Climate Policy in a Distorted World

Nikita Lyssenko
Department of Economics
Memorial University of Newfoundland

Leslie Shiell
Department of Economics
University of Ottawa

October 25, 2018

Acknowledgements:
CARE (Collaborative Applied Research in Economics); Yuyu Zhou (Iowa State)

I. Introduction

Integrated assessment models:

- empirically relevant or just test laboratories?
- perfect world or distorted world? (Nordhaus 1994+, Barrage 2018)

Climate policy and distortions:

- tax interaction effect (Bovenberg and de Mooij 1994, Parry 1995, Goulder 1995, Bovenberg and Goulder 1996, Goulder, Parry, Williams, and Burtraw 1999, and Parry, Williams, and Goulder 1999).
- market power (Smith 2009)
- discount rate (Ramsey 1928, Pigou 1937, Solow 1974, Stern 2007)
- insecure resource tenure (Long 1975, Adelman 1986, Weijermars 2015)

I. Introduction

Distortions in our paper:

- discount rate premium in resource markets
- a capital cost premium in resource markets
- OPEC cartel in crude oil (limit pricing)
- pre-existing distortionary taxes across the economy

Our IAM:

- aggregated world model of growth, climate, and taxation
- disaggregated energy sector including:
    - coal,
    - oil,
    - natural gas,
    - hydroelectricity,
    - clean backstop for fossil fuels

I. Introduction

World Consumption Growth of Energy, 2005-2015

source	%
Oil	10.1
Natural gas	25.2
Coal	22.7
Nuclear	-6.9
Hydroelectricity	35.0

Source: BP (2016)

I. Introduction

Our IAM (cont.):

- aggregated world model of growth, climate, and taxation
- simultaneous exploitation of energy sources, despite price differentials
- three corrective policy interventions:
    - a carbon tax,
    - severance taxes on coal, oil and natural gas,
    - economy-wide tax reform.
- simulate optimal time paths of severance and carbon taxes in the first-best as well as a variety of second-best scenarios (different stages of tax reform).
- Barrage (2016) includes distortionary taxation but not fossil fuel markets

I. Introduction

Conclusions:

- governments should rationalize the existing toolkit of taxation in the energy sector – royalties, end-user (excise) taxes, emissions tax, severance taxes, rent taxes
- rely on an economy-wide emission tax, a common resource rent tax and sector-specific severance taxes
- royalties and end-user taxes should be removed, including excise taxes on gasoline
- overarching result: coal is presently under-taxed, oil overtaxed, and natural gas taxed about right

II. Model Structure

Production and damages:

$$Q_t = \zeta_t \left[\alpha_K K_t^{\frac{\sigma-1}{\sigma}} + \alpha_L L_t^{\frac{\sigma-1}{\sigma}} + \alpha_{EN} EN_t^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

$$Y_t = D_t Q_t$$

$$D_t = 1/(1 + \xi TE_t^2)$$

II. Model Structure

Energy sectors:

$$F_t = \left[\alpha_{CL} CL_t^{\frac{\sigma_F - 1}{\sigma_F}} + \alpha_O O_t^{\frac{\sigma_F - 1}{\sigma_F}} + \alpha_{NG} NG_t^{\frac{\sigma_F - 1}{\sigma_F}}\right]^{\frac{\sigma_F}{\sigma_F - 1}}$$

$$F_t = \left[\alpha_{CL} CL_t^{\frac{\sigma_F - 1}{\sigma_F}} + \alpha_O O_t^{\frac{\sigma_F - 1}{\sigma_F}} + \alpha_{NG} NG_t^{\frac{\sigma_F - 1}{\sigma_F}}\right]^{\frac{\sigma_F}{\sigma_F - 1}}$$

$$FS_t = F_t + BK_t$$

$$EN_t = \left[\alpha_{FS} FS_t^{\frac{\sigma_{EN} - 1}{\sigma_{EN}}} + \alpha_{EL} EL_t^{\frac{\sigma_{EN} - 1}{\sigma_{EN}}}\right]^{\frac{\sigma_{EN}}{\sigma_{EN} - 1}}$$

II. Model Structure

Capital accumulation and allocation:

$$A_t = K_t + \sum_{X \in \{CL,O,NG\}} Z_{X,t} X_t + TZ_{EL,t}$$

$$A_{t+1} = (1-\delta)^{\Delta} A_t + \Delta \cdot I_t$$

Output allocation:

$$Y_t = C_t + I_t + \sum_{X \in \{CL,O,NG\}} OC_{X,t} X_t + TOC_{EL,t} + P_t^{BK} BK_t + G_t$$

II. Model Structure

Preferences:

$$\mathbb{W} = \sum_{t=1}^{\infty} \frac{N_t U(c_t, \ell_t, TE_t)}{(1+\theta)^{\Delta(t-1)}}$$

$$U(c_t, \ell_t, TE_t) = \frac{[c_t(1-\phi\ell_t)^{\gamma}]^{1-\rho}}{1-\rho} + \frac{(1+\kappa TE_t^2)^{-(1-\rho)}}{1-\rho} + \mathcal{V}(G_t)$$

$$\frac{-U_\ell(t)}{U_{C/N}(t)} = (1-\tau_{\ell,t})w_t$$

II. Model Structure

Government – pre-existing fiscal instruments:

$\tau_{\ell,t}$, $\tau_{K,t}$, $\tau^{X}_{R,t}$, $\tau_{RR,t}$, $\tau^{X}_{U,t}$, B_t

Government – corrective policy variables:

$\tau_{E,t}$, $\tau^{X}_{S,t}$

II. Model Structure

Transition to backstop:

$$D(\widehat{TE}_t)Q_{EN}(t)\left(\frac{\widehat{EN}_t}{\widehat{FS}_t}\right)^{\frac{1}{\sigma_{EN}}}\alpha_{FS} \leq P_t^{BK} + \tau_{U,t}^{BK} \text{ and } \widehat{BK}_t \geq 0 \text{ with complementary slackness}$$

$$D(\widehat{TE}_t)Q_{EN}(t)\left(\frac{\widehat{EN}_t}{\widehat{FS}_t}\right)^{\frac{1}{\sigma_{EN}}}\alpha_{FS} \leq \hat{P}_t^{F} \text{ and } \hat{F}_t \geq 0 \text{ with complementary slackness}$$

