UNSW Business School

Centre for Applied Economic Research

Value added and Productivity Decompositions with Natural Capital

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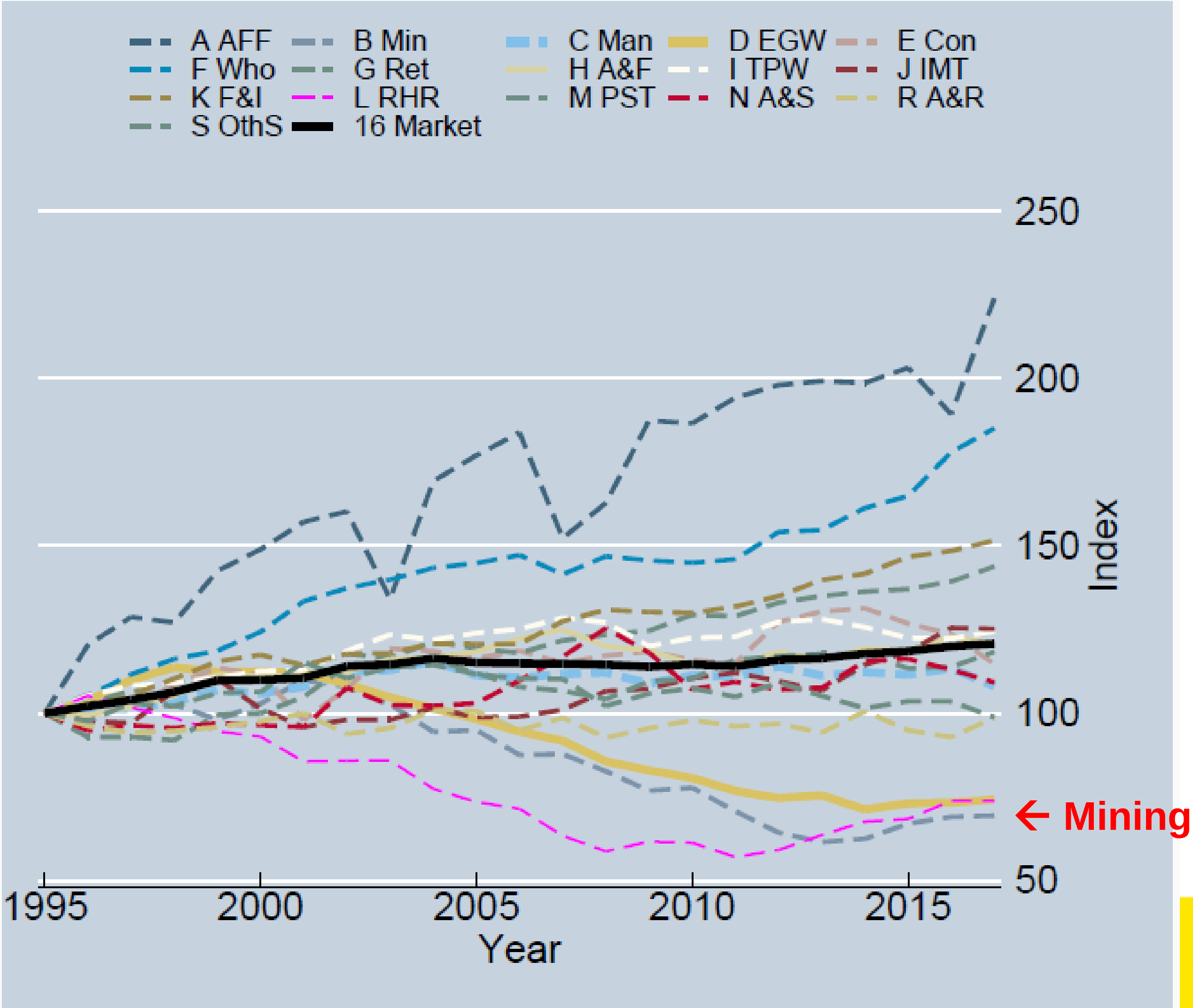
ABS MFP:


A AFF
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G Ret
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Summary

- **Decompose nominal value added growth for the Australian Mining Sector, taking into account natural capital, specifically, subsoil assets.**

- **Explanatory factors are**
  - **efficiency changes,**
  - **changes in output prices,**
  - **changes in primary inputs,**
  - **changes in input prices, and**
  - **technical progress**

Summary

- **Build on the work of Brandt, Schreyer and Zipperer (2017), Diewert and Fox (2016), Diewert and Fox (2018) and Zeng, Diewert and Fox (2018) and Hoang (2018).**

- **Use access to privileged data from the Australian Bureau of Statistics on subsoil assets.**

- **Consider impact of alternative valuation methods in deriving the capital services from such natural capital.**

- **Results provide insights into the drivers of value added and productivity growth.**

Value Added Decomposition

- **Need sector's best practice technology for the periods under consideration.**
- **Could use econometric or nonparametric (DEA) techniques**
- **Use a Free Disposal Hull approach – no convexity assumptions**
- **Our approach has the advantage that it does not involve econometric estimation, and involves only observable data.**
- **Simple enough to be implemented by national statistical offices**

