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Antipodean agricultural and resource economics at 60: environmental economics*

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Environmental economics has been an increasingly significant focus for AARES and its members. Significant contributions began in the 1960s and 1970s with conceptual insights into the causes for market failure and the design of appropriate policy responses. The practical orientation of the profession led to the development and application of analytical tools in a wide array of contexts. Prominent amongst these have been nonmarket valuation, market-based policy instruments and the private sector provision of environmental protection. Interaction with natural and social scientists has been a feature. Cross-fertilisation has resulted to define emergent fields such as behavioural economics and ecological economics. Multidisciplinary endeavours have also grown in areas such as ecosystem service provision and integrated assessment modelling. These areas are likely to expand further with the ongoing contribution of core elements of the economics discipline.

Key words: market failure, market-based instruments, multidisciplinary, nonmarket valuation, policy.

1. Introduction

1.1 An historical perspective

Interest in matters relating to environmental protection began to emerge in the agricultural economics community of scholars in the mid-1960s, relatively early in the 60-year history of the Australian Agricultural and Resource Economics Society (AARES). However, it was not until the 1980s that the Society's journals and conference programmes began to feature conceptual analyses to justify environmental conservation and analytical tools designed to assist in managing the environment for its benefits as focal topics.

Earlier in the Society's history, the environment was largely considered as an impediment to agricultural development. The earliest reference in the AJAE to what would now be regarded as an environmental topic – the

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clearing of remnant vegetation – was Moncrieff and Mauldon (1963S). Requirements to clear leases around Esperance, WA, were shown to yield suboptimal profitability for capital-poor farmers. Similarly, K. O. Campbell (1967S) appreciated the significance of land administration policies, including tenure, to the efficiency of resource use. However, these authors were concerned more with agricultural productivity and profitability than with the environmental benefits that might attend sound policies.

Nevertheless, early contributions by Society luminaries pointed the way to a prominent role for members of the Australian agricultural economics profession in the analysis of environmental issues. In his presidential address, Parish (1969S) noted that ‘future agricultural economists might apply their skills increasingly to non-agricultural problems’ (p. 1). Those trained in agricultural economics were applied microeconomists with quantitative competencies that are readily transferrable to nonagricultural application, and were not (quoting Harry Johnson’s critique of British economists) ‘excessively concerned with macroeconomics’. Among potential areas of interest that would benefit from the input of agricultural economists’ skills, Parish mentioned urban issues, defence and immigration, but not the environment.

The interaction of a growing community interest in environmental protection, the long-held understanding of the agricultural economics profession regarding the relationship between the condition of the terrestrial estate and agricultural management practices, and the skill set of the profession were conducive to the eventual flourishing of the subdiscipline of environmental economics in Australia and New Zealand (ANZ). The contributions made have been significant, ranging from initial conceptual insights through to the application of practical tools of analysis in a wide range of contexts. Doing justice to this array of contributions is a tall order but is attempted in this paper by addressing four types of contributions in the following sections.

In section 2, key conceptual advances are presented. Many of these are at the core of public economics and policy more generally, as they focus on factors that may justify government intervention or suggest limits to state involvement. Other conceptual advances have been more specifically related to the environment as they have expanded on basic welfare economic principles in order to incorporate features that address concerns about the long-term capacity of the environment to sustain humanity.

Section 3 documents the strength of the profession in ANZ by highlighting some of the key advances made in the development of three types of analytical tools and policy instruments: nonmarket environmental valuation for benefit-cost analysis; market-based instruments for environmental goals; and the private provision of environmental protection goods and services. As illustration, a number of ground-breaking applications across a range of contexts are described – including biodiversity, river

health, nutrient run-off control, remnant vegetation protection and private nature reserves.

Environmental economics brings its practitioners into close and continuing contact with natural and social scientists and policy practitioners from a variety of backgrounds. All of the above are influenced more than they might recognise by the humanities, including but not limited to environmental ethics. We highlight, in section 4, some of the main areas of active cross-fertilisation: behavioural economics, ecological economics, environmental risk and environmental ethics; and in section 5, two active research programs that are inherently multidisciplinary: ecosystem services and integrated assessment modelling. Again, we find ANZ environmental economists taking leading roles in broadening the perspective of environmental economics and forging multidisciplinary collaborations.