Extractive Firms – Competition:

$$\tilde{\pi}_t^X = \left(1-\tau_{K,t}-\tau_{RR,t}\right)\left[\left(1-\tau_{R,t}^X\right)P_t^X - OC_{X,t} - (r_t + r^* + \delta)Z_{X,t} - \tau_{S,t}^X\right]\hat{X}_t$$

$$\left(1-\tau_{R,t}^X\right)\hat{P}_t^X = \widehat{OC}_{X,t} + (r_t + r^* + \delta)\hat{Z}_{X,t} + \tau_{S,t}^X - \frac{\Delta\hat{P}_t^{Cum,X}}{\left(1-\tau_{K,t}-\tau_{RR,t}\right)}$$

II. Model Structure

Extractive Firms – Limit Pricing:

$$D\left(\widehat{TE}_t\right)Q_{EN}(t)\left(\frac{\widehat{EN}_t}{\widehat{FS}_t}\right)^{\frac{1}{\sigma_{EN}}}\left(\frac{\hat{F}_t}{\hat{O}_t}\right)^{\frac{1}{\sigma_F}}\alpha_{FS}\alpha_O = \hat{P}_t^O + \tau_{E,t} + \tau_{U,t}^O$$

$$\hat{P}_t^O = \frac{\mathcal{P}^O + \tau_{S,t}^O}{\left(1 - \tau_{R,t}^O\right)}$$

Resource market equilibrium conditions – notice substitutability among $\tau_{E,t}$, $\tau_{U,t}^X$, and $\tau_{S,t}^X$:

$$\left(1 - \tau_{R,t}^X\right)\left\{D\left(\widehat{TE}_t\right)Q_{EN}(t)\left(\frac{\widehat{EN}_t}{\hat{F}_t}\right)^{\frac{1}{\sigma_{EN}}}\left(\frac{\hat{F}_t}{\hat{X}_t}\right)^{\frac{1}{\sigma_F}}\alpha_{FS}\alpha_X - \tau_{E,t} - \tau_{U,t}^X\right\} - \tau_{S,t}^X =$$
$$\widehat{OC}_X(t) + \left[D\left(\widehat{TE}_t\right)Q_K(t) + r^*\right]\hat{Z}_X(t) + \frac{\Delta\hat{P}_t^{Cum,X}}{\left(1 - \tau_{K,t} - \tau_{RR,t}\right)}$$

III. Policy Scenarios

Scenario 1 (business-as-usual – BAU):

- $\tau_{E,t} = \tau^X_{S,t} = 0 \;\; \forall t,$
- $\tau_{K,t}$, $\tau^X_{U,t}$ and $\tau^X_{R,t}$ set to currently observed $(t = 1)$ values $\forall t,$
- $\tau_{RR,t} = 0.25 \;\; \forall t,$
- $B_t \leq s_B Y_t \;\; \forall t,$
- $\tau_{\ell,t}$ set at a constant value to satisfy govt budget $\forall t.$

Scenario 2 (first-best policy – lump sum taxes)

- $\tau_{\ell,t} = \tau_{K,t} = \tau^X_{U,t} = \tau^X_{R,t} = \tau_{RR,t} = B_t = 0,$
- $\tau_{E,t},\; \tau^X_{S,t}$, and $-T^G_t$ (lump-sum tax) chosen to replicate the planner's solution.

III. Policy Scenarios

Second-best (distortionary taxes)

Scenario 3 (climate tax shift): $\tau_{E,t}$ optimized subject to:

- $\tau_{U,t}^{X}$, $\tau_{R,t}^{X}$, $\tau_{RR,t}$, B_t fixed at BAU rates,
- $\tau_{S,t}^{X} = 0$,
- labour and capital taxes fixed at exogenous BAU rates, except for revenue recycling
- Scenario 3(a): $\tau_{K,t}$ fixed at exogenous BAU rate, $\tau_{E,t}$ revenue recycled through $\tau_{\ell,t}$
- Scenario 3(b): $\tau_{\ell,t}$ fixed at exogenous BAU rate, $\tau_{E,t}$ revenue recycled through $\tau_{K,t}$

Scenario 4 (climate tax shift): same as Scenario 3 except:

- Remove $\tau_{K,t}$ from resource rents; increase $\tau_{RR,t}$ by a corresponding amount

III. Policy Scenarios

Scenario 5 (optimal tax policy): $\tau_{E,t}$, $\tau_{U,t}^{X}$, $\tau_{R,t}^{X}$, $\tau_{S,t}^{X}$, $\tau_{\ell,t}$, $\tau_{K,t}$, and $B_t$optimized subject to:

- $\tau_{RR,t}$ tax fixed at various levels
- in practice this means setting $\tau_{E,t} = \tau_{U,t}^{X} = \tau_{R,t}^{X} = 0$; focus instead on $\tau_{S,t}^{X}$
- once optimal path of $\tau_{S,t}^{X}$ is obtained, decompose it into a carbon component and a residual corrective tax as follows:

III. Policy Scenarios

Scenario 5 (cont.):

$$\tau_{E,t} = \begin{Bmatrix} \frac{1}{MCF_t}\sum_{s=1}^{\infty}\frac{1}{(1+\theta)^{\Delta s}}\left(\frac{-U_{TE,t+s}}{U_{C/N,t}}\right)\frac{\partial TE_{t+s}}{\partial(\sum_X X_t)} \\ +\sum_{s=1}^{\infty}\frac{1}{(1+\theta)^{\Delta s}}\frac{\lambda_{t+s}}{\lambda_t}\left(-\frac{\partial Y_{t+s}}{\partial TE_{t+s}}\right)\frac{\partial TE_{t+s}}{\partial(\sum_X X_t)} \end{Bmatrix} \qquad (88)$$

$$\tau_{S,t}^{X} = -r^{*}\hat{Z}_{X,t} + \Delta\left(\hat{P}_t^{Cum,X} - \frac{\eta_t^X}{\lambda_t}\right) + \frac{1}{MCF_t}\sum_{s=1}^{\infty} D^{s}\left(\sum_{v=0}^{t+s} D^{v-(t+s)}\psi\frac{U_{c,v}}{U_{ct}}\sum_X\frac{\partial \pi_v^X}{\partial TE_{t+s}}\right)\frac{\partial TE_{t+s}}{\partial(\sum_X X_t)} +$$

$$\frac{1}{MCF_t}\sum_{s=0}^{t} D^{s-t}\psi\frac{U_{c,s}}{U_{ct}}\left(\frac{\partial \pi_s^X}{\partial X_t} + \sum_X\frac{\partial \pi_s^X}{\partial EN_t}F_{2X,t}\right) - \frac{1}{MCF_t}\sum_{s=0}^{t} D^{s-t}\psi\frac{U_{c,s}}{U_{ct}}\sum_X\frac{\partial \pi_s^X}{\partial K_t}Z_{X,t}\,, \quad X\in\{CL,NG\} \qquad (89)$$