Value Added Decomposition

- **A sector produces M net outputs, $y \equiv [y_1,\ldots,y_M]$, using N primary inputs $x \equiv [x_1,\ldots,x_N] \geq 0_N$.**

- **If $y_m > 0$, then the sector produces the m^{th} net output during period t while if $y_m < 0$, then the sector uses the m^{th} net output as an intermediate input.**

- **Strictly positive vector of net output prices $p \equiv [p_1,\ldots,p_M] \gg 0_M$ and strictly positive vector of input prices $w \equiv [w_1,\ldots,w_N] \gg 0_N$**

- ***Period t production possibilities set* for the sector S^t satisfies some (minimal) regularity conditions**

Value Added Decomposition

Period t cost constrained value added function:

$$R^t(p,w,x) \equiv \max_{y,z} \{p \cdot y : (y,z) \in S^t;\ w \cdot z \leq w \cdot x\}$$

If S^t is a cone, so that production is subject to constant returns to scale, Diewert-Fox show that

$$R^t(p,w,x) \equiv w \cdot x / c^t(w,p)$$

where $c^t(w,p)$ is the unit cost function for producing a unit of value added.

Value Added Decomposition

Observed value added, $p^t \cdot y^t$, may not equal the optimal value added.

Value added efficiency of the sector during period t:

$$e^t \equiv p^t \cdot y^t / R^t(p^t, w^t, x^t) \leq 1$$

Change in value added efficiency:

$$\varepsilon^t \equiv e^t / e^{t-1}$$

If $\varepsilon^t > 1$, value added efficiency has *improved, fallen* if $\varepsilon^t < 1$.

Value Added Decomposition

Family of *input quantity indexes*:

$$\beta(x^{t-1},x^t,w) \equiv w \cdot x^t / w \cdot x^{t-1}.$$

Laspeyres and Paasche type special cases:

$$\beta_L{}^t \equiv w^{t-1} \cdot x^t / w^{t-1} \cdot x^{t-1} \;;$$

$$\beta_P{}^t \equiv w^t \cdot x^t / w^t \cdot x^{t-1} \;.$$

Preferred overall measure of input quantity growth is the geometric average of the above two estimates of input growth (Fisher index):

$$\beta^t \equiv [\beta_L{}^t \, \beta_P{}^t]^{1/2}.$$

Value Added Decomposition

Family of *output price indexes*:

$$\alpha(p^{t-1},p^t,w,x,s) \equiv R^s(p^t,w,x)/R^s(p^{t-1},w,x).$$

Laspeyres and Paasche type special cases:

$\alpha_L{}^t \equiv R^{t-1}(p^t,w^{t-1},x^{t-1})/R^{t-1}(p^{t-1},w^{t-1},x^{t-1})$;

$\alpha_P{}^t \equiv R^t(p^t,w^t,x^t)/R^t(p^{t-1},w^t,x^t).$

Preferred overall measure of output price growth:

$\alpha^t \equiv [\alpha_L{}^t\,\alpha_P{}^t]^{1/2}$

Value Added Decomposition

Family of *input mix indexes*:

$$\gamma(w^{t-1},w^t,p,x,s) \equiv R^s(p,w^t,x)/R^s(p,w^{t-1},x)$$

Laspeyres and Paasche type special cases:

$$\gamma_{LPP}{}^t \equiv R^t(p^{t-1},w^t,x^t)/R^t(p^{t-1},w^{t-1},x^t);$$

$$\gamma_{PLL}{}^t \equiv R^{t-1}(p^t,w^t,x^{t-1})/R^{t-1}(p^t,w^{t-1},x^{t-1}).$$

Take the geometric average of the above two measures:

$$\gamma^t \equiv [\gamma_{LPP}{}^t\,\gamma_{PLL}{}^t]^{1/2}.$$

Value Added Decomposition

Family *of* *technical progress indexes*:

$$\tau(t-1,t,p,w,x) \equiv R^t(p,w,x)/R^{t-1}(p,w,x)$$

$$\tau_L{}^t \equiv R^t(p^{t-1},w^{t-1},x^t)/R^{t-1}(p^{t-1},w^{t-1},x^t).$$

$$\tau_P{}^t \equiv R^t(p^t,w^t,x^{t-1})/R^{t-1}(p^t,w^t,x^{t-1}).$$

For the cone case:

$\tau_L{}^t = c^{t-1}(w^{t-1},p^{t-1})/c^t(w^{t-1},p^{t-1})$ and $\tau_P{}^t = c^{t-1}(w^t,p^t)/c^t(w^t,p^t)$

(independent of x)

$$\tau^t \equiv [\tau_L{}^t\, \tau_P{}^t]^{1/2}.$$

Value Added Decomposition

With CRS, five factors that explain value added growth:

1. Change in cost constrained value added efficiency: $\varepsilon^t \equiv e^t/e^{t-1}$

2. Change in output prices: $\alpha(p^{t-1},p^t,w,x,s)$

3. Change in input quantities: $\beta(x^{t-1},x^t,w)$

4. Change in input prices: $\gamma(w^{t-1},w^t,p,x,s)$

5. Changes due to technical progress: $\tau(t-1,t,p,w,x)$

Value Added Growth: $p^t \cdot y^t/p^{t-1} \cdot y^{t-1} = \varepsilon^t\,\alpha^t\,\beta^t\,\gamma^t\,\delta^t\,\tau^t$