A final section sums up the retrospective view of ANZ environmental economists and offers some suggestions about future directions of the profession and the implications of those directions for AARES.

1.2 The international context

AARES members have been engaged in the international scholarly community from the beginning. In the 1960s and 1970s, interactions tended to be one on one, as exemplified by Jack Sinden and Jack Knetsch in the 1970s, but more institutionalised interactions were emerging. An ongoing US regional research project has engaged many of the world's leading researchers in nonmarket valuation since its initial incarnation as a recreation economics project in the early 1960s. The Association of Environmental and Resource Economics was founded in North America in the early 1970s. Global connections have burgeoned since about the mid-1980s, as environmental economics associations were organised in Europe, Asia and Latin America, and 'Resources' was inserted into the name of our Society. The first quadrennial World Congress of Environmental and Resource Economists was held in 1998.

In a global scholarly community, theory and methods quickly become global public goods and AARES members have been serious global players, producing as well as benefitting from these public goods. Our Society has maintained a strong commitment to strengthening global ties and speeding cross-fertilisation by, for example, participating in the conferences of several international associations and bringing outstanding international speakers to address the AARES annual conference. Here, we recognise and celebrate some of the important AARES contributions to environmental economics theory and methods, and some of the ways in which environmental economists contributed to environmental policy and practice in Australasia. Our AARES focus is appropriate in the context of our Society's 60th anniversary and implies no disrespect for the many contributions of leading international scholars.

2. Conceptual advances

ANZ agricultural economists in the early 1970s embraced the notion of market failure as a necessary but not sufficient condition for government intervention to protect the environment in the face of development pressure. Taking the foundational work of Pigou and Coase as applied by Krutilla to the case for 'conservation', Sinden (1970S) provided a 'rationale for environmental protection'.

Tisdell (1970S) set out the theory of externalities in general terms and then joined with Walsh (Walsh and Tisdell, 1973S) to write specifically about nonmarginal externalities. Parish (1972S) set out the economic principles underpinning the notion of externalities (pollution or congestion) and established the parameters on which taxes and regulations may be applied. Randall (1972S) analysed the prospects of Coasian liability rules in facilitating markets to resolve externalities but was pessimistic that transaction costs would impede efficient resource allocation. Chisholm *et al.* (1974) compared the prospects of alternative policy instruments for dealing with externalities, notably taxes versus regulations, concluding that price-based instruments were likely to be more efficient than the regulatory alternative.

Parallel to the focus on environmental externalities as a source of market failure, the public good characteristics of many environmental goods were recognised. Tisdell (1972) turned his analytical attention to the provision of national parks and protection of the natural environment more generally. He pointed to the nonexcludable characteristics of species protection as a factor that would prevent the operation of markets in securing efficient supply.

The interest in environmental externalities as a rationale for government intervention was fuelled by the Balderstone Report into agricultural policy in 1982¹. Land degradation, as a limit to agricultural productivity growth, was analysed by Kirby and Blythe (1987S). Applying the analysis of externalities developed in the previous decade, they argued that government intervention was not warranted in the case of land degradation when the land owner bore the costs of reduced productivity, but might be in the case of environmental impacts experienced off-farm².

Quiggin (1986) used the concept of common property to analyse the dryland salinity issue. He formulated the notion of common property as distinct from the case where no rights are defined, and suggests the possibility of negotiated outcomes between groups of people assigned the common rights to natural resource assets. His work highlighted the tension between those who followed the broadly Pigovian approach of 'correcting' for environmental externalities by imposing taxes, subsidies or regulations and those who favoured the Coasian approach of trading rights to well-defined

¹ See Jarrett (1983S).