III. Costs, parameters, and initial values

• coal – costs:	GEA (2012)
• oil and natural gas – costs:	Aguilera (2014), Aguilera et al. (2009)
• carbon factors:	IEA (2016)
• hydroelectricity – costs:	Zhou et al. (2015), IRENA (2012)
• Initial values & climate parameters:	Nordhaus (2013), Traeger (2014)
• Population:	United Nations (2004), Feenstra et al. (2015, 2016).
• Preferences:	Nordhaus (2013), Barrage (2016).
• Government spending and transfers:	Barrage (2016).
• Government debt:	IMF (2016a,b), worldbank.org.
• Coal royalties:	PWC (2017), EIA (2015), BP (2016), Australia (2016), Western Australia (2015), Queensland (2016), NSW Mining (2017)

III. Costs, parameters, and initial values

- coal – costs: GEA (2012)
- crude oil royalties: Nakhle (2010), BP (2016).
- natural gas royalties: EY (2016), BP (2016), Kellas (2010).
- end-use taxes on fossil fuels: OECD (2015).
- labour tax, capital tax: Barrage (2016).
- elasticities of substitution: Stern (2012), van der Werf (2008)

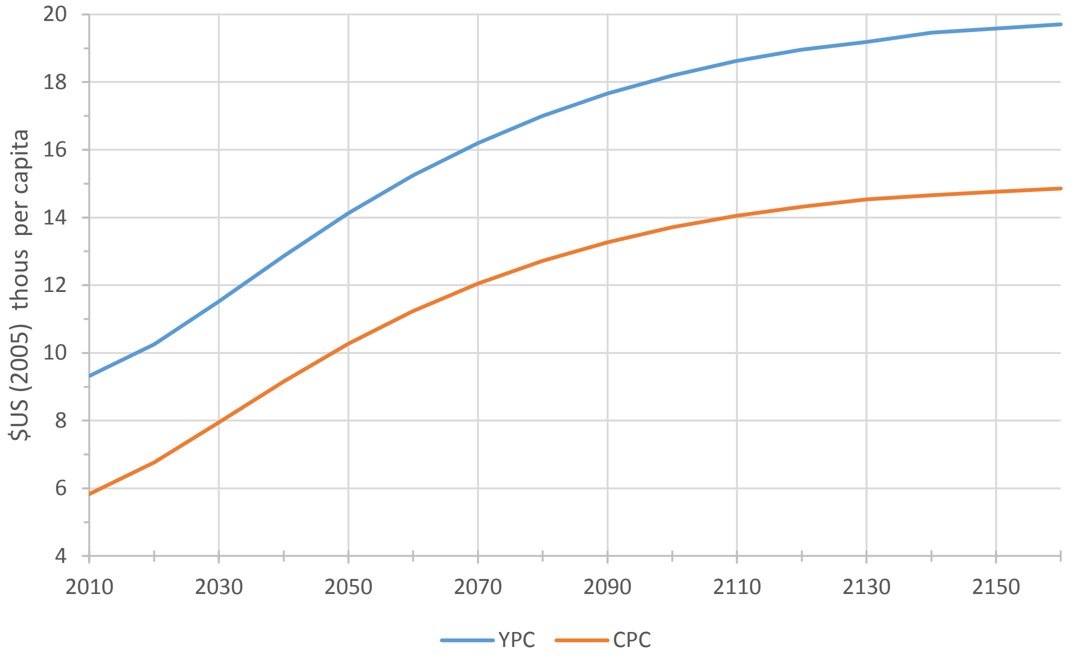
III. Costs, parameters, and initial values

Exogenous tax rates:

	43.01%
	34.87%
	9.80%
	13.90%
	14.40%
	\$6.55 / t C
	\$204.42 / t C
	\$18.11 / t C
	25%