TFP Growth: $\{[p^t \cdot y^t/p^{t-1} \cdot y^{t-1}]/\alpha^t\}/\beta^t = \varepsilon^t\,\gamma^t\,\delta^t\,\tau^t$

Value Added Decomposition

Approximate the production unit's period t production possibilities **set S^t by the conical free disposal hull of the period t actual production vector and past production vectors.**

$R^t(p,w,x)$ can be estimated by solving a very simple one constraint linear programming problem:

$$R^t(p,w,x) \equiv \max_{\lambda} \{p\cdot(\Sigma_{s=1}^{t} y^s\lambda_s) \; ; \; w\cdot(\Sigma_{s=1}^{t} x^s\lambda_s) \le w\cdot x \; ; \; \lambda_1 \ge 0 ,\ldots, \lambda_t \ge 0\}$$

$$= w\cdot x/c^t(w,p)$$

where $c^t(w,p)$ is the *period t nonparametric unit cost function that corresponds to* $R^t(p,w,x)$.

Valuation of Natural Capital: Resource Rent Method

World Bank; Brandt, Schreyer & Zipperer 2017:

Unit rent:

$$u = p \cdot \alpha - w \cdot \beta$$

α = vector of final product amounts generated by 1 unit of resource

p = the corresponding market output price vector

β = a positive vector of input requirements for mining one unit

w = the corresponding market input price vector.

Valuation of Natural Capital: Residual Method

Used by Statistics Canada, one of the approaches recommended by the UN SEEA, when the resource rent can’t be directly calculated.

The resource rent is then:

Gross Operating Surplus less user cost of produced capital

Split GOS into returns on produced capital and returns on natural capital.

Effectively an indirect measure of resource rent.

Valuation of Natural Capital: Traditional User Cost

Similar to the approach used by NSOs in calculating capital services:

$$P^0[r - i + (1+i)\delta]$$

P^0 = beginning of the period price for a unit of the resource

r = one period opportunity cost of capital

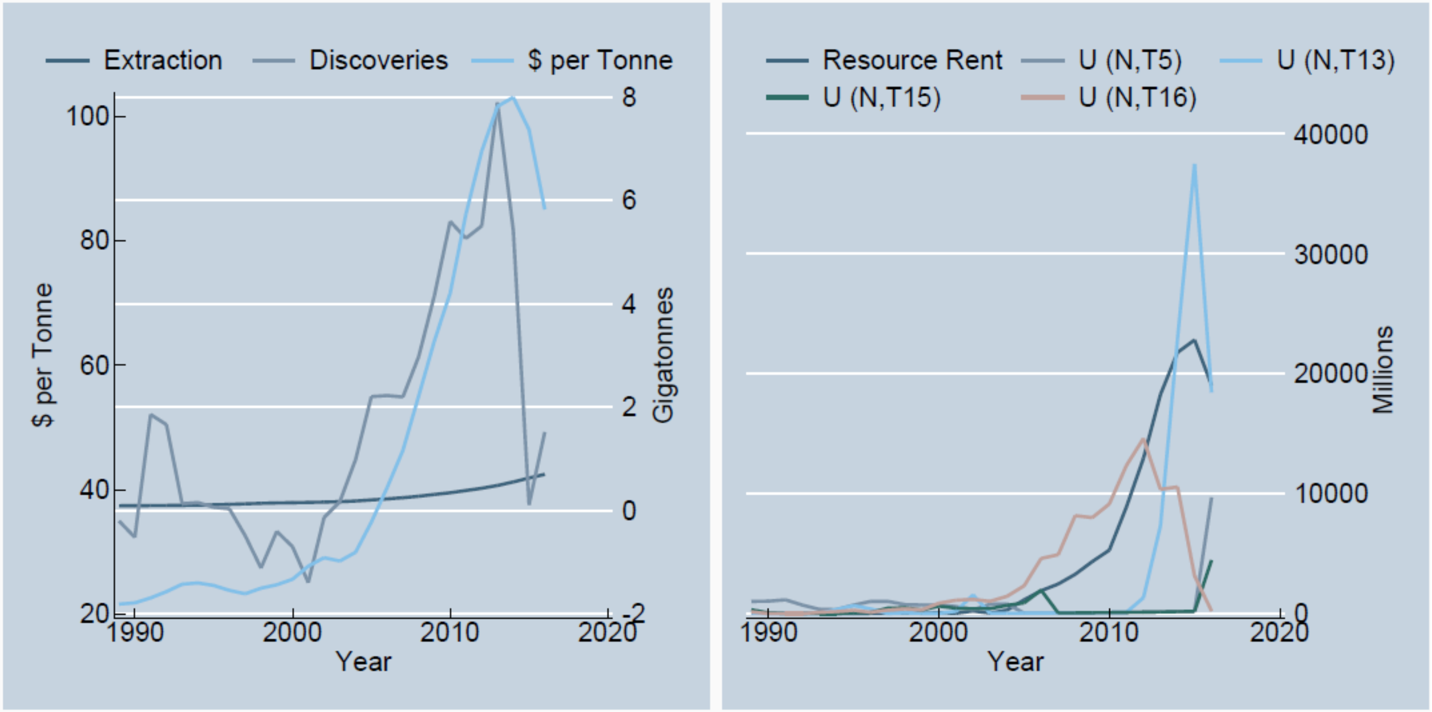
i = inflation rate for a unit of the resource