² Specific cases of resource degradation were considered by Greig and Devonshire (1981S) (dryland salinity), Sinden and Jones (1985S) (eucalypt dieback) and Chisholm and Dumsday (1987S) (erosion).

environmental assets. The latter approach had not featured prominently in the ANZ literature but was highlighted by Wills (1987). While the concept of property rights had been well understood in the context of environmental resources, with their absence being used as a rationale for government intervention, Wills' work helped to clarify why defining property rights was not always a viable solution; for example, resource degradation was an 'information problem' attributable to high transaction costs. This established the institutional economics approach to environmental issues in the ANZ setting. It also highlighted the question of whether the costs of developing regulatory and/or price-based instruments were covered by the resultant benefits of the policy.

Stoneham *et al.* (2003) applied the insight from the pollution control literature that tradeable permits had advantages over the Pigovian tax/subsidy approach, in developing reverse auctions to provide incentives for farmers to set aside areas of their properties for vegetation protection. This in turn triggered a greater interest in 'market-based instruments' for environmental protection. Applications of such instruments are reviewed in the next section.

The institutional economics branch of the discipline also spawned further conceptual advances. Anderson (2004S) gave renewed impetus to Coasian analysis. For instance, Coggan *et al.* (2015S) used transaction cost analysis to understand farmer participation in water quality improvement programmes and Bennett (2012S) analysed private sector incentives for nature protection.

ANZ economists have been attracted to the issue of sustainability, which incorporates the condition of the environment as a dimension of well-being alongside social and economic considerations. Pezzey (1989) was an early contributor to this literature, pointing out the proliferation of definitions and resolving some of the conceptual differences between genuine savings and weak sustainability (Pezzey and Toman, 2002S; Pezzey and Bourke, 2014S). Sustainability was the theme of two major AARES conference presentations by economists with strong neoclassical roots: Chisholm's 1991 presidential address and Randall's 2006 opening plenary.

The issue of whether or not Australia is achieving the goal of sustainability raises fundamental questions about the capacity of a market-based economy to resolve emerging environmental problems. The 'Kuznets Curve' hypothesis suggests that a combination of technological advancement and increased demands for quality of life will deliver, eventually, a positive marginal relationship between economic wealth and environmental conditions. Stern, Common and Barbier (1996S) argued that the data fail to show consistently that the relationship eventually turns positive. Tisdell (2001S) expressed concern with the Kuznets curve concept because some negative environmental impacts cannot be reversed by continuing economic growth, pointing to the distinction between weak and strong sustainability. He specifically notes the role played by the WTO and 'globalisation' in stimulating economic growth. Sinner (1994S) showed that trade restrictions designed to achieve

environmental goals are likely to cause reductions in well-being while failing to achieve their stated purpose as did Anderson and Blackhurst (1992S). A similar trade-related paradox was exposed by fellow New Zealanders Saunders, Barber and Taylor (2006S). They demonstrated that the use of 'food miles' as an indicator of differential environmental harm done as a result of product choice can be contradictory.

An entirely different approach to environmental economics was advanced by Thampapillai (2012S), who suggested that the failure of conventional macroeconomic models to incorporate depreciation of the environmental capital stock was a factor in the limited success of those models and associated policy approaches. His model of the macroeconomy includes environmental capital as a constraint to economic performance and suggests alternative policies that would see the environmental capital stock enhanced.

3. Analytical tools

The ANZ agricultural and resource economics profession has been and remains heavily orientated towards applying economic principles to matters of current (especially policy) interest. Many of the advances attributable to ANZ economists have been in developing analytical tools and deploying them for practical purposes. The scope of these advances is wide. Here, only a relatively small selection of tools and applications can be presented.

3.1 Extending benefit-cost analysis

The core principle that market failure was only a necessary but not sufficient condition for government intervention requires the use of benefit-cost analysis (BCA) to justify policy implementation. ANZ economists were at the forefront of making sure BCA was fit for purpose in environmental protection contexts. Abelson (1979S) was one of the first in that genre as was Sinden and Worrell (1979), which set out the available techniques for estimating nonmarketed environmental benefits and costs, a key element of any BCA attempting to investigate environmental policy options. It drew on Sinden's (1967) review of 'extra-market' benefits. ANZ economists would go on to be amongst those at the forefront internationally of the development and application of nonmarket valuation techniques, particularly the stated preference techniques.