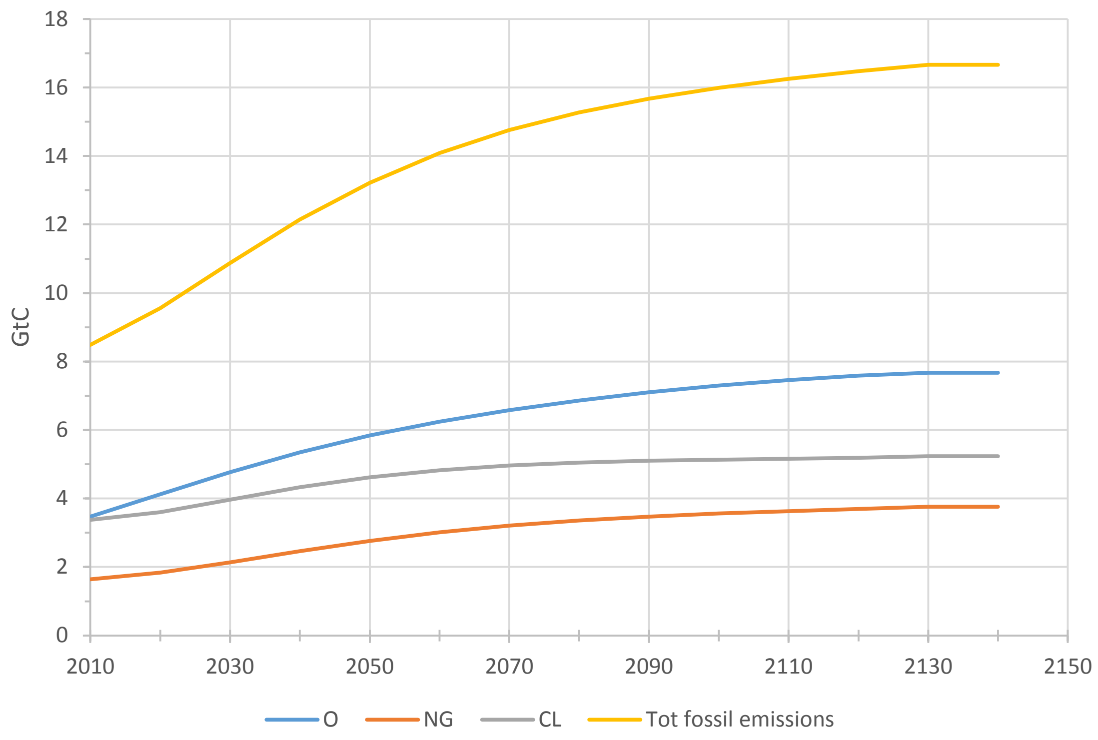
IV. Results

Figure 1 Output and Consumption in BAU



IV. Results

Figure 2 Fossil Fuels in BAU



IV. Results

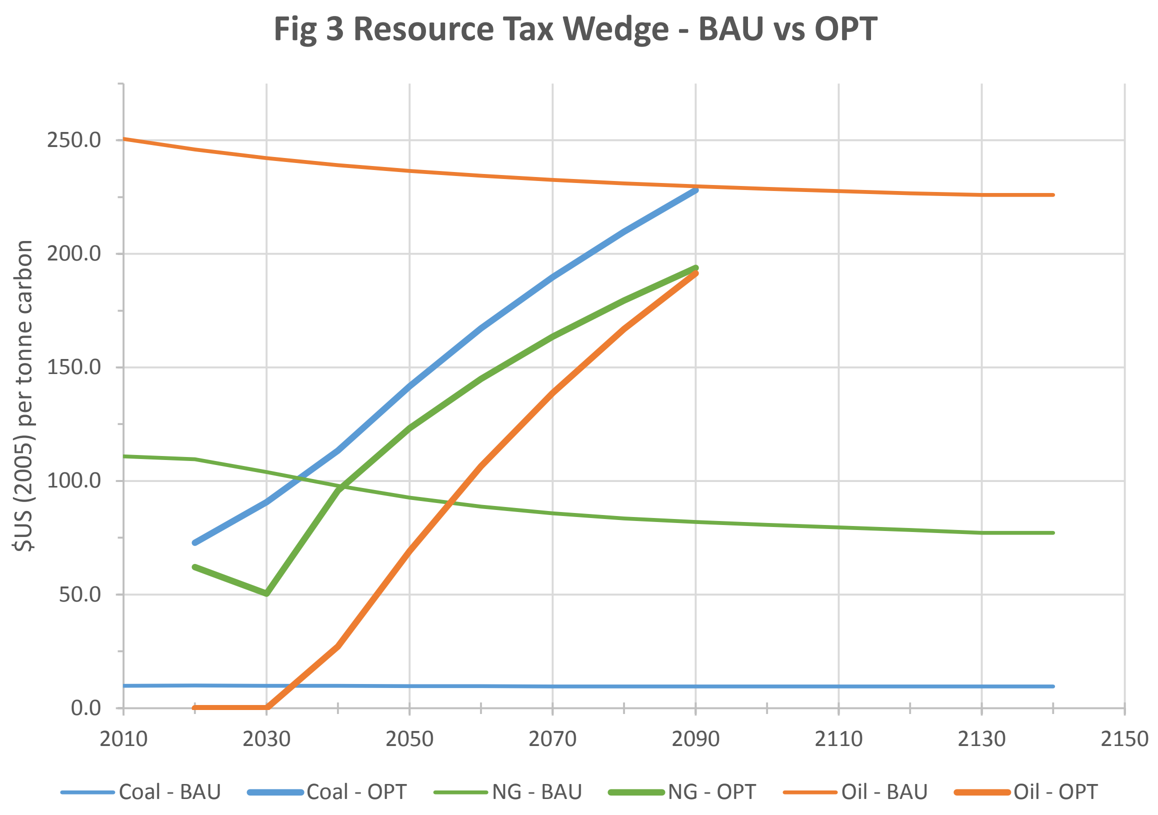
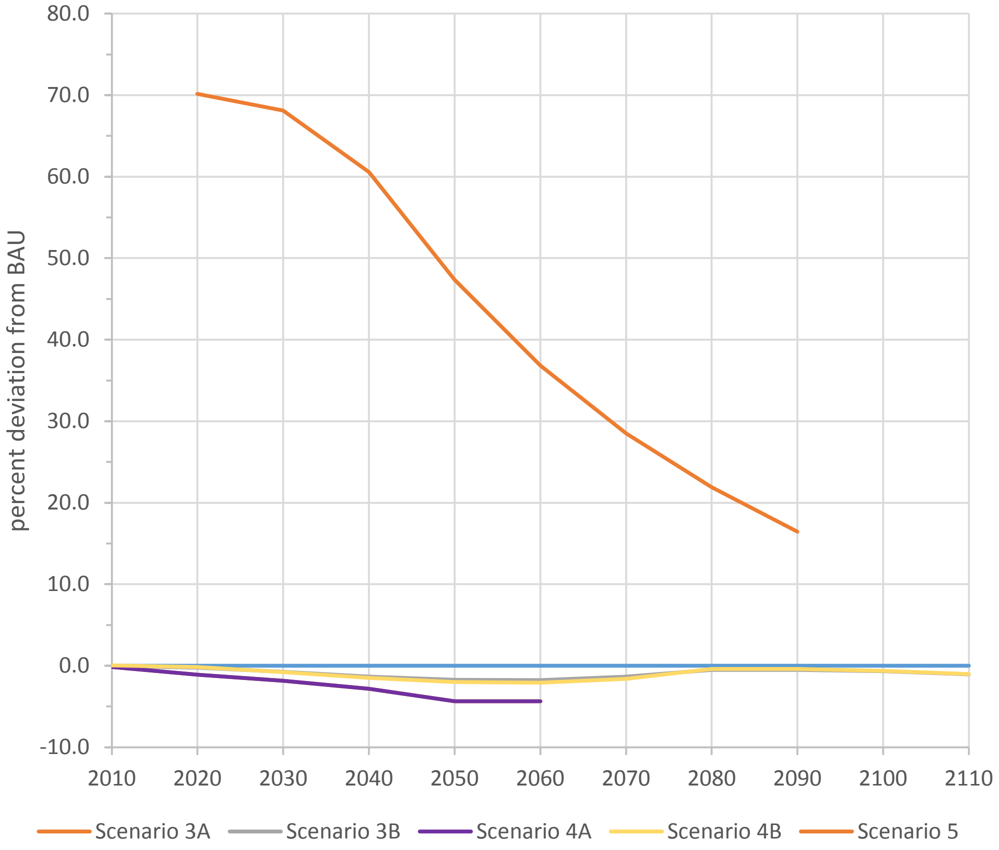


