UNSW Business School
Centre for Applied Economic Research

Natural Resources and Ecosystem Services in Productivity Measurement

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Montréal Environment and Resource Economics Workshop
McGill University
12 May 2017

What has Kevin been doing at UBC?

- **“ET Interview: Professor W. Erwin Diewert,” *Econometric Theory*, forthcoming.**

- **“Output Growth and Inflation across Space and Time,” *EURONA* – Eurostat review on National Accounts and Macroeconomic Indicators, forthcoming, with W.E. Diewert.**

- **“The Contribution of Research and Innovation to Productivity,” *Journal of Productivity Analysis*, forthcoming, with A. Elnasri.**

- **“Decomposing Value Added Growth into Explanatory Factors,” in E. Grifell-Tatje, C.A.K. Lovell and R. Sickles (eds.), *The Oxford Handbook of Productivity Analysis*, Oxford University Press, with W.E. Diewert, forthcoming.**

What has Kevin been doing at UBC?

- **"Efficiency Analysis in Uncertain Operating Environments: The Problem with Outliers," in T. Ancev, M.A.S. Azad and F. Hernandez (eds.), *New Directions in Productivity Measurement and Efficiency Analysis: Counting the Environment and Natural Resources*, Edward Elgar, June 2017, with Lisa Y.T. Lee.**

- **"Alternative User Costs, Productivity and Inequality: US Nonfinancial Corporate and Noncorporate Business Sectors, 1960-2014," in Greene, Khalaf, Makdissi, Sickles, and Voia (eds.), *Productivity and Inequality*, Springer, forthcoming, with W.E. Diewert.**

What has Kevin been doing at UBC?

- **“Substitution Bias in Multilateral Methods for CPI Construction using Scanner Data,” with W.E. Diewert.**
- **“Consumer Benefits of Infrastructure Services,” with C. Schwartz and W.E. Diewert, R&R *J. of Urban Economics***
- **“The Allocation and Valuation of Time,” with W.E. Diewert and P. Schreyer**
- **“The Digital Economy, GDP and Consumer Welfare,” with W.E. Diewert (to be presented at the NBER Summer Institute, July 2017).**
- **“Money and the Measurement of Total Factor Productivity,” with W.E. Diewert (to be presented at the Bank of England Conference “Financial Services Indices, Liquidity and Economic Activity,” May 2017**