δ = depletion rate (rather than the usual depreciation rate)

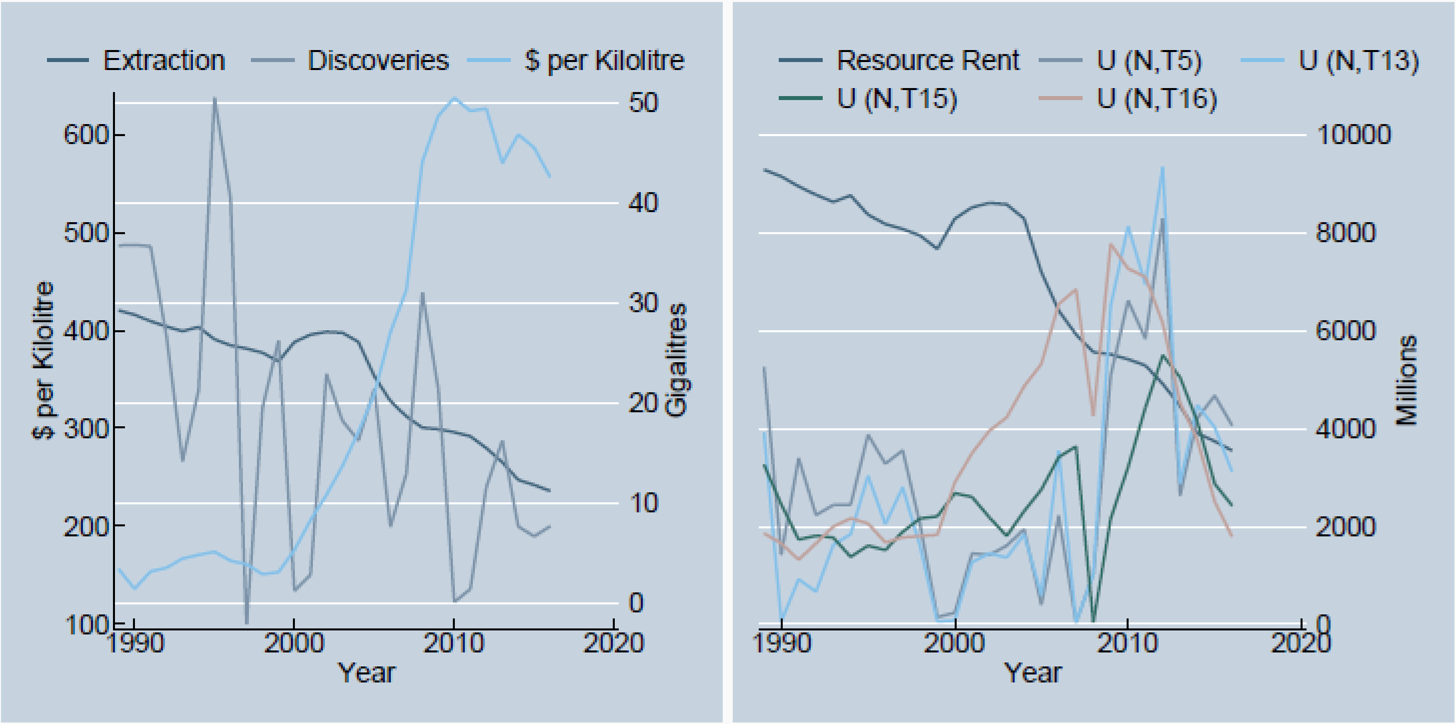
Valuation of Natural Capital: Traditional User Cost, Choices!

Model	Natural Capital r_N	i_N	π_N	Produced Capital r_K
U_N^{T1}	RBA Business Loan rate	Price deflater	Yes	RBA cash rate
U_N^{T2}	RBA Business Loan rate	Exponential smoothing	Yes	RBA cash rate
U_N^{T3}	RBA Business Loan rate	Geometric smoothing	Yes	RBA cash rate
U_N^{T4}	RBA Business Loan rate	Price deflater	No	RBA cash rate
U_N^{T5}	RBA cash rate	Price deflater	Yes	RBA cash rate
U_N^{T6}	RBA cash rate	Exponential smoothing	Yes	RBA cash rate
U_N^{T7}	RBA cash rate	Geometric smoothing	Yes	RBA cash rate
U_N^{T8}	RBA cash rate	Price deflater	No	RBA cash rate
U_N^{T9}	K Endogenous rate	Price deflater	Yes	RBA cash rate
U_N^{T10}	K Endogenous rate	Exponential smoothing	Yes	RBA cash rate
U_N^{T11}	K Endogenous rate	Geometric smoothing	Yes	RBA cash rate
U_N^{T12}	K Endogenous rate	Price deflater	No	RBA cash rate
U_N^{T13}	K and N Endogenous rate	Price deflater	Yes	K and N Endogenous rate
U_N^{T14}	K and N Endogenous rate	Exponential smoothing	Yes	K and N Endogenous rate
U_N^{T15}	K and N Endogenous rate	Geometric smoothing	Yes	K and N Endogenous rate
U_N^{T16}	K and N Endogenous rate	Price deflater	No	K and N Endogenous rate