Randall *et al.* (1974) conducted one of the first contingent valuation applications in the context of air pollution impacts of power stations in the four corners region of the USA. Bennett's (1984) first Australian application explored the nascent concept of existence value. In NZ, Sandrey (1986S) first applied contingent valuation to outdoor recreation and in doing so detected 'payment vehicle' bias. These studies broke new ground both in terms of the contexts of their application and the methodological testing they conducted.

This early empirical work led to advances in the theory as well as the practice of welfare change measurement, for example, specifying the theoretically correct welfare change measures in the case of public goods (Randall and Stoll 1980S). Hoehn and Randall (1989) presented theorems proving that the benefit of a suite of public goods projects evaluated as a package is systematically less than the sum of benefits of the component projects evaluated one at a time.

There has been a strong ANZ contribution to the development of another stated preference technique, Choice Modelling (CM). The technique is based conceptually on the Lancasterian characteristics theory of demand (Lancaster, 1966S). The CM method was developed by Hensher and Louviere (1979S), initially in the context of transportation. Morrison *et al.* (1999) and Blamey, Bennett, Louviere, Morrison and Rolfe (2000S) were amongst the first to transfer the technique to Australian environmental contexts. In NZ, Kerr and Sharp (2008) first used CM in the context of valuing Auckland urban streams.

Several significant methodological advances in stated preference techniques have come from the work of ANZ environment economists. For example, Blamey *et al.* (1999) developed the ‘polychotomous choice’ version of the contingent valuation technique and applied it to the case of wetland management in South Australia. Kerr (2000S) at Lincoln University analysed dichotomous choice data from a contingent valuation application focused on water quality improvements in the Waimakariri River to solve the ‘fat-tail’ problem. Burton (2000S) at UWA also considered refinements to the analysis of dichotomous choice CV data using a semiparametric estimator. In the CM space, Rolfe *et al.* (2000) developed an approach to framing choices in the presence of substitute goods using the context of protecting tropical rainforests. In a trans-Tasman collaboration, Scarpa and Rose (2008) refined the practice of experimental design to improve the estimation efficiency of choice models. Burton and Rigby (2009S) used hurdle and latent class models to consider nonparticipation by respondents to CM questionnaires.

Given the cost of original nonmarket valuation studies, governments have encouraged benefits transfer as an efficient way of using results from existing studies to evaluate new problem sites. Rolfe and Windle (2008) suggested appropriate protocols for benefit transfer to meet this policy demand, while a number of valuation studies were conducted specifically to act as source studies for benefit transfer. For instance, Morrison *et al.* (2004S) valued environmental attributes across a range of NSW Rivers relevant to the formulation of catchment management plans.

The application of stated preference techniques in high profile resource use decision-making – notably the Coronation Hill mining case (Imber *et al.*, 1991S) – sparked significant controversy. In response to the doubts cast over the validity of nonmarket value estimates by lobbyists and members of the economics profession, considerable effort was made to subject the techniques to criticism, validation and improvement.

In terms of criticisms, Knetsch and Sinden (1984) noted differences between willingness to pay and willingness to accept estimates in a contingent valuation application that were greater than would be predicted by theory. Blamey *et al.* (1996S) questioned the validity of responses to CV questions as reflections of individual preferences and proposed that stated preference questioning prompts respondents to answer as ‘citizens’. Lockwood (1996S) also questioned the validity of responses to CV questions on the grounds that values expressed were compromised by not taking into account the intrinsic value of environmental assets given that such values were ‘noncompensatory’ and so void the axioms of neoclassical consumer theory.