Fig 3 Resource Tax Wedge - BAU vs OPT
$US (2005) per tonne carbon
250.0
200.0
150.0
100.0
50.0
0.0
2010
2030
2050
2070
2090
2110
2130
2150
Coal - BAU
Coal - OPT
NG - BAU
NG - OPT
Oil - BAU
Oil - OPT

IV. Results

Fig 4 Oil Trends



IV. Results

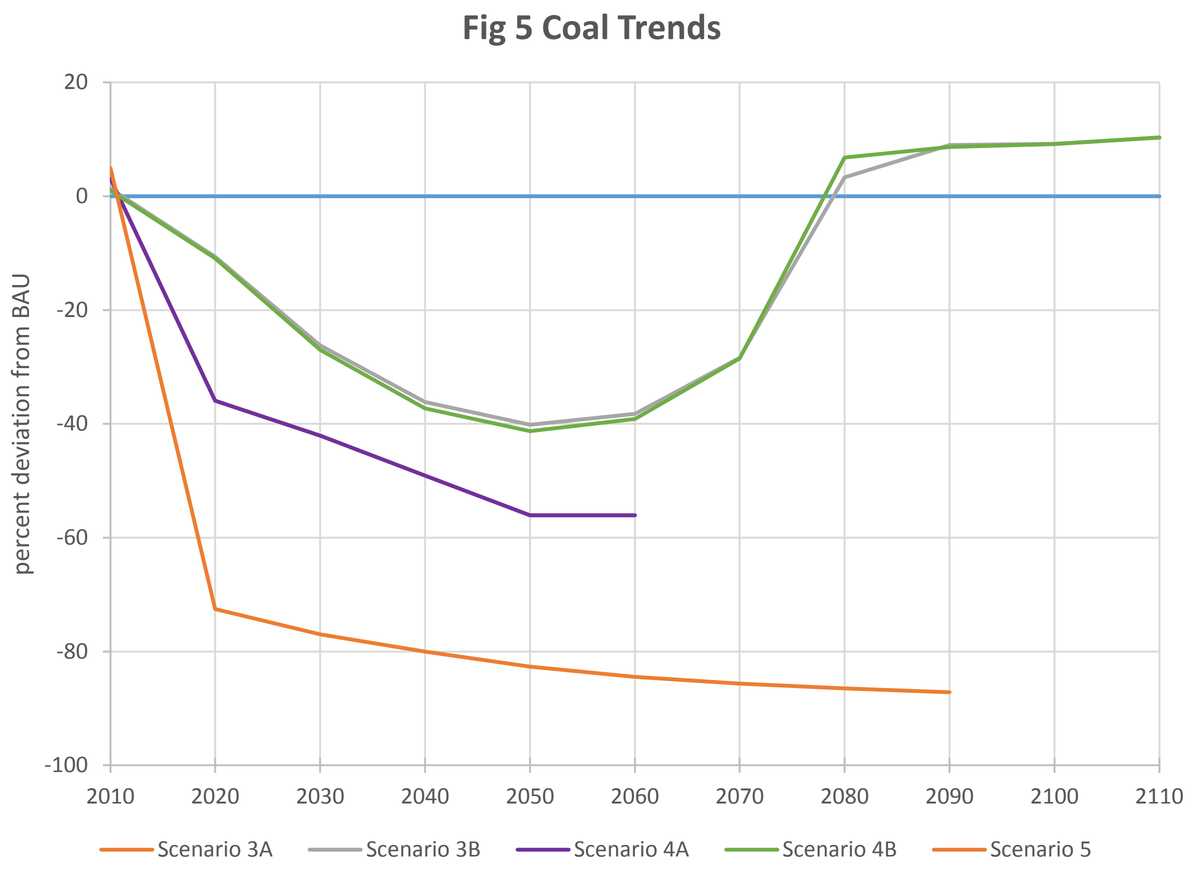


Fig 5 Coal Trends
20
0
-20
-40
-60
-80
-100
percent deviation from BAU
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
Scenario 3A
Scenario 3B
Scenario 4A
Scenario 4B
Scenario 5