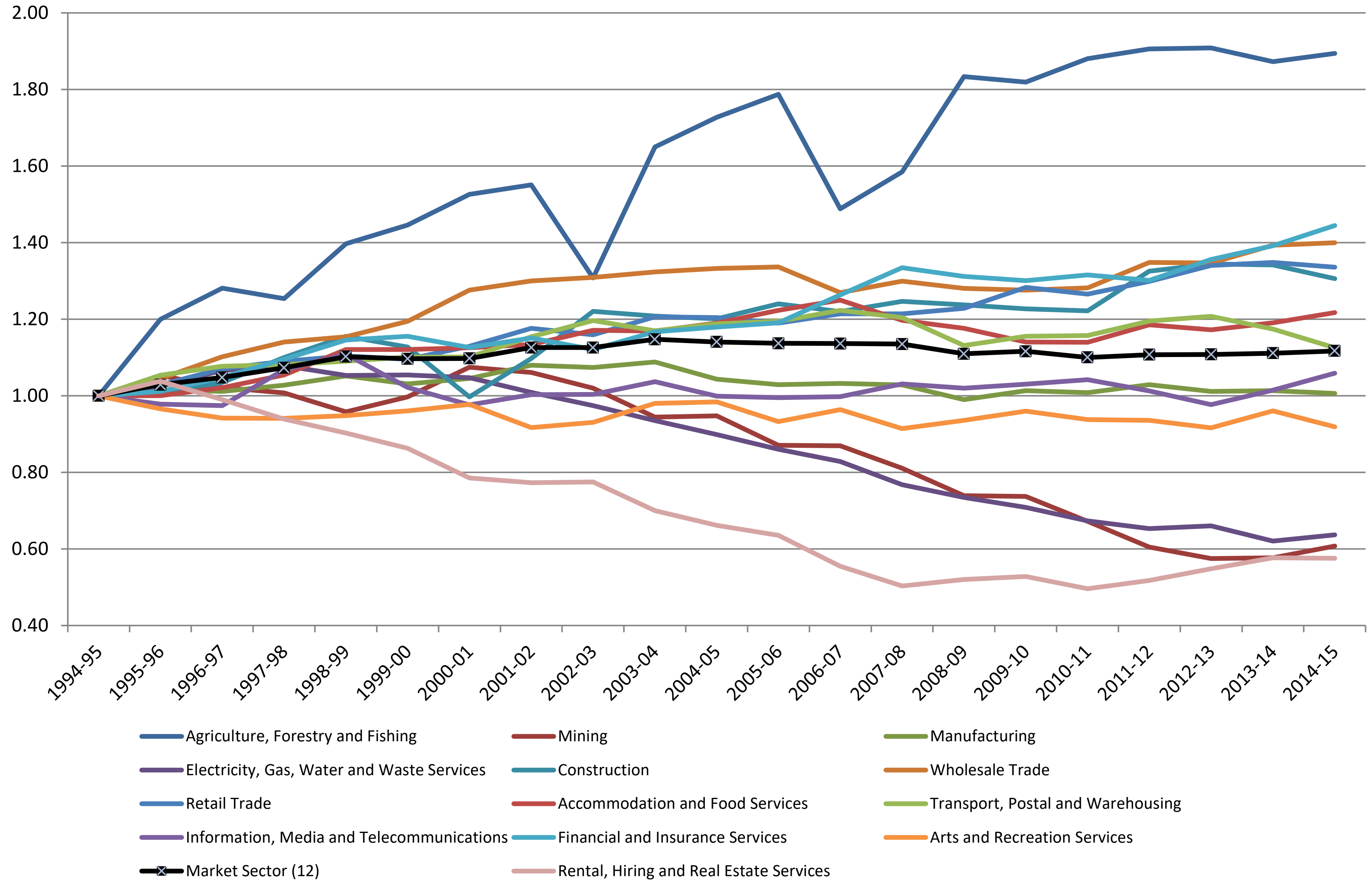
Outline

Some Progress in Accounting for the Environment

Natural Resources and Ecosystem Services in Productivity Measurement

The User Cost of Nonrenewable Resources and Green Accounting

Progress in Accounting for the Environment



Progress in Accounting for the Environment

- **Australia: Agriculture, Forestry and Fishing sector has been the star productivity performer productivity improved by almost 90 percent from 1989-90 to 2013-14.**

- **Aggregate Market Sector productivity, increased by only 18 percent over the same period.**

- **Key environmental inputs, such as water and soil quality are not measured as part of the input index, nor are broader contributions of ecosystem services from the environment.**

- **There also remain significant problems in measuring land (even unadjusted for quality), which is a fundamental input into agricultural productivity.**