The defence of stated preference techniques came through theoretical examination of the incentives for strategic response (Hoehn and Randall 1987) and numerous empirical studies that applied various tests of validity to their results. From amongst these studies, Bennett (1987S) carried out some early experimental economics to investigate the occurrence of strategic behaviour amongst respondents to hypothetical valuation questioning. Sinden (1988S) tested for the presence of hypothetical bias in CV results and concluded that there was little evidence for the bias. Randall and Hoehn (1996S) demonstrated that embedding is observed in market data, as well as in contingent valuation data sets. Bennett *et al.* (1998S) applied a scope test to demonstrate that the embedding problem had been avoided in their CV study of the Coorong in South Australia.

Another stream of validity testing involved comparison between SP study results and comparable revealed preference technique estimates of value. This approach was implemented by Rolfe and Dyack (2010S) using travel cost data to demonstrate convergent validity with CV estimates as did Mwebaze and Bennett (2012S) in the context of valuing botanical gardens. This approach implicitly assumes that revealed preference value estimates such as those obtained by the travel cost method are a valid baseline for comparison. This assumption has been questioned. For instance, Randall (1994S) argued that decisions made by travellers to recreational destinations are responses to subjectively determined costs rather than the objective cost estimates used in most TCM applications. Common, Bull and Stoeckl (1999S) demonstrated the so-called Randall’s difficulty in their TCM application for Tidbinbilla Nature Reserve. Beal’s (1998S) TCM study of visitors to Carnarvon Gorge National Park was criticised by Chotikapanich and Griffith (1998S) and Kennedy (1998S) for the sensitivity of the results obtained under different econometric assumptions.

Revealed preference methods have been used in ANZ as the valuation methods of first resort, as well as to provide results for comparison with those of stated preference methods. For example, Farr *et al.* (2012S) used the travel cost method in an evaluation of the environmental management programs in the Great Barrier Reef Marine Park. Bob Richardson, famed for his service to the Australian wool industry, collaborated earlier in a pioneering hedonic price analysis of the value of disamenities from solid waste landfills (Havlicek

et al. 1971S). Tapsuwan *et al.* (2009S) used a hedonic property price approach to estimate the amenity value of urban wetlands near Perth; Samarasinghe and Sharp (2010S) completed a spatial hedonic analysis of exposure to risk of flooding in and near North Shore City NZ.

Regardless of the methods used to generate estimates of benefits and costs, the rate at which future values are discounted looms large in BCA. Recent concerns about climate change, where benefits of mitigation are projected to peak several generations after the costs have been incurred, have re-ignited controversies about the justification for discounting and the appropriate discount rate. Scarborough and Bennett (2012S) showed that stated preference techniques can provide evidence about citizen time preferences, Pannell and Schillizzi (editors, 2006S) offer a book-length discourse on discounting, and Scarborough (2011S) presented a sophisticated review and critique of the discounting literature.

In reaction to the controversies regarding the use of nonmarket value estimates, some ANZ environmental economists have searched for ways to address policy issues without recourse to full BCA. One such approach is the threshold value method. It was used by Saddler *et al.* (1980) as an input to the decision regarding damming the Franklin River for hydropower development. Later, Allen and Gooday (1998S) applied the approach in the context of regenerating vegetation after mining activities as did Bennett (1999S) to inform the debate on the future of the South East Forests.

3.2 Policy instruments

Tony Chisholm and colleagues were among those showing that, in some externality situations, market forces can be harnessed to deliver environmentally beneficial outcomes more efficiently. In the 1960s, North American economists proposed trading in pollution permits or pollution reduction credits, and Cramton and Kerr (2002S) showed why and how permits could be distributed at the outset by auction rather than grandfathered to incumbent polluters. The earliest environmental markets in Australasia included the tradeable permit schemes devised by Collins (2002S) for dealing with saline wastewater from mining operations in the Hunter Valley and sewage treatment in the Hawkesbury Nepean system. Trading schemes also became established in NZ with a nitrogen trading scheme for Lake Taupo (Greenhalgh, 2015S), with another mooted for Lake Rotorua (Lock and Kerr, 2008S).

