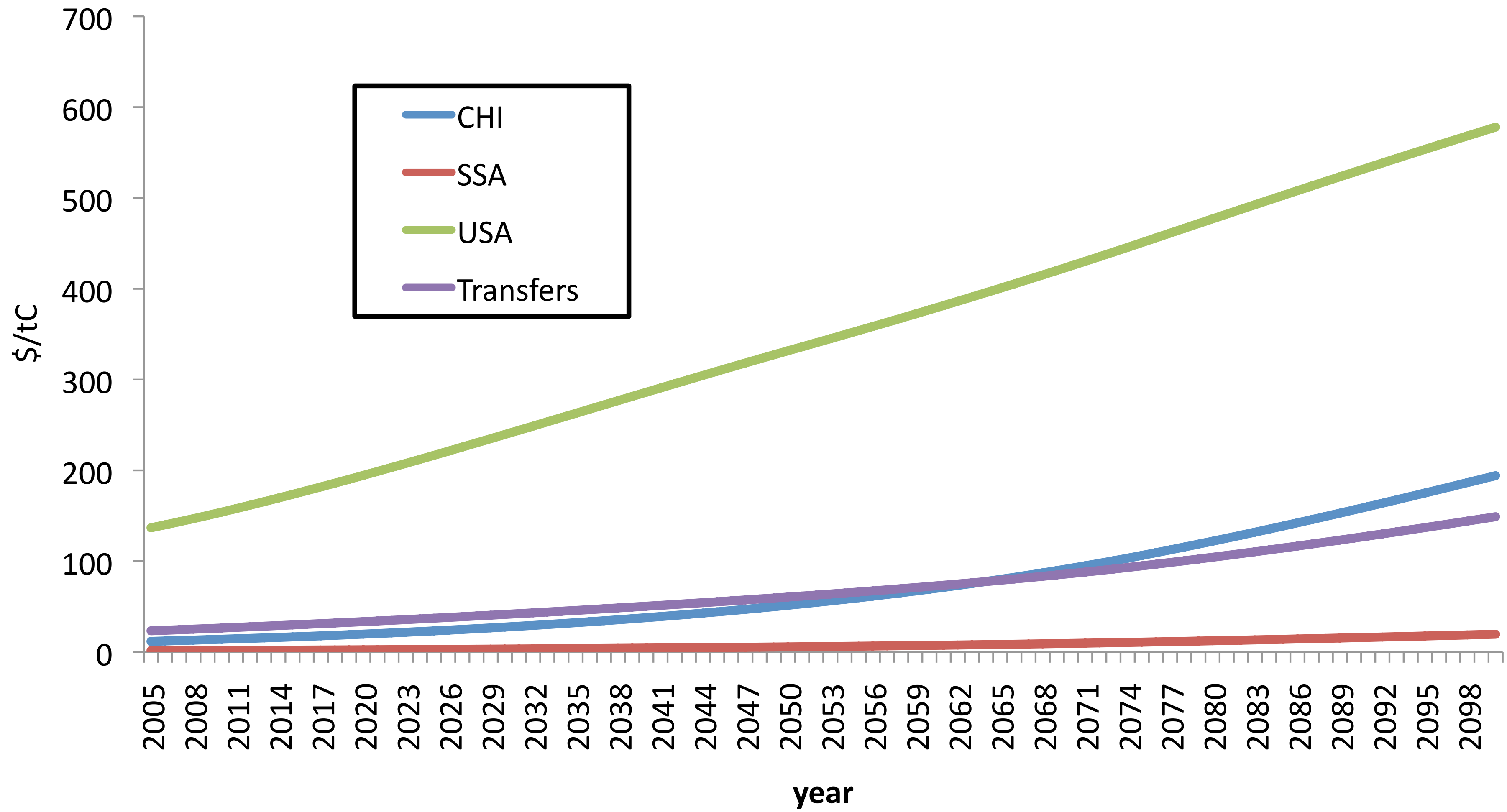
Optimal taxes in 2005



FUND 3.4; η=1; ρ=1%; USD 1995

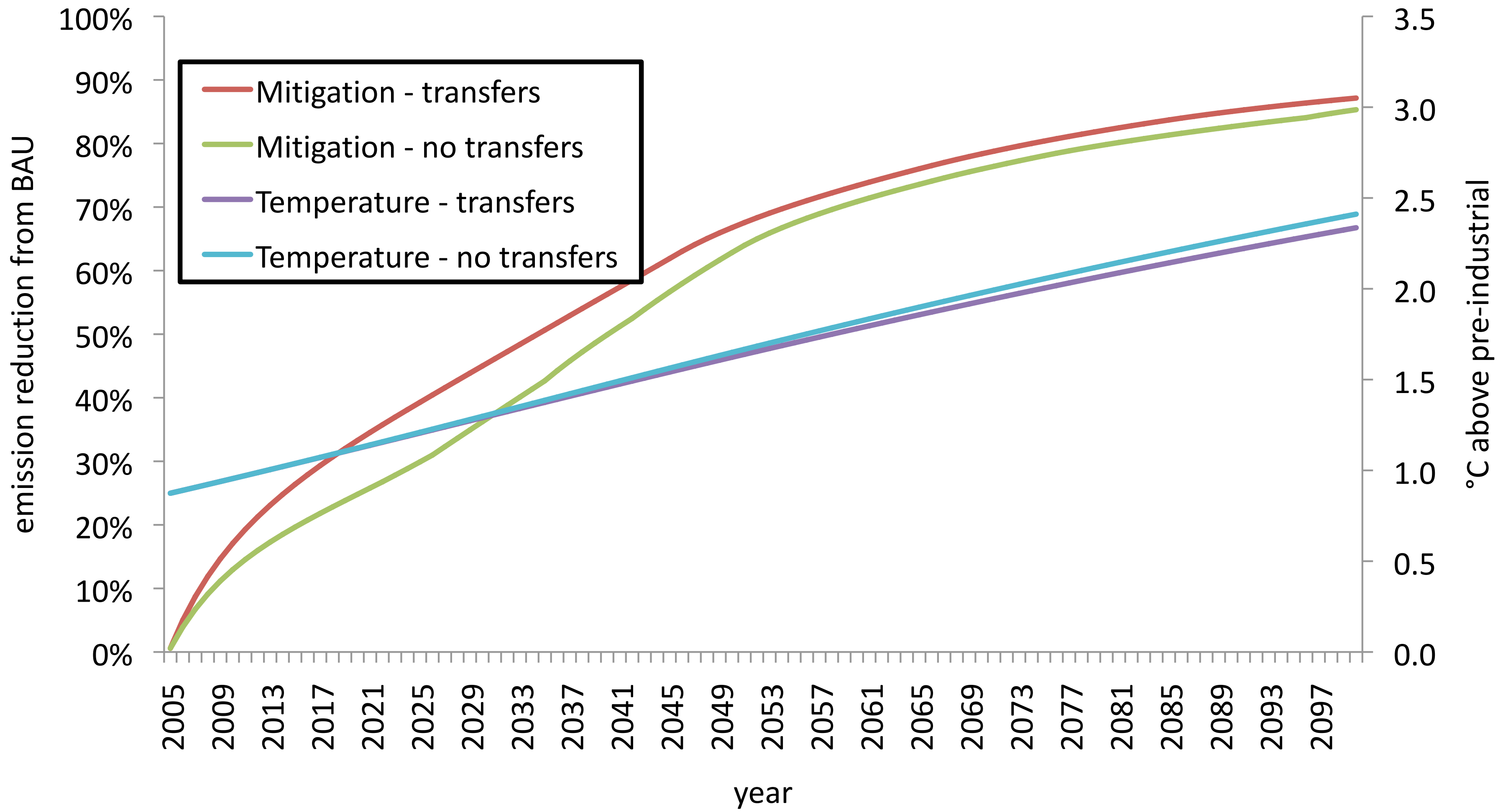
Optimal Taxes over Time