Progress in Accounting for the Environment

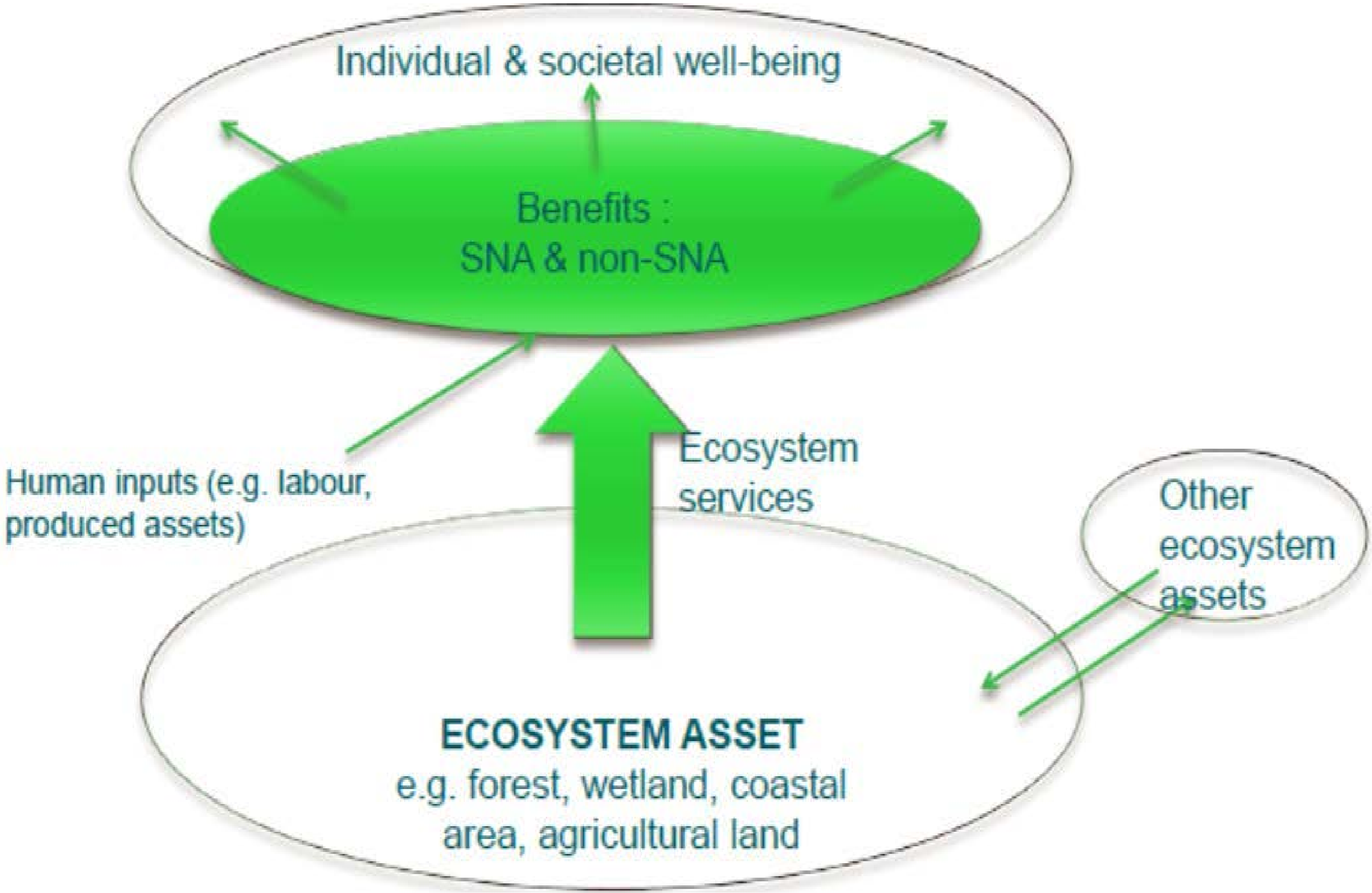
- **System of Environmental-Economic Accounting (SEEA) (UN 2014a and 2014b)**
  - **Central Framework**
  - **Experimental Ecosystem Accounting**

- **Explicit measurement of the service flows from ecosystem assets into production, consistent with the System of National Accounts (SNA), as well as measuring broader societal benefits from ecosystems.**

- **More accurately captures the role of ecosystems in economic activity, allowing an evaluation of the sustainability of economic growth through more complete statistics that can better inform public policy at both national and regional levels.**

- **Following figure from Obst, C. (2015), "Completing the Picture: Bringing Ecosystem Services into MFP," presented to the Economic Measurement Group Workshop, UNSW, 4 December 2015.**

Progress in Accounting for the Environment



Progress in Accounting for the Environment

World Bank (2011), *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium*, The World Bank, Washington, USA.

UN/EU/FAO/OECD/World Bank (2014a), *System of Environmental-Economic Accounting: Central Framework*, United Nations, New York.

UN/EU/FAO/OECD/World Bank (2014b), *System of Environmental-Economic Accounting: Experimental Ecosystem Accounting*, United Nations, New York.