These applications were paralleled by the development of other 'market-based instruments' for achieving biodiversity protection and land degradation reversal goals. Initial work in this field was carried out by Stoneham *et al.* (2003) in Victoria (the BushTender scheme) but was soon followed by other applications. Technical advancements were also achieved. For example, Cason and Gangadharan (2004S) developed auction design principles and Schillizzi and Latacz-Lohmann (2013S) developed a model of a budget constrained (rather than goal directed) auction scheme.

A characteristic of most of these studies is the use of a reverse auction in which environmental ‘suppliers’ bid for access to government funds on offer. Bids were ranked according to their ‘cost-effectiveness’ in achieving the environmental goal of interest. The latter is usually measured by some nonmonetary metric: inputs of effort, reductions in pollutants or ‘habitat hectares’, which is an index³ reflecting inputs, potential outcomes and the biophysical context, in the BushTender case.

Numerous refinements of the reverse auction process were developed. For example, schemes were introduced to encourage collaboration between bidders where contiguous areas of remnant vegetation provided ecological advantages (e.g. Rolfe *et al.*, 2009S). Whitten *et al.* (2012S) sought to facilitate landowner participation in auctions through the design of the tendering process.

Criticisms of reverse auction schemes have been based on their relatively poor performance in attracting prospective suppliers and their failure to guarantee a net improvement in social welfare when no monetary estimate of the benefits achieved is incorporated into the process of selecting the preferred suppliers. While some (Moon and Cocklin, 2011S) have argued that low participation has been due to social factors, others (Scheufele, 2015S) have suggested that while efficient revelation of costs has its obvious virtues, participation might be encouraged by sharing some of the welfare surplus with suppliers. The use of CM-generated monetary estimates of the individual level benefits predicted for reverse auction bid proposals by Wang *et al.* (2012S) allowed the ranking of supply options using standard BCA. However, this procedure would generate additional information and transaction costs, raising the bar for a net welfare improvement.

3.3 Private vs public provision

The same comparison of transaction costs with intervention benefits is central to the choice to allow a greater role for the private sector in providing environmental protection. The possibility of public sector action ‘crowding out’ private sector initiatives was raised by Bennett (1995S). Aretino *et al.* (2001S) further explored this by analysing the operation of Earth Sanctuaries Pty Ltd, a private corporation established to own and operate private conservation sanctuaries. The subsequent growth of private sanctuaries was reviewed by Bennett (2015S), and Iftekhhar, Tisdell and Gilfedder (2014S) reviewed covenanting as a strategy for achieving conservation goals on private lands in Tasmania.

The emergence of water markets in the Murray Darling Basin presented the opportunity to purchase water rights for environmental (rather than extractive) purposes. Crase *et al.* (2012S) examined the welfare implications

³ The use of such indices has been criticised by Dobes and Bennett (2009S) because they face the same pitfalls as Multi Criteria Analysis, an alternative decision support tool to BCA.

of such purchases, but Young (2012S) argued that purchases of environmental water by the Commonwealth Environmental Water Holder demonstrate government 'crowding out' of private sector conservation actions.

Environmental markets also may be driven by consumer demand, as in the cases of labelling and certification programs. Umberger *et al.* (2015S) looked at the demand for 'ecolabelling' and corporate social responsibility as drivers for improved environmental outcomes in food producing areas. In a similar vein, Grafton *et al.* (2015S) investigated how 'green growth' can be achieved in fisheries with innovation responding to consumer demands for greater environmental sensitivity in the industry.

4. Intra- and interdisciplinary cross-fertilisation

4.1 Behavioural economics

It is hard to imagine the rise of behavioural economics without the early stated preference research by environmental economists. From the beginning, stated preference techniques of nonmarket valuation exposed systematic patterns of response that seemed anomalous to people predisposed to regard economic rationality as the behavioural norm. Willingness to accept compensation in lieu of promised environmental improvement diverged from willingness to pay to a greater extent than most economists expected; and reserve prices to sell ordinary goods (e.g. coffee mugs) were much greater than willingness to pay, suggesting that the fact of possession *per se* made them more valuable. Soon environmental economists had undertaken laboratory and field experiments to test the robustness of these findings from early stated preference surveys, and psychologists were collaborating with environmental economists (Kahneman, Knetch and Thaler 1991S). Terms such as the endowment effect and loss aversion became entrenched in the emerging field of behavioural economics. The ANZ connection was forged early with Knetsch and Sinden's influential paper (1984), and behavioural economists currently are active in environmental economics research, for example studying farmer participation in conservation auctions.