IV. Results

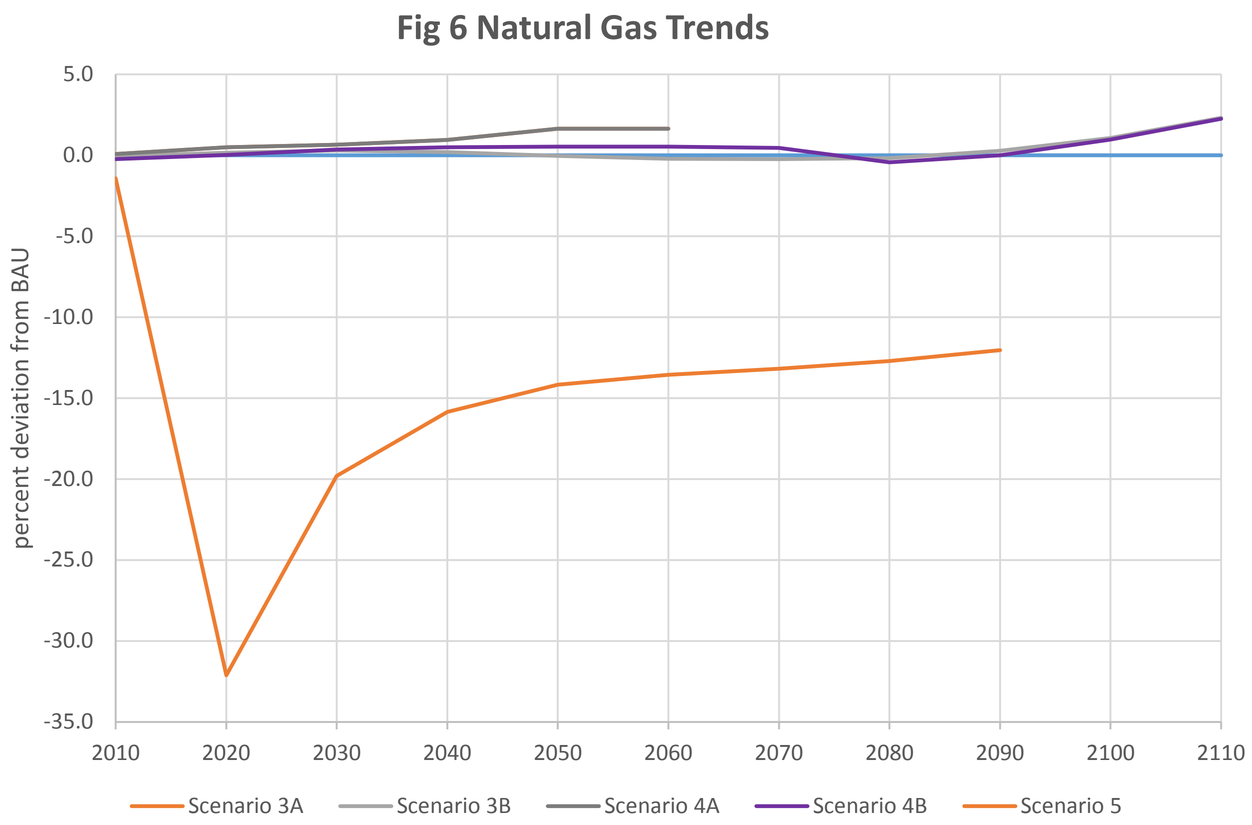


Fig 6 Natural Gas Trends
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
percent deviation from BAU
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
Scenario 3A
Scenario 3B
Scenario 4A
Scenario 4B
Scenario 5

IV. Results

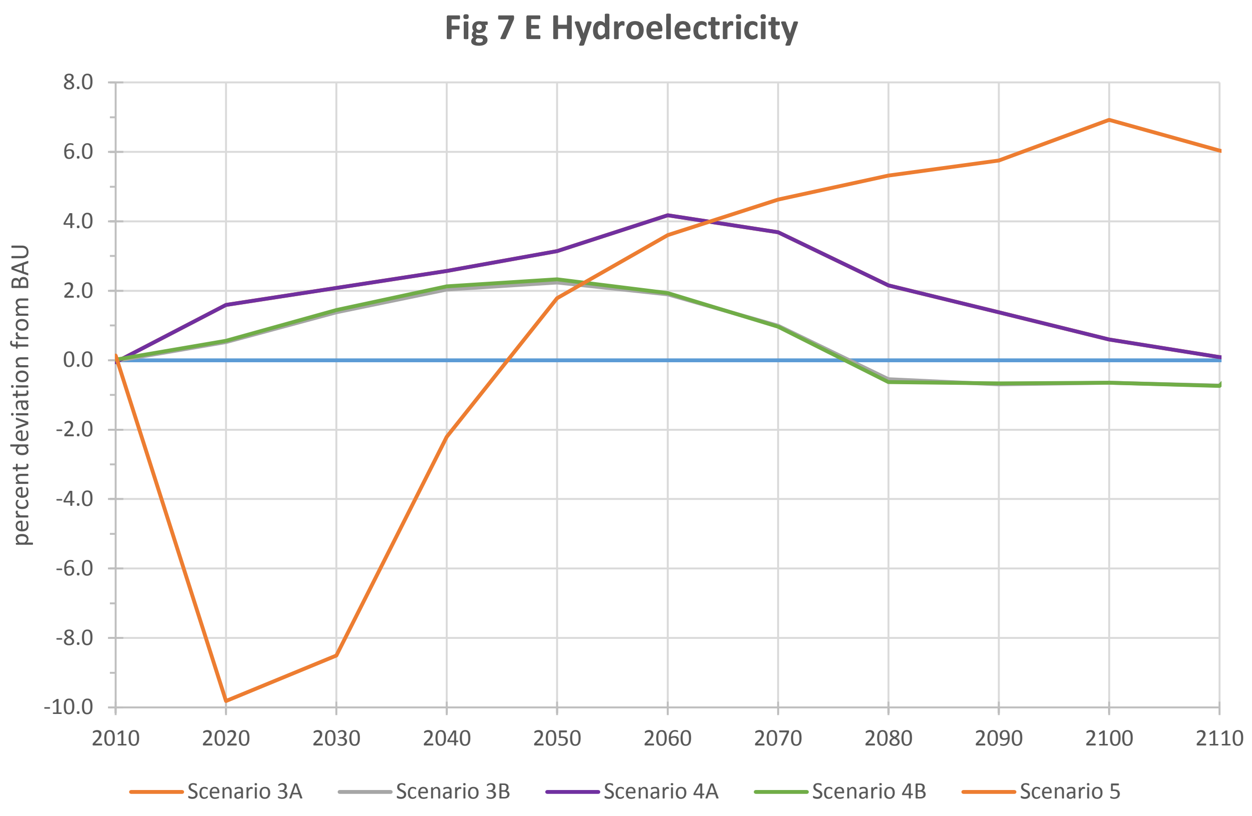


Fig 7 E Hydroelectricity
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
percent deviation from BAU
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
Scenario 3A
Scenario 3B
Scenario 4A
Scenario 4B
Scenario 5