Schreyer, P. and C. Obst (2015) "Towards complete balance sheets in the national accounts: The case of mineral and energy resources", OECD Green Growth Papers 2015/02

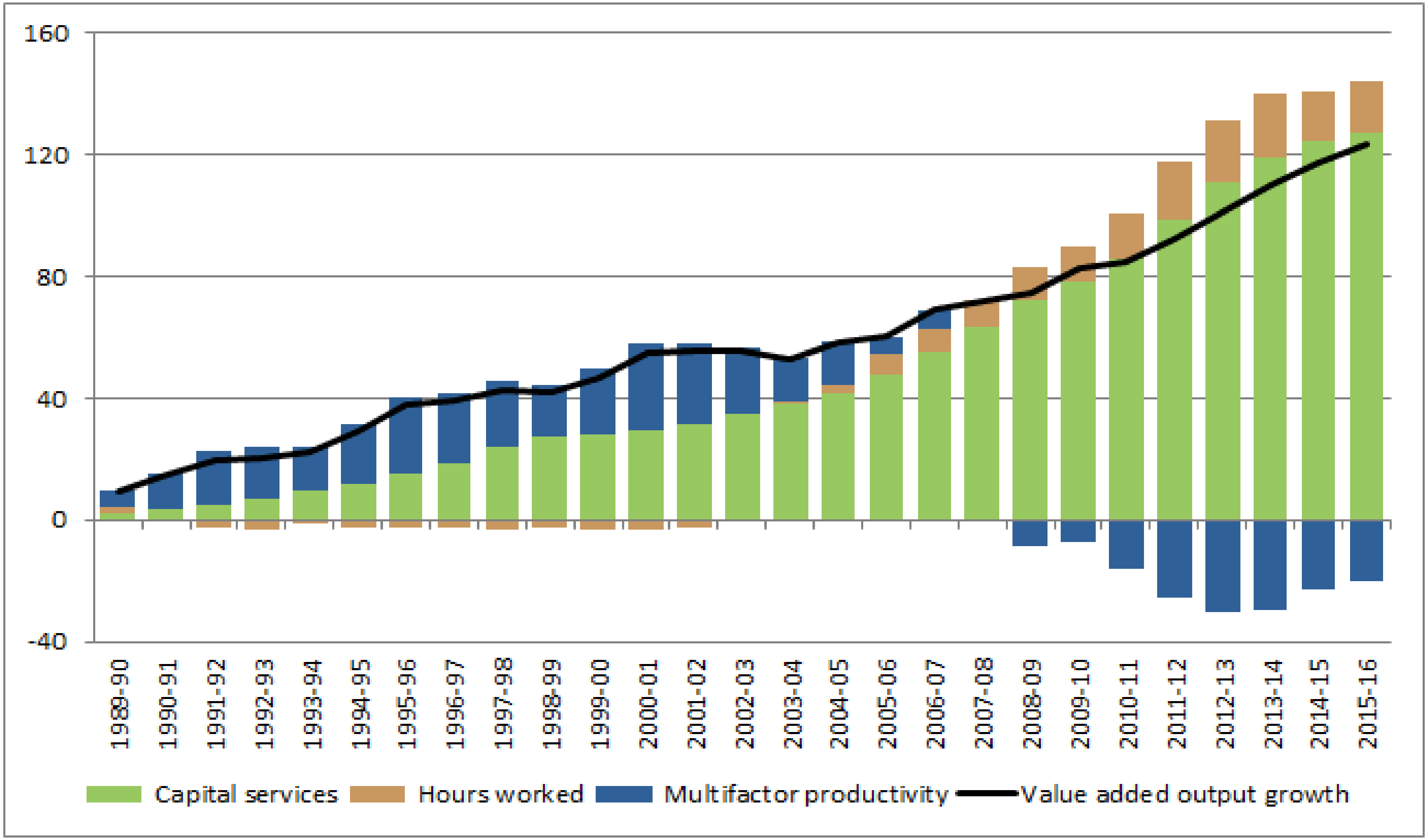
Outline

Some Progress in Accounting for the Environment

Natural Resources and Ecosystem Services in Productivity Measurement

The User Cost of Nonrenewable Resources and Green Accounting

Australia: Cumulative Contributions to Value Added Output Growth - Mining



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Mining: ABS Standard and Experimental MFP