FUND 3.4; $\eta=1$; $\rho=1\%$; USD 1995

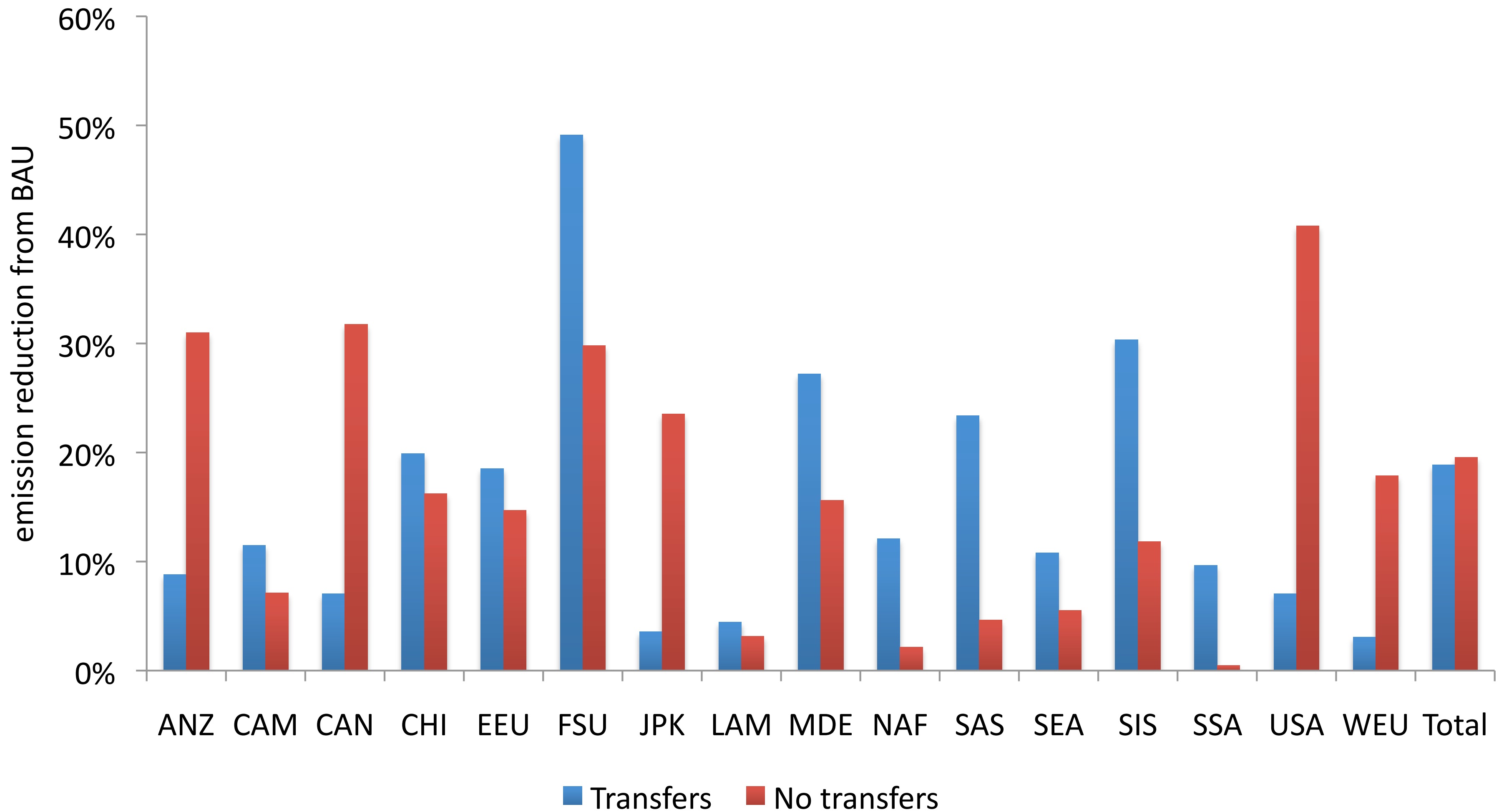
Business as usual warming: 3.17		
Utility calibration	No transfers	Transfers
η=1		
prtp=0.1%	2.41	2.34
prtp=1.0%	2.92	2.91
prtp=3.0%	3.12	3.12
η=1.5		
prtp=0.1%	2.65	2.75
prtp=1.0%	2.96	3.03
prtp=3.0%	3.13	3.13
η=2		
prtp=0.1%	2.69	2.98
prtp=1.0%	2.95	3.09
prtp=3.0%	3.13	3.14