IV. Results

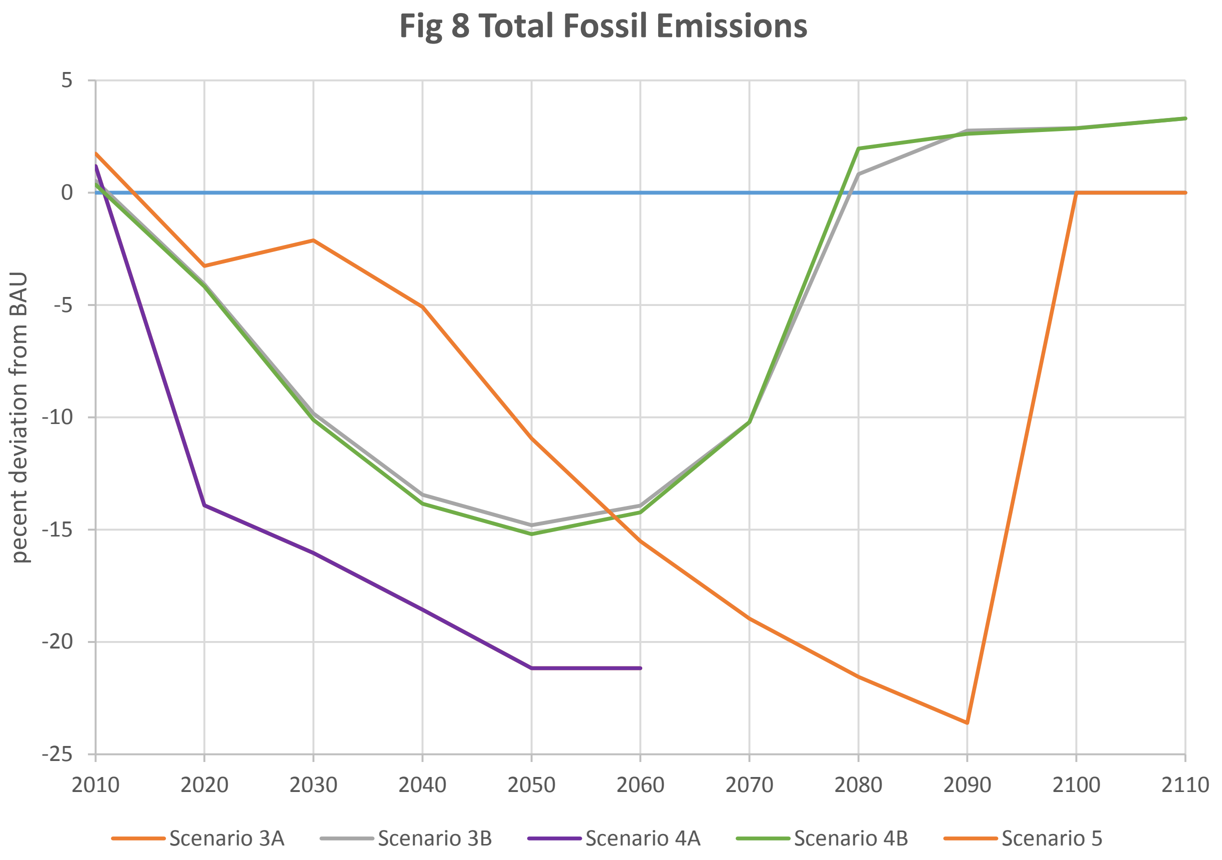


Fig 8 Total Fossil Emissions
pecent deviation from BAU
5
0
-5
-10
-15
-20
-25
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
Scenario 3A
Scenario 3B
Scenario 4A
Scenario 4B
Scenario 5

IV. Results

Total Emissions 2010-2140
(deviation from BAU)

Scenario	%
3A	-74.2
3B	-22.3
4A	-74.2
4B	-22.3
5	-44.5

IV. Results

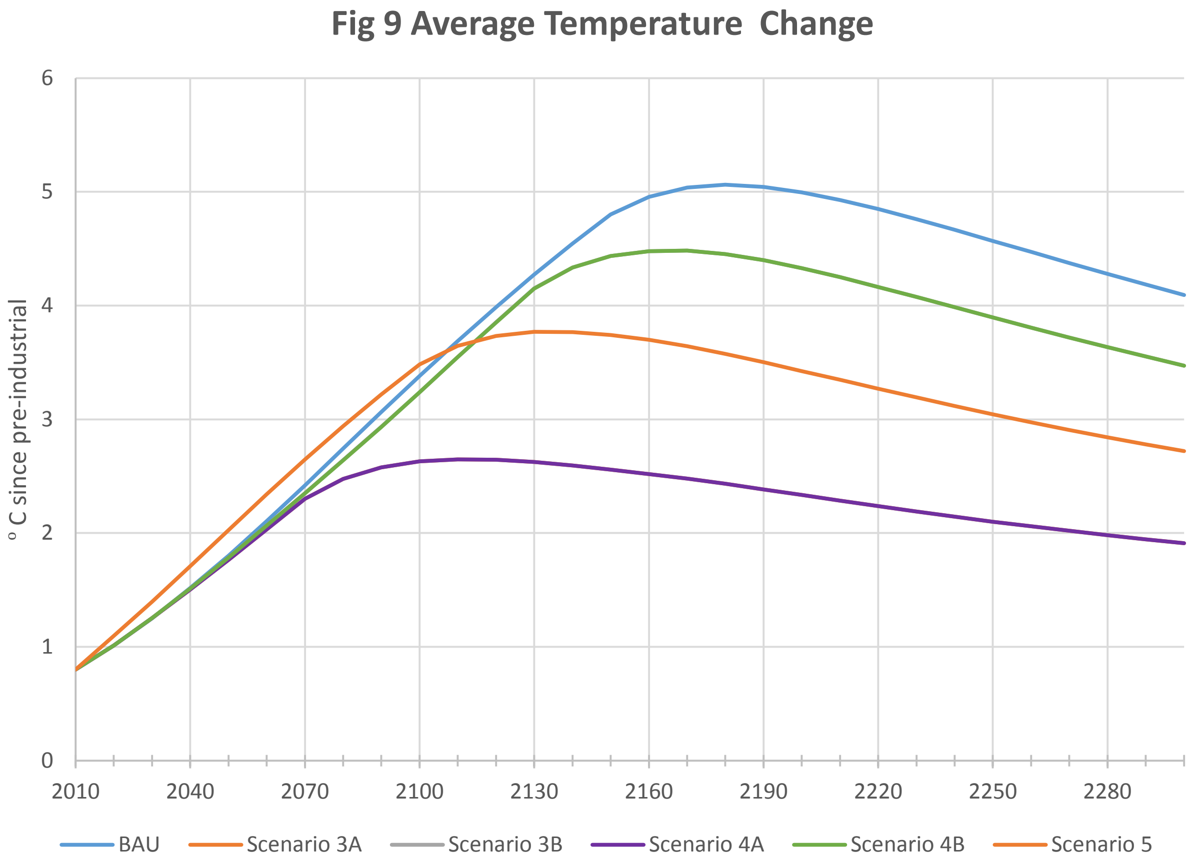
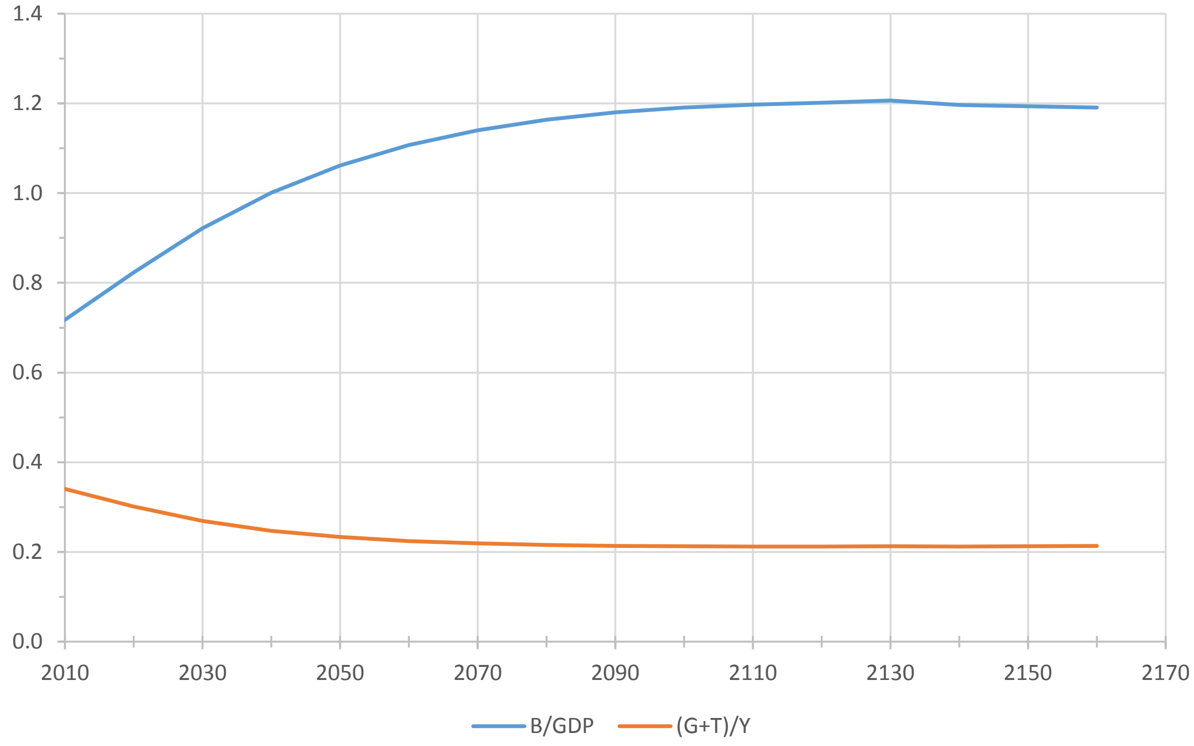