Experimental series includes mineral and energy resources

Natural Resources and Productivity Measurement

Brandt, N., P. Schreyer and V. Zipperer (2017), "Productivity Measurement with Natural Capital," ***Review of Income and Wealth*** **63, Supplement 1, S7-S21.**

- **Proposed a measurement framework that explicitly accounts for the role of natural capital in productivity measurement.**
- **OECD Productivity Database combined with World Bank natural capital data – subsoil assets only.**
- **Direction of the adjustment to productivity growth depends on rate of change of natural capital extraction *relative* to the rate of change of other inputs.**

Natural Resources and Productivity Measurement

TABLE 2

AVERAGE PRODUCTIVITY GROWTH PER YEAR, WITH AND WITHOUT NATURAL CAPITAL BASED ON DATA FROM THE OECD PRODUCTIVITY DATABASE, 1986–2008[1]

Country	Traditional MFP growth in %	MFP growth with natural resources in %	Difference in percentage points	Traditional inputs growth in %	Natural capital growth in%	Share of resource rent in total cost in %
AUS	0.92	0.88	−0.04	2.41	4.14	4.35
AUT	1.43	1.44	0.00	1.14	0.19	0.21
BEL	1.32	1.32	0.00	0.99	−20.00	0.00
CAN	0.38	0.42	0.04	2.26	1.51	3.97
CHE	0.06	0.06	0.00	1.42	−6.96	0.00
DEU	1.10	1.11	0.01	0.38	−1.00	0.19
DNK	0.75	0.72	−0.03	1.27	7.91	2.25
ESP	0.35	0.35	0.01	2.87	−10.52	0.06
FIN	2.07	2.07	−0.01	0.54	6.88	0.07
FRA	1.06	1.06	0.00	1.03	−6.15	0.05
GBR	1.26	1.33	0.08	1.43	−1.20	2.09
IRL	2.84	2.86	0.02	2.40	−7.05	0.34
ITA	0.45	0.45	0.00	1.20	0.19	0.21
JPN	1.46	1.46	0.00	0.53	0.63	0.02
KOR	3.93	3.93	0.00	2.47	−6.54	0.05
NLD	0.95	1.00	0.05	1.85	−0.69	1.83
NOR	1.18	1.02	−0.16	1.46	4.97	16.77
NZL	0.68	0.66	−0.02	1.78	2.11	1.41
PRT	1.29	1.29	0.00	1.17	−3.31	0.01
SWE	1.03	1.03	0.00	1.26	0.08	0.23
USA	1.03	1.05	0.02	1.84	−0.99	1.09

[1]1996–2007 for Austria, 1986–2004 for Belgium, 1991–2008 for Switzerland, 1992–2008 for Germany, 1986–2007 for the Netherlands, Denmark, U.K., and 1996–2005 for Portugal.

Natural Resources and Productivity Measurement

Australian Research Council Grant

"Natural Resources and Ecosystem Services in Productivity Measurement" Kevin Fox (UNSW), Quentin Grafton (ANU), Carl Obst (U. Melbourne) and Erwin Diewert (UBC and UNSW)

Funding for three years from 1 January 2017: $320,000

The two themes to be addressed are as follows:

1. **Valuation of Non-renewable Resources and Ecosystem Services**

2. **Accounting for Natural Resource Depletion and Ecosystem Services in Productivity Measurement**

Outline

Some Progress in Accounting for the Environment

Natural Resources and Ecosystem Services in Productivity Measurement

The User Cost of Nonrenewable Resources and Green Accounting

The User Cost of Nonrenewable Resources and Green Accounting: Diewert and Fox (2016)

- **Derive and compare two alternative user cost, or "depletion rent" approaches in the context of non-renewable resources:**
    - **taking unit rent as user cost**
    - **and traditional user cost.**