Mitigation & Temperature „Stern like“



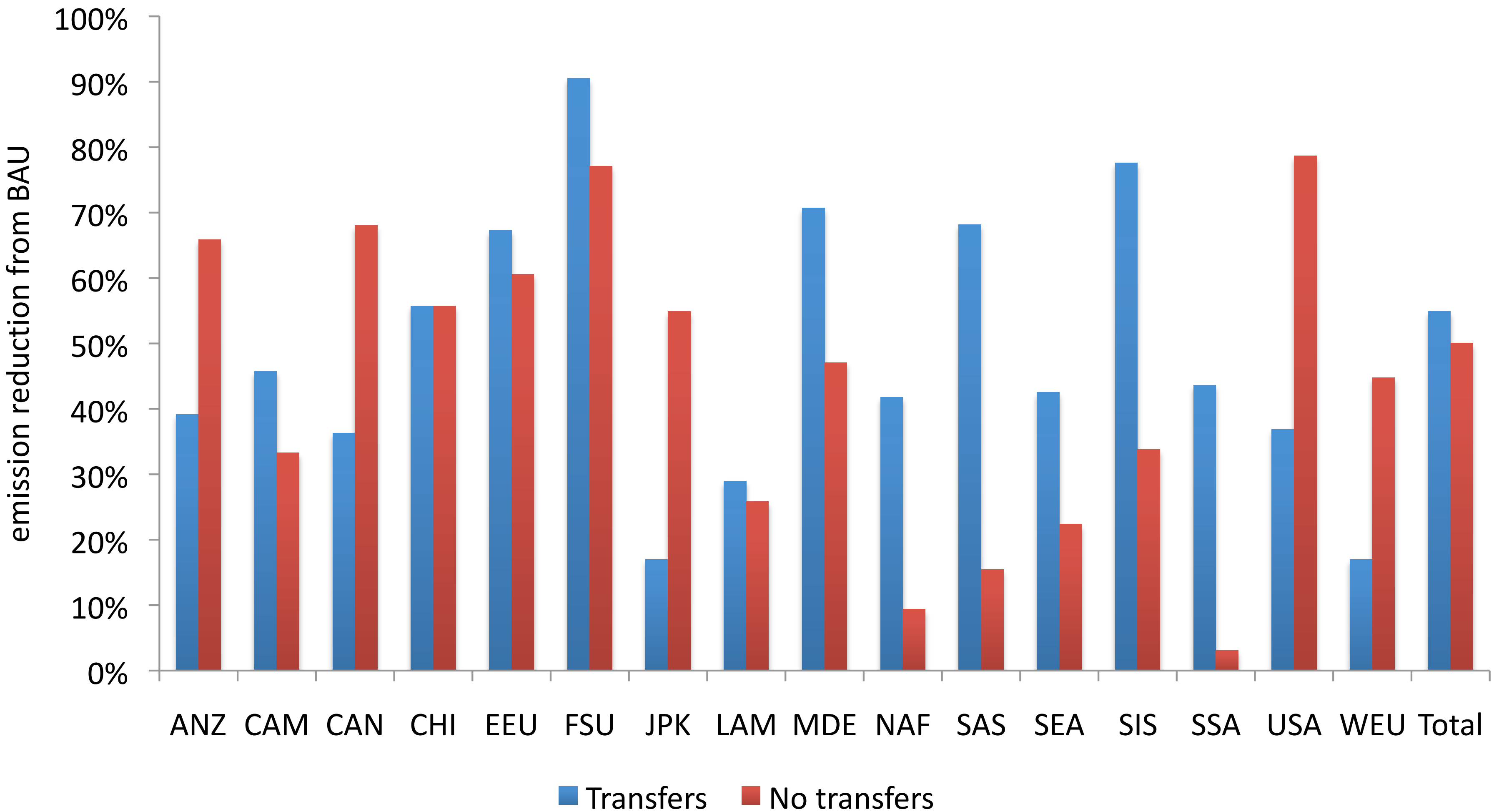
FUND 3.4; η=1; ρ=0.1%; USD 1995

Mitigation- 2050



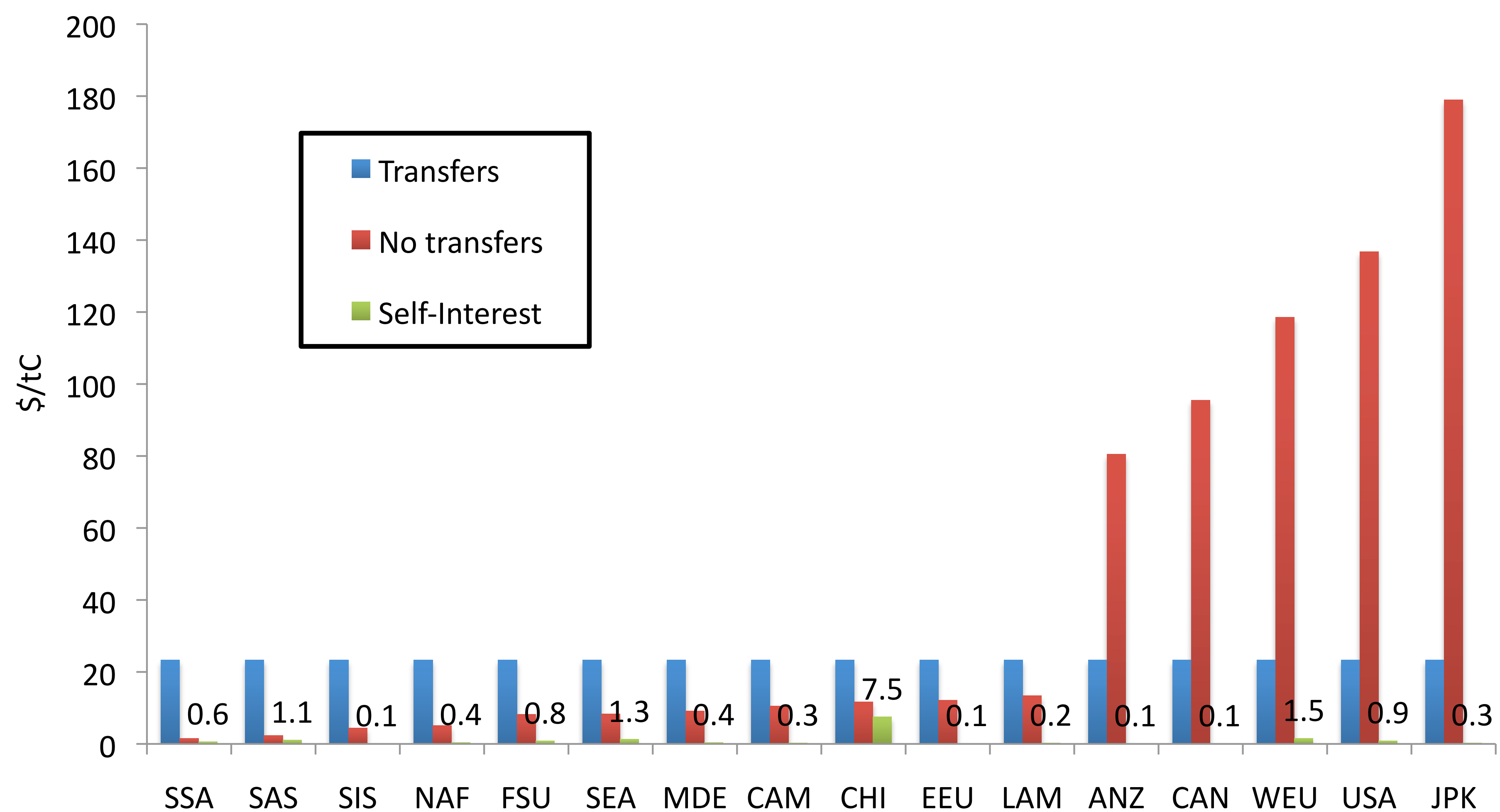
FUND 3.4; η=1; ρ=1%; USD 1995

Mitigation - 2100



FUND 3.4; η=1; ρ=1%; USD 1995

Optimal Taxes in 2005



FUND 3.4; η=1; ρ=1%; USD 1995

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Conclusions

- Optimal total emissions and optimal temperature fairly robust
- Distribution of abatement costs depends critically on possibility of lump sum transfers
- Very large gap between global optimum and national self-interest

Thank you!

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