4.2 Ecological economics

Ecological economics began as something of a protest movement objecting to the reductive methodology of mainstream economics and its perceived insensitivity to environmental concerns. But, it matured quickly to nurture collaborations among economists and natural scientists that have expanded the scope of environmental economics in important ways: for example understanding and modelling the complexity of natural systems, modelling coupled dynamic natural and human systems and characterising the crucial role of resilience in system stability and sustainability (e.g. Walker *et al.* 2010).

There is continuing participation of AARES members in the ecological economics community, as indicated by individuals publishing in *Ecological Economics*, joining the International Society for Ecological Economics and its Australasian affiliate, ANZSEE, and participating in their conferences. Nevertheless, overtly ecological-economic articles in AJARE and invited speakers at our annual conferences have been rare.

4.3 Environmental risk

The mainstream economic analysis of risk was constructed around the analogy of well-specified games of chance. The early risk management agenda in environmental economics was aimed mostly at elucidating the conditions under which willingness to pay to ensure risky supply of amenities might deviate from expected value. Concepts like option price and option value, and methods of real options analysis, were adapted to the nonmarket and public goods contexts. In the past fifteen years, growing concern about sustainability and recognition of the threat from climate change have changed the conversation about environmental risk and motivated a search for methods of dealing with risk in the context of complexity, uncertainty and ambiguity, and threats of unlikely but potentially catastrophic harm. Simon Dietz's opening plenary address at the 2014 annual conference opened a window on this controversy.

In ANZ, Peterson (2006) applied the precautionary principle (PP) to risk in natural resource management. Randall (2011S) established the usefulness of the PP in conditions of complexity that typify environmental policy making. He sketched an integrated approach to risk management that paid more than customary attention to prerelease testing of novel interventions, and was more open to precautionary instruments for managing natural systems under stress from overexploitation.

4.4 Environmental ethics

Environmental ethics is not so much about how people actually behave towards the environment, but about the search for justifiable principles and values relating to how they ought to think and act. In that respect, it is not so far removed from welfare economics and BCA, which attempt to cast light on the value of good and harm that might result from proposed public policies and investments. A few environmental economists have maintained a dialogue with environmental ethicists since the mid-1980s. Randall (2013S, 2014S) summarised several decades of this work, recognising economic challenges to environmental ethics thinking but also ethical challenges, perhaps even more insistent, to positions congenial to many environmental economists, and finding nontrivial but nevertheless limited ethical justifications for a BC test. He proposed that the legitimate domain of BC be bounded with constraints that may derive from a number of different ethical

stances, and may include safe minimum standards (SMS) of conservation to sustain essential resources and preserve rare and highly valued environmental entities.⁴

5. Multidisciplinary advances

5.1 Ecosystem services

Early progress in empirical welfare change estimation regarding the environment emphasised the demand for environmental services, defined as goods to be ranked in terms of preference and valued economically. Services included everything from fish nurseries to aesthetic amenities, and the uses to be valued were active and/or passive. What was missing was the supply response. We could value different levels of service, but we had little evidence about what it would cost to move from one level to another. By the mid-2000s, the ecosystem services (ES) framing was all the rage. The research community was abruptly expanded to include a wider variety of natural and social scientists, and there was some wheel spinning as ES researchers re-invented some of the concepts and tools of nonmarket valuation. But, more importantly, the field attracted researchers with interests and capabilities in looking more seriously at the production side of ES. Establishing ‘environmental production functions’ now enjoys similar priority to that of agricultural production functions in the early years of the Society.