- **Show that while they seem quite different, they coincide when beginning of period expectations are realized.**

- **Practical considerations lead us to recommend the traditional user cost approach.**

- **Motivated by the unit rent approach used by Brandt, Schreyer and Zipperer (2016) and the World Bank (2011).**

Unit Rent

- **Without loss of generality, we consider the non-renewable resource to be a body of ore.**

- **Let V^0 and V^1 denote the market value of an ore body at the beginning and end of period 1.**

- **P^t is the price of one unit of ore at the beginning of period t and S^t is the corresponding stock of the ore body:**

$$V^t = P^t S^t \; ; \qquad t = 0,1.$$

Unit Rent

- **If expectations about revenues and the price of ore at the end of the period are realized, and if R^1 is the net revenue generated by selling mined ore during period 1, then:**

$$V^0 = (1+r)^{-1} R^1 + (1+r)^{-1} V^1.$$

- **Depletion of the ore body during period 1, D^1, is defined as the difference between the starting stock of ore and the finishing stock of ore:**

$$D^1 \equiv S^0 - S^1 \geq 0.$$

Unit Rent

The *total cash flow generated by mining D^1 units of ore during period 1* is:

$$R^1 \equiv [p^1 \cdot \alpha - w^1 \cdot \beta] D^1 = u^1 D^1,$$

where α is a positive *vector of ore final product amounts* generated by mining one unit of ore, and β is a positive *vector of input requirements* for mining one unit of ore. p^1 and w^1 are the corresponding market price vectors.

$$u^1 \equiv p^1 \cdot \alpha - w^1 \cdot \beta > 0$$

is the unit rent, or the *Brandt, Schreyer and Zipperer user cost of mining one unit of the ore body during period 1.*

User Cost

Applying the Hicks (1939) and Diewert (1974) (2005) user cost methodology leads to the (end of) period 1 *user cost value of the ore body*:

$$UCV^1 \equiv (1+r)V^0 - V^1$$
$$= (1+r)[\,(1+r)^{-1} R^1 + (1+r)^{-1} V^1] - V^1$$
$$= R^1$$
$$= u^1 D^1$$
$$= u^1 [S^0 - S^1]$$

Which is a simple derivation of the Brandt, Schreyer and Zipperer user cost for a non renewable resource stock.

User Cost

- **Framework can be implemented for each mine where we can collect the opening and closing stocks for the ore body, S^0 and S^1 and the net revenues generated by extracting the ore during the period, R^1.**

- **Then u^1 can be estimated as $R^1/[S^0 - S^1]$.**

- **The mine's vectors of period 1 outputs y^1 and non-ore inputs x^1 can be defined as follows:**

  $y^1 \equiv \alpha[S^0 - S^1]$ and the companion price vector is p^1 ;

  $x^1 \equiv \beta[S^0 - S^1]$ and the companion price vector is w^1.

- **Conversely, if y^1 and x^1 are known along with S^0 and S^1, then can back out α and β.**

Traditional User Cost

Period 1 *inflation rate for the price of a unit of the ore body*:

$$1+i \equiv P^1/P^0$$

where P^0 is the beginning of the period price of ore and P^1 is the end of period price of ore.

Period 1 *depletion rate* for the ore body, δ:

$$1-\delta \equiv S^1/S^0,$$

where S^0 is the beginning of the period stock of ore and S^1 is the end of period stock.

Traditional User Cost

Substitute these expressions into the user cost value for the ore body:

$$\begin{aligned} UCV^1 &\equiv V^0(1+r) - V^1 \\ &= P^0S^0(1+r) - P^1S^1 \\ &= P^0S^0(1+r) - P^0(1+i)(1-\delta)S^0 \\ &= P^0[(1+r) - (1+i)(1-\delta)]S^0 \\ &= P^0[r - i + (1+i)\delta]S^0, \end{aligned}$$

$P^0[r - i + (1+i)\delta]$ can be recognized as the *traditional user cost of capital*

(except that δ represents a depletion rate rather than a wear and tear depreciation rate).