Iron Ore: Extraction, Discoveries, Price and User Cost Values



Crude Oil: Extraction, Discoveries, Price and User Cost Values



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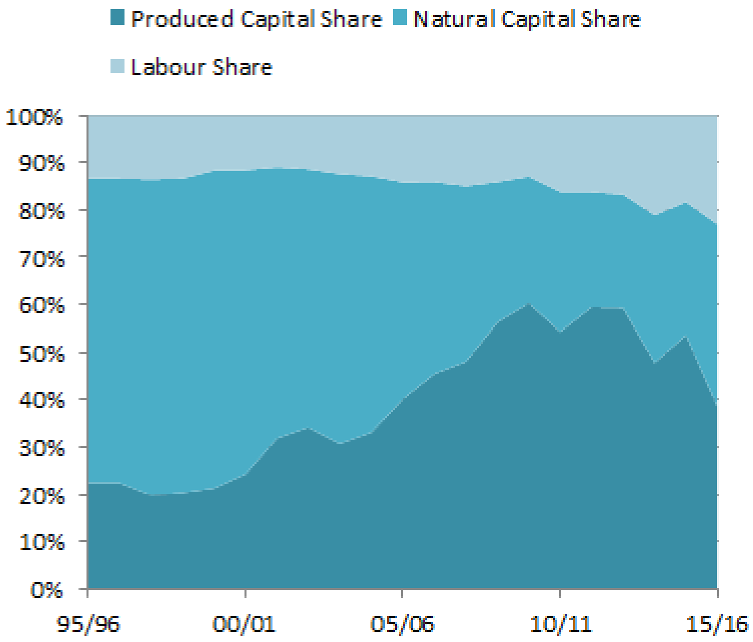
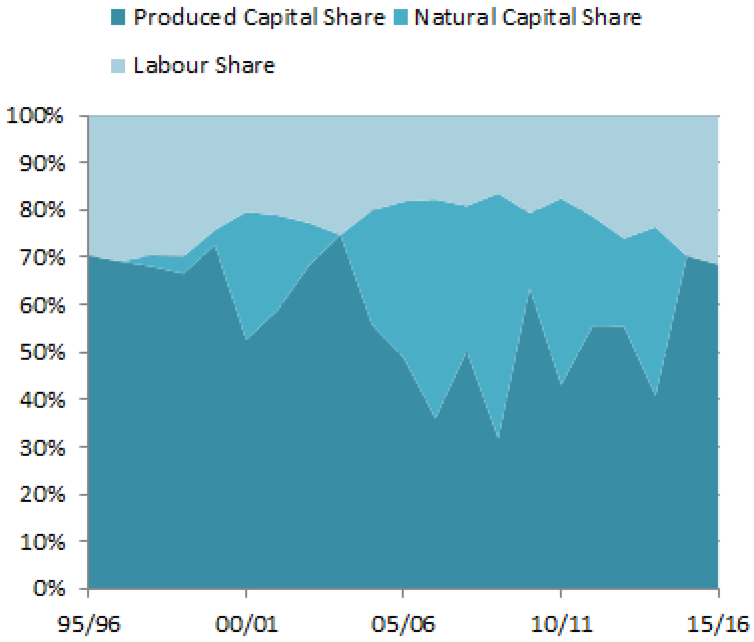
Factor Cost Shares