ES research has been prominent at AARES annual conferences for more than a decade (e.g. Antle in 2005 and Polasky in 2010). In AJARE, ES research has included papers attending to prominent Australian ES issues such as salinity in riverine environments, environmental flows, and biodiversity and habitat conservation, as well ES issues of international concern (Quiggin 2001S, Heaney *et al.* 2001S, Qureshi *et al.* 2007S, Jones *et al.* 2007S, Antle and Valdivia 2006S, Halkowicz *et al.* 2007S, Antle *et al.* 2010S and Figueroa and Pasten 2015S).

5.2 Integrated assessment modelling

Integrated assessment modelling (IAM) is employed, typically, in projecting future conditions under a variety of assumptions about drivers, including policies. The results cast light on likely outcomes of business as usual and a suite of alternative policy stances, and perhaps a variety of hypothetical but plausible shocks to the system. Output is reported in terms of multiple variables, rather than boiled down to a single summary measure as is typical of welfare change measurement. The IAM enterprise is inherently

⁴ Rolfe (1995S) critiqued an early version of this work, arguing that an SMS may be interpreted consistently with economic utilitarianism, as little more than an allowance for strong risk aversion.

multidisciplinary in every respect: it is conducted by multidisciplinary teams, it takes input from a wide variety of disciplines, and its outputs cast light on a wider variety of issues and concerns than could be addressed by any discipline alone. The goal often is an integrated dynamic model of a whole natural, economic and social system, often but not always on a global scale. Modelling should capture the feedbacks and complexity in natural systems, and the market clearing tendency of economic systems. The enormity of the task usually leads to something less: rather than starting with a blank slate, existing models may be adapted and linked; some of these models may fall far short of the ideal dynamic models; some concerns may be addressed more informally, for example by substituting expert opinion for formal models; and some issues may be omitted for lack of expertise, evidence or computational resources.

More than a handful of AARES members have contributed to CSIRO's Australian National Outlook (ANO) project, a huge IAM effort to project scenarios for Australia through the year 2050 in response to global climate change, international markets and hypothetical Australian policy stances (Hatfield-Dodds *et al.* 2015). The results suggest that Australia has more scope to make meaningful choices about its future than one would infer from the day-to-day policy discourse. Many challenges remain for integrated assessment modelling: linking models at multiple spatial and temporal scales, addressing inconsistencies in component models, completing the feedback loops and making the IAM truly dynamic, and introducing complex systems properties. Ironically, the typical IAM is very complicated but not truly complex. Getting beyond linear thinking – whether it be unidirectional causation, or linear and continuous expressions of phenomena that may in fact be nonconvex and/or discontinuous – has proven more difficult than the optimists expected. Nevertheless, IAM efforts are expanding around the world, and the ANO project brings Australia on board and positioned towards the head of the pack.

6. Conclusion

Australian and New Zealand environmental economists have 'punched above their weight' in the international arena of conceptual analysis and empirical applications. The local profession was well prepared to achieve this standing by the strength of the agricultural economics training infrastructure and the relevance given to the use of economic analysis in government agencies. The applied and empirical emphasis so established made for an easy transition to considering the interface between agriculture and the environment and then to the analysis of environmental issues in their own right.

Key contributions have been made in the formative debates regarding the basic economic principles at the core of environmental economics right through to pioneering applications of state-of-the-art analytical tools.

Australia and New Zealand have been international focal points particularly for nonmarket valuation and the use of market-based policy instruments.

The continued strength of AARES has in part been due to the Society's willingness to include environmental economics as one of its core interests. Universities too have refocused towards environmental economics offerings as demand for traditional agricultural economics has slowed. We offer a few guiding principles for environmental economists going forward. First, the applied nature of environmental economics inherently demands interaction with biophysical sciences and other social sciences. Pay-offs from constructive interaction with other disciplines will continue to grow, and environmental economists need to recognise that theirs is not the only game in town. There appears to be no holding back of novel techniques that seek to integrate a range of disciplinary inputs, such as IAMs. The core strengths of economics in establishing opportunity costs and predicting the perhaps unintended consequences of policy measures should, however, remain at the heart of what the profession offers in these multidisciplinary endeavours.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Supplementary references