Comparison

So we have the following user cost value expressions:

$$UCV^1 = [p^1 \cdot \alpha - w^1 \cdot \beta]\,[S^0 - S^1]$$

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

Look entirely different, but under the assumption that expectations formed at the *beginning* of period 1 are actually realized at the *end* of period 1, the two formulae are equal to each other!

Dividing both these equations of user cost value by resource depletion provides another justification for using unit rents as user costs; unit rents are equal to traditional user costs if expectations are realized.

Comparison

We favour the traditional user cost for two reasons:

<u>Reason 1</u>

- **Unit rent approach is only valid if expectations about R^1 and V^1 formed at the beginning of the period turn out to be realized at the end of the period.**
- **It is extremely unlikely that this assumption will hold.**
- **The traditional user cost approach does not require this assumption. (But need expected values for δ and i, as in the usual formula for the user cost of reproducible capital.)**

Comparison

Reason 2

- **Recall the traditional user cost value equation: $P^0[r - i + (1+i)\delta]\ S^0$**
  Unit rent approach cannot be decomposed into the sum of:
  - **waiting services (rP^0S^0),**
  - **revaluation ($- iP^0S^0$)**
  - **and depletion terms ($[1+i]\delta P^0S^0$).**

- **It is useful to be able to make this decomposition if we want to measure net output or income, as may be desired in green accounting contexts.**

- **It is of interest to examine these alternative concepts in the context of defining income in the context of resource depletion and to contrast the physical and real financial maintenance of capital concepts due to Hayek (1941) and Pigou (1941) respectively.**

Alternative Income Concepts

Income Concept	Net Income Definition	User Cost Value
Gross Income (GDP)	Value Added	$(rP^0 - iP^0 + \delta P^1)S^0$
Income A	Value Added - $\delta P^1 S^0$	$(rP^0 - iP^0)S^0$
Income B	Value Added - $\delta P^1 S^0 + iP^0 S^0$	$(rP^0)S^0$

Alternative Income Concepts

- **Income A results from the subtraction of the value of environmental depletion from Value Added to get a measure of net income. That is, income net of the value of natural resources exhausted in producing consumption goods.**

- **This accounts for the fact that national wealth has been diminished through economic activity impacting on environmental resources.**

- **Such an adjustment is consistent with the recommended approach of the UN System of Environmental-Economic Accounting (UN 2014, p. xii).**

- **This is consistent with the maintenance of physical capital concept of Pigou (1941).**

Alternative Income Concepts

- **An alternative is to also subtract the revaluation term from Value Added. This results in Income B.**

- **This takes into account that a revaluation of the environmental resource can impact on wealth, due to e.g. increased information on resource degradation or exogenous shocks such as a fall in demand for ore.**

- **That is, by holding the environmental asset a financial cost is incurred and the fall in value should be reflected in the (net) income earned for the period.**

- **This view is consistent with the real financial maintenance of capital concept advocated by Hayek (1941).**

Alternative Income Concepts

Income Concept	Net Income Definition	User Cost Value
Gross Income (GDP)	Value Added	$(rP^0 - iP^0 + \delta P^1)S^0$
Income A	Value Added - $\delta P^1 S^0$	$(rP^0 - iP^0)S^0$
Income B	Value Added - $\delta P^1 S^0 + iP^0 S^0$	$(rP^0)S^0$

Alternative Income Concepts

- **In the usual case of a produced asset, the asset-specific inflation rate, i, will normally be negative due to, for example, foreseen obsolescence, so Gross Income > Income A > Income B.**