(a) Resource Rent

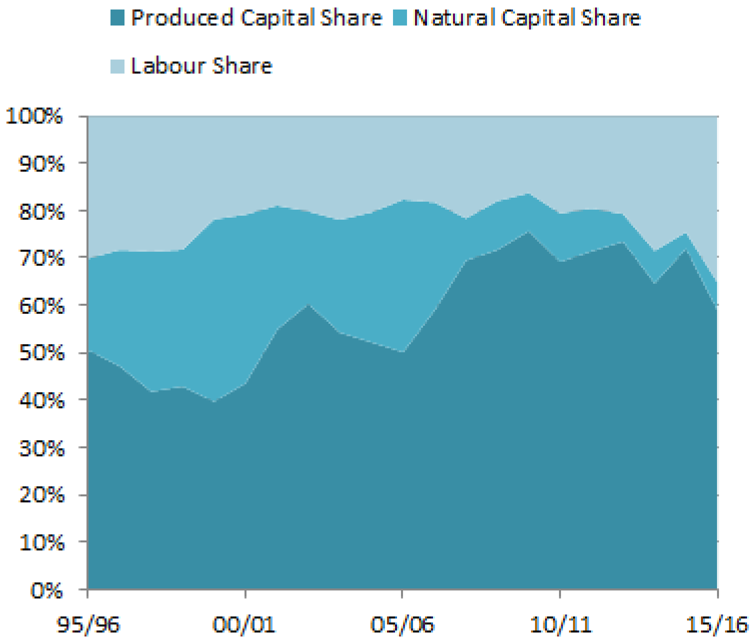


(b) Residual Method

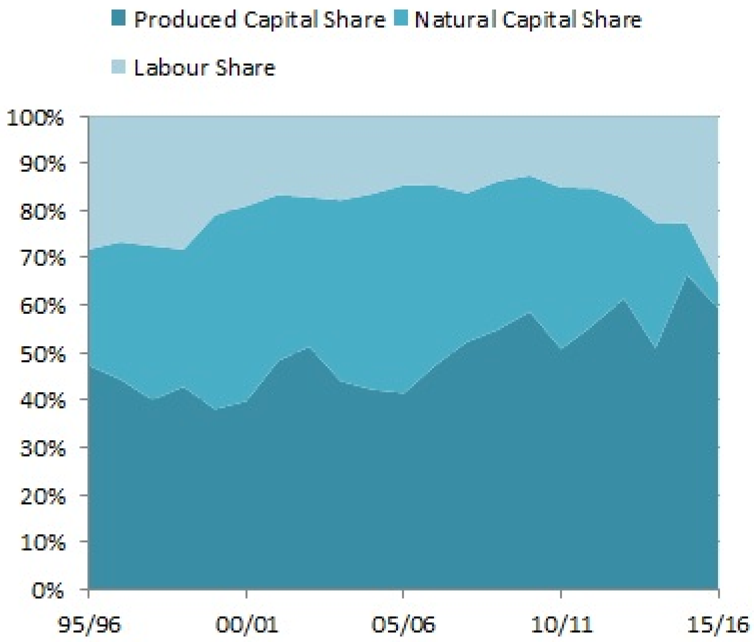


Factor Cost Shares: User Cost

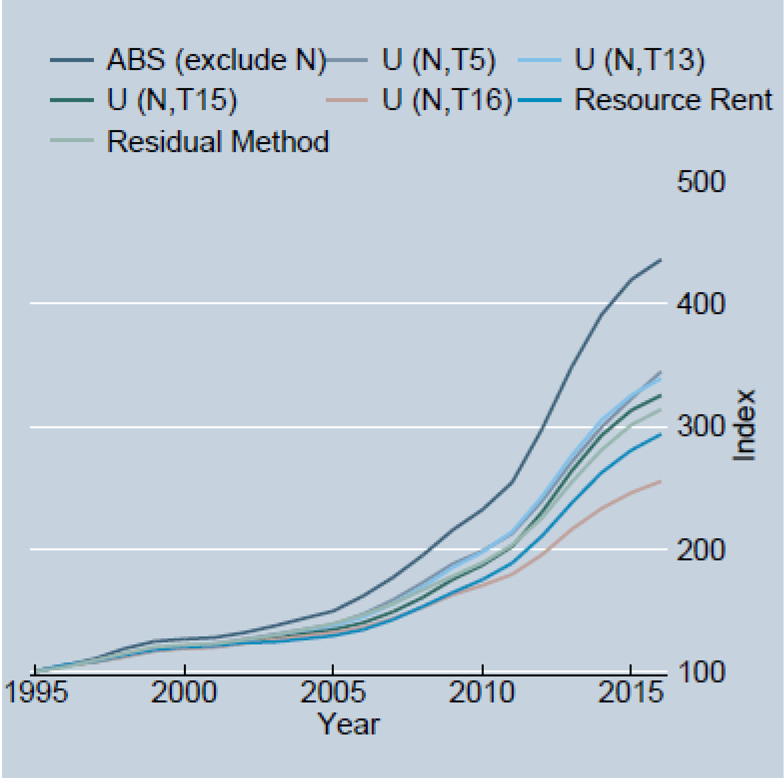
(a) Diewert-Fox Method, U(15)



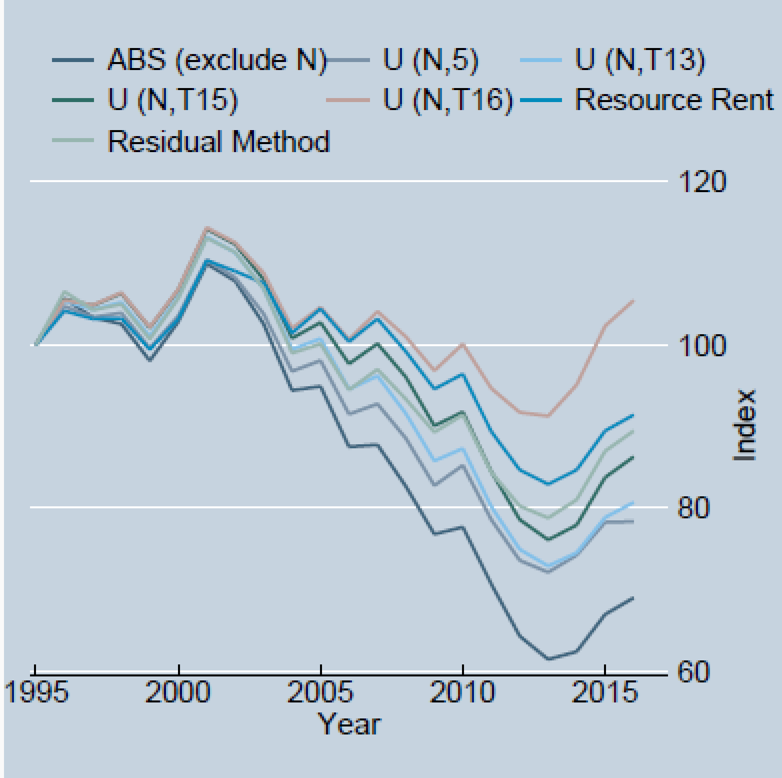
(b) No Capital Gains, U(16)