Fig 9 Average Temperature Change
º C since pre-industrial
6
5
4
3
2
1
0
2010
2040
2070
2100
2130
2160
2190
2220
2250
2280
BAU
Scenario 3A
Scenario 3B
Scenario 4A
Scenario 4B
Scenario 5

IV. Results

Fig 10 Public Debt and Spending Ratios in BAU



IV. Results

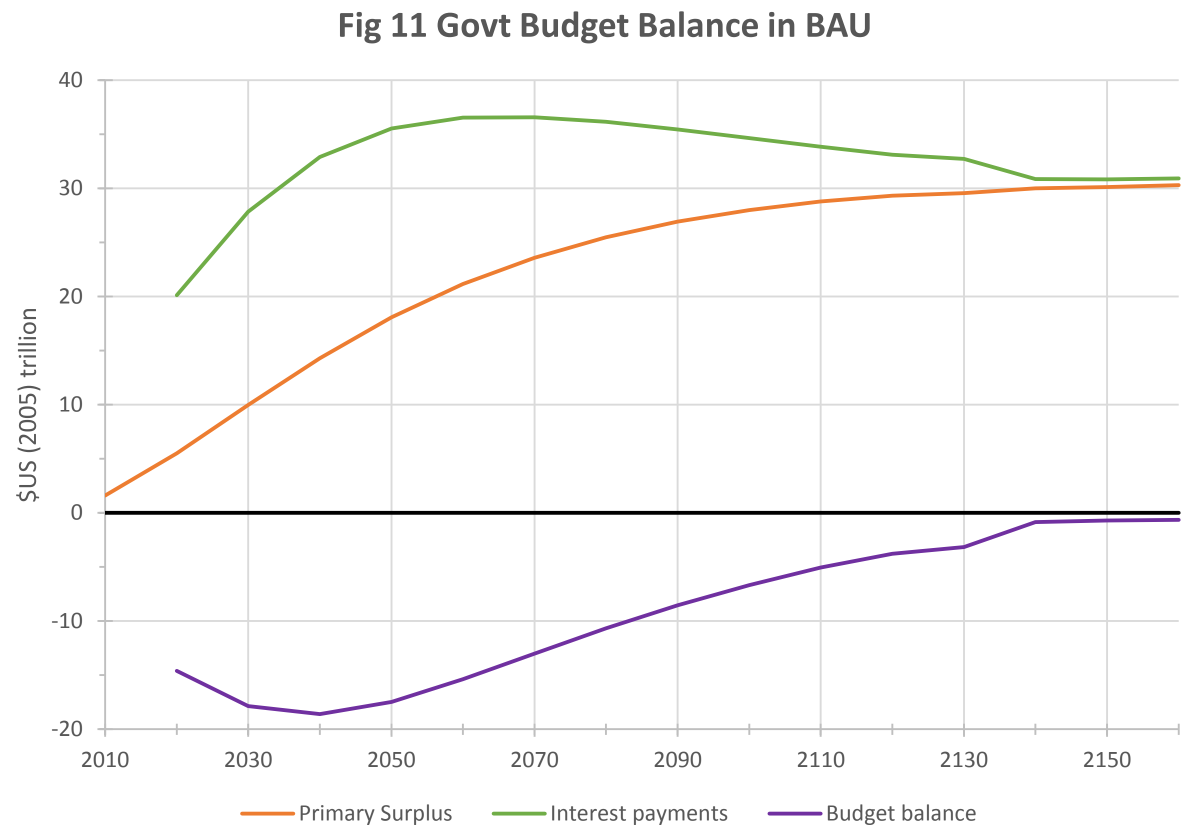


Fig 11 Govt Budget Balance in BAU
40
30
20
10
0
-10
-20
$US (2005) trillion
2010
2030
2050
2070
2090
2110
2130
2150
Primary Surplus
Interest payments
Budget balance

IV. Conclusion

- governments should rationalize the existing toolkit of taxation in the energy sector – royalties, end-user (excise) taxes, emissions tax, severance taxes, rent taxes
- rely on an economy-wide emission tax, a common resource rent tax and sector-specific severance taxes
- royalties and end-user taxes should be removed, including excise taxes on gasoline
- overarching result: coal is presently under-taxed, oil overtaxed, and natural gas taxed about right
- caveat: Paris Agreement "not optimal" – target of 2 ºmax