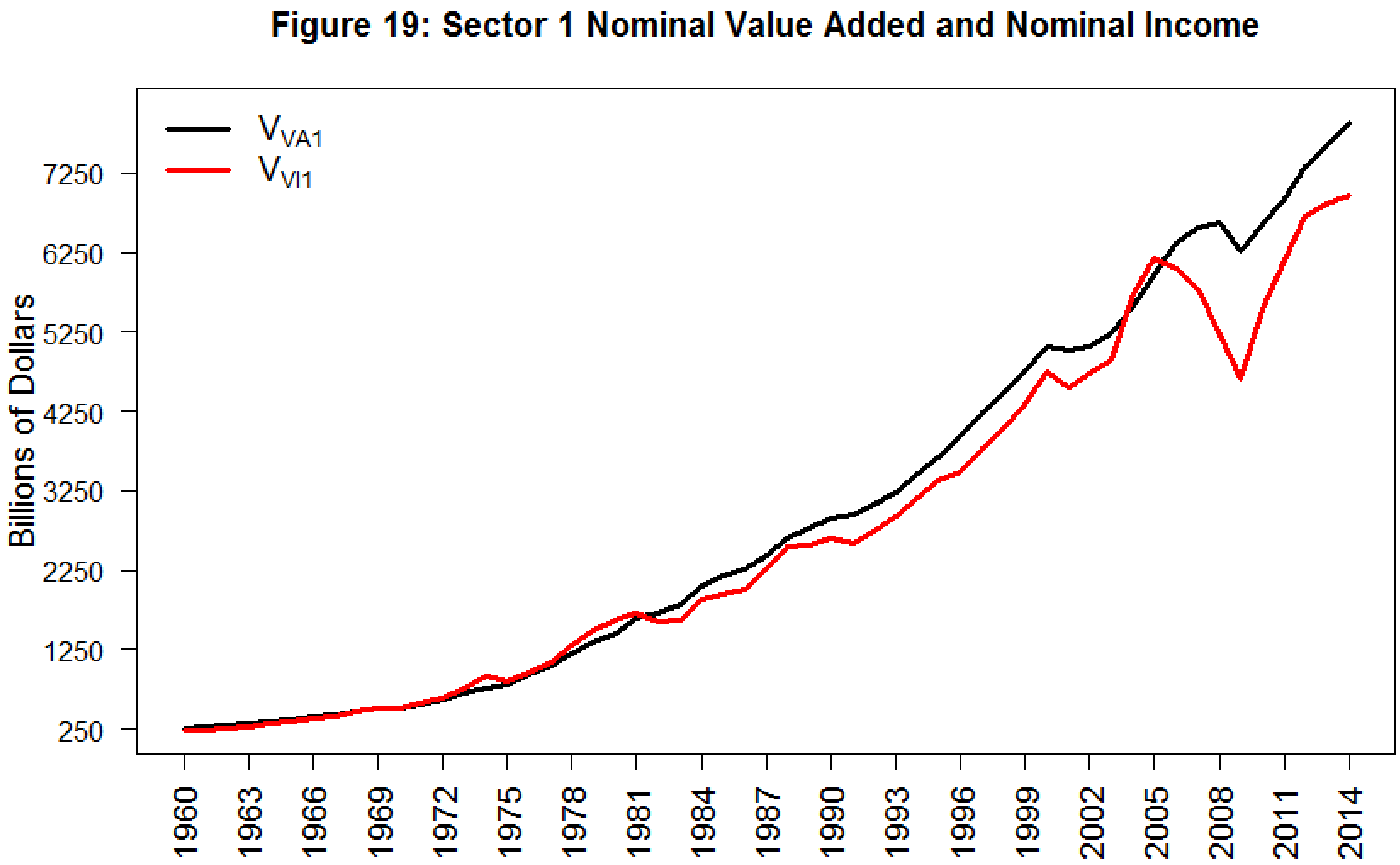
- **For a natural resource asset, scarcity and macroeconomic conditions driving international demand may cause i to be positive so that Income B may become larger than Gross Income.**

- **Alternatively, technological advances and degradation of the resource may cause i to fall in a similar manner to produced capital.**

- **Hayek (1941) argued that Income A would overstate income in any period due to not accounting for (foreseen, produced-asset) obsolescence.**

- **This argument appears to have merit in the natural resources context as well as the produced asset context.**

US Nonfinancial Corporate Sector



US Nonfinancial Corporate Sector

Figure 20: Sector 1 Labour and Capital Shares of Value Added and Income