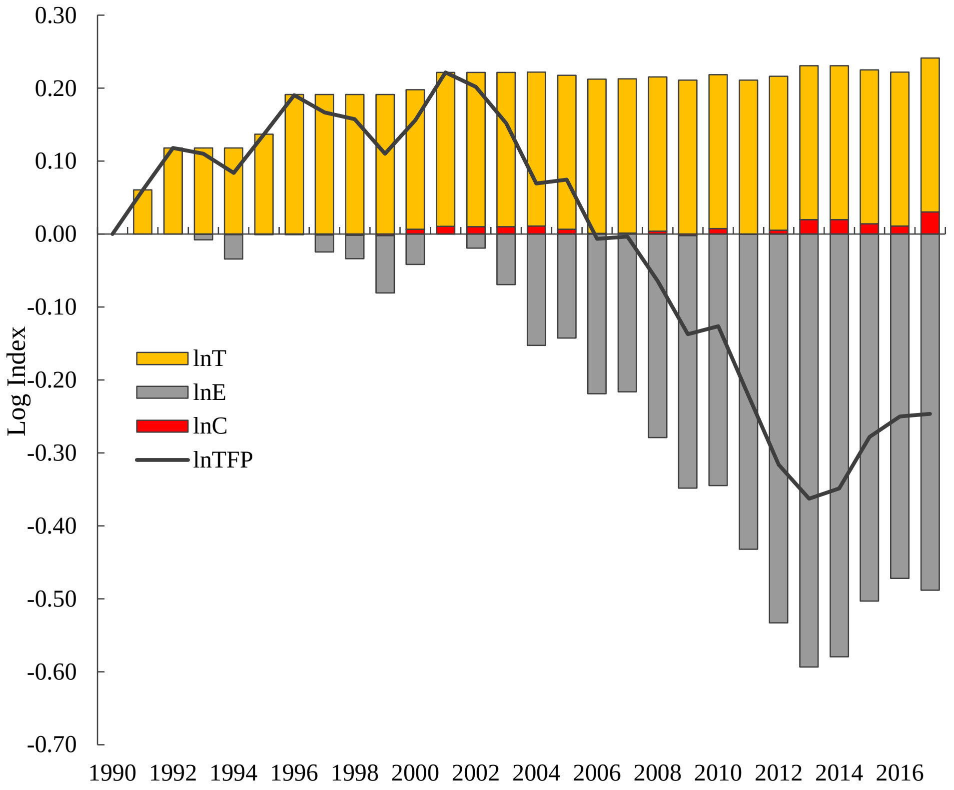
(a) Capital Services



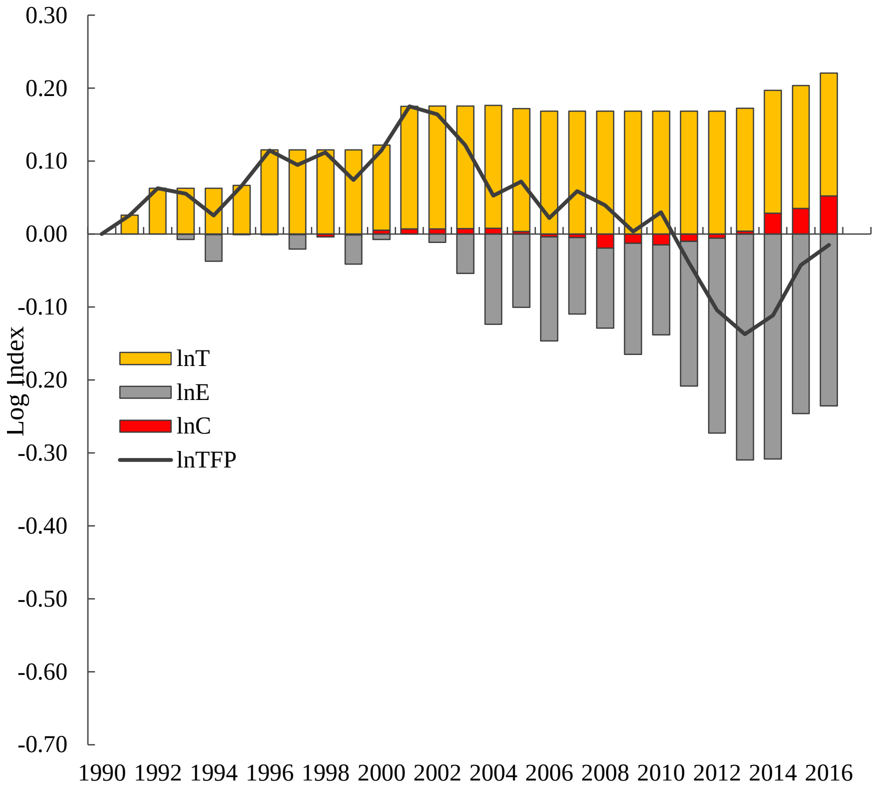
(b) Multifactor Productivity



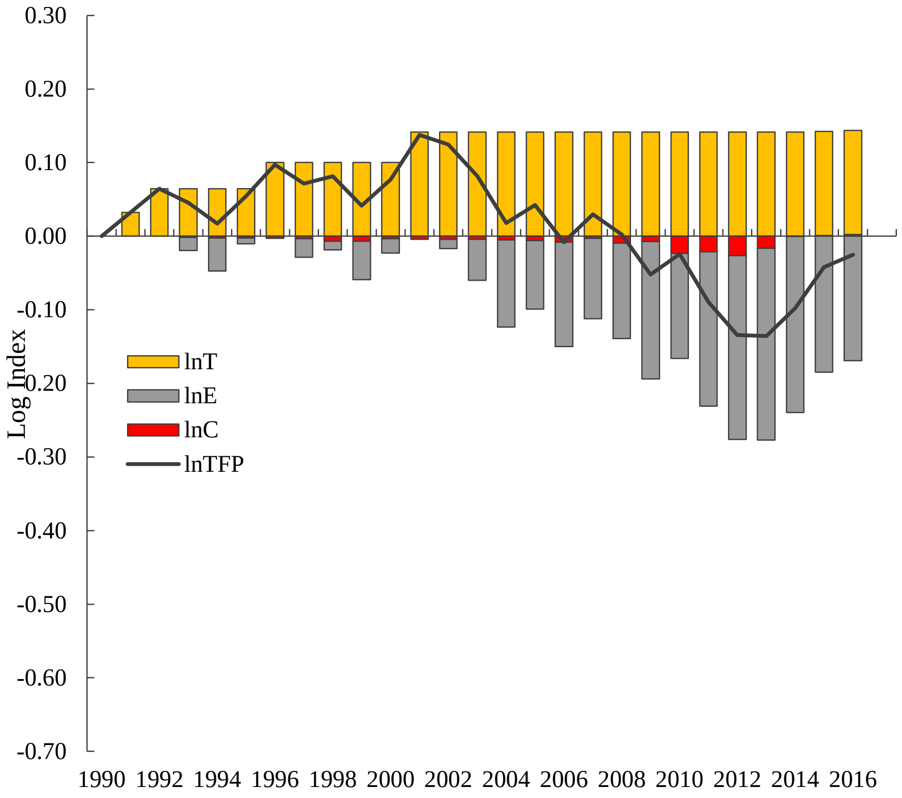
(a) Without Natural Capital: ABS



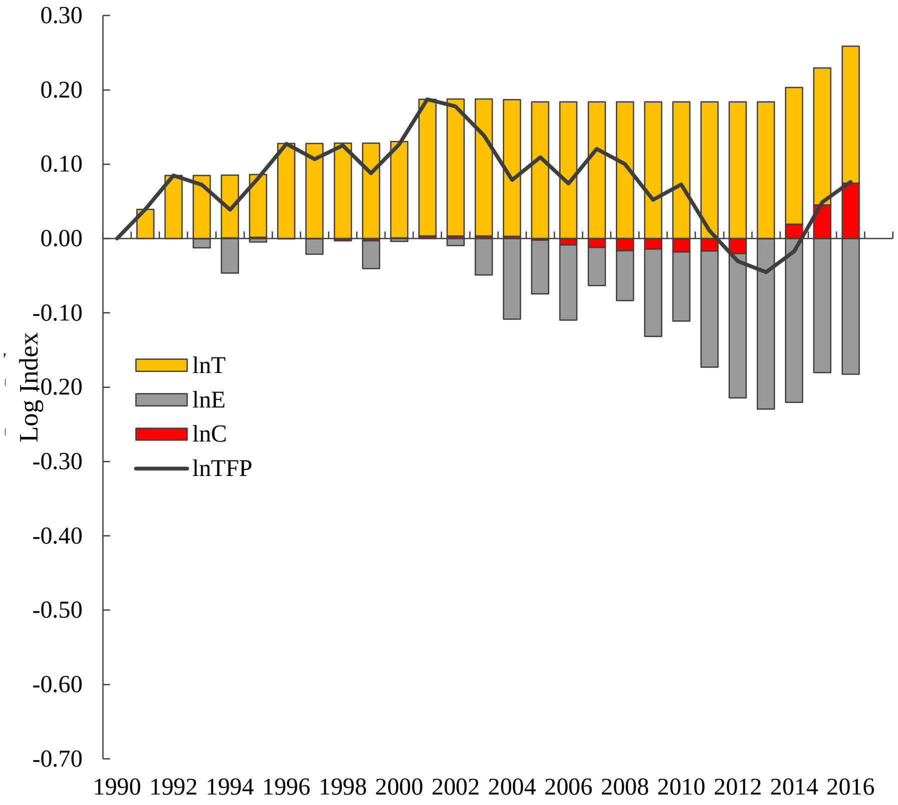
(b) With Natural Capital: DF Method, U15



(c) Resource Rent Method
(Residual Method Almost Identical)



(d) No Capital Gains: U16



Conclusions

- Have used an innovative decomposition of value added.
- Looked at the impact on productivity and its sources from the introduction of natural capital.
- Considered alternative valuation methods for natural capital.
- Differing results can be found depending on the valuation method, but the key thing is to include natural capital.
- The role of inefficiency highlighted, rather than negative TFP growth indicating technical regress.
- Methods are easily implementable by NSOs.