Journal of Benefit-Cost Analysis

Volume 3, *Issue* 2 | 2012 | *Article* 4

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Recommended Citation:

Gillespie, Rob and Kragt, Marit E. (2012) "Accounting for Nonmarket Impacts in a Benefit-Cost Analysis of Underground Coal Mining in New South Wales, Australia," *Journal of Benefit-Cost Analysis*: Vol. 3: Iss. 2, Article 4.
DOI: 10.1515/2152-2812.1101

Accounting for Nonmarket Impacts in a Benefit-Cost Analysis of Underground Coal Mining in New South Wales, Australia

Rob Gillespie and Marit E. Kragt

Abstract

Strategic inquiries into coal mining by Australian Governments advocate increased use of comprehensive benefit cost analyses and nonmarket valuation studies when assessing individual project proposals. The study reported in this paper addresses these Government concerns, by integrating results of a choice experiment into a benefit cost analysis undertaken for a Colliery in the Southern Coalfield of New South Wales, Australia. Results of the study were used to aid the State government in evaluating proposals for continued underground coal mining. We show that impacts of mine subsidence on streams, swamps, and Aboriginal sites negatively affect community wellbeing. Social welfare increases with the length of time that the mine provides direct employment. We demonstrate how implicit price estimates from the choice experiment can be incorporated into a benefit cost analysis of continued mining. Benefit cost analyses were carried out for a range of policy scenarios—including policies that would restrict mining activities at the Colliery and protect environmental and cultural features in the Southern Coalfield. Notwithstanding the environmental impacts generated by mining operations, continued mining is shown to be a more economically efficient course of action.

KEYWORDS: benefit cost analysis, coal mining, choice experiments, mining externalities, natural resource management, nonmarket valuation

Author Notes: The authors thank Professor Jeff Bennett from the Crawford School of Economics and Government at the Australian National University, and member of the Planning and Assessment Commission Panel reviewing the Colliery's application to Government, for his helpful comments on earlier versions of this paper. Comments from two anonymous reviewers further helped to greatly improve an earlier version of this paper.
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1. INTRODUCTION

Coal mining in Australia is under increasing scrutiny – in response to community concerns – about the potential environmental, cultural, and social impacts of mining. This has manifested itself in policy requirements for existing mines to obtain Government consent for continuing their operations. The consent process includes the submission of benefit cost analyses (BCA) that jointly assess the financial, environmental, cultural, and social impacts of mining operations.

Properly conducted, a BCA will comprehensively account for all the incremental costs and benefits of a proposed project, including impacts on community wellbeing (Hanley and Barbier, 2009). As such, BCA can help decision-makers to make more efficient use of available resources and increase social welfare.

In the context of a coal mining project, some of the benefits and costs can be readily observed from market transactions. These include mining revenues, capital costs, operating costs, opportunity cost of land and capital, and financial costs of mine site rehabilitation. However, coal mining may also impact values that are not traded in markets, such as environmental, cultural, and social features. It is now widely recognised that such nonmarket values need to be incorporated into BCA studies (e.g. Loomis, 2011; Robinson and Hammitt, 2011). Estimating the impacts on nonmarket values can be one of the most difficult aspects of conducting a comprehensive BCA (Hanley and Barbier, 2009: 314).

In this paper, we describe a BCA study that was conducted to assess the economic efficiency of underground coal mining in the Southern Coalfield of New South Wales (NSW), Australia (Figure 1). A unique feature of the study is the recognition of the project developer that the nonmarket environmental, cultural, and social impacts of their operations should be quantified in the analysis. In Australia, most nonmarket valuation studies are commissioned by government agencies or research organisations that may have an interest in curtailing extractive resource uses. This is the first known example in Australia where a commercial developer mandated a BCA that included the nonmarket values of the externalities associated with its business proposal.

A nonmarket valuation technique known as choice experiments (CEs) was used to estimate preferences of NSW households for the impacts of underground coal mining in the Southern Coalfield. There are currently few studies that have estimated nonmarket value impacts of mining operations. A study by Trigg and Dubourg (1993) used hedonic pricing to assess the value of the environmental impacts of coal mining in the UK. The study found that, based on the measured impact on local house prices, the monetary environmental costs of opencast coal mining could substantially reduce mining's economic viability. Lambert and Shaw (2000) estimated welfare impacts of river flow changes due to gold mining operations in Nevada, USA. The authors analysed the impact of flow changes on farmers using an agricultural production model, and on recreation using the travel cost method. They concluded that both agricultural producers and recreational users will benefit from a reduction in flow volatility. However, welfare may decrease in the post-mining period as a result of a reduction in surface flows. Damigos (2006) described three case studies where contingent valuation, hedonic pricing, and benefit transfer were used to estimate willingness to pay for mine site rehabilitation, and impacts of mining activities on property values. In each case (and perhaps not surprisingly), limiting or restoring environmental damages associated with mining facilities was found to significantly increase social welfare.

CEs are now widely used to evaluate people's preferences in transportation, environmental, health, and tourism contexts (see, e.g., Axsen et al., 2009; Hanley et al., 2005; Hole, 2008; Scarpa et al., 2008). However, their application to mining appears limited to a study by Ivanova et al. (2007), who assessed the impacts of mining on migration, employment, town services, and medical facilities in a rural Queensland community. To the best of the authors' knowledge, there are no previously published BCA studies that have included nonmarket valuation estimates for environmental, cultural, and social impacts of underground coal mining. Extension of BCA to incorporate nonmarket values can enhance the role of BCA and guide decision-makers on the economic efficiency of mining and other proposals. However, BCA and nonmarket valuation should not be seen as solely the domain of governments but arguably should be a routine requirement of private sector development proposals that require detailed environmental assessment.

Section 2 of this paper provides information about the case study area, while the CE method and econometric models used to analyse CE data are described in Section 3. Section 4 details the CE questionnaire development. Model results and implicit price estimates are presented in Section 5. The implicit price estimates are used in a BCA to assess changes in the economic efficiency of underground coal mining in Section 6. Conclusions are provided in Section 7.

2. POLICY CONTEXT

The Southern Coalfield (15,000 km^2) extends from the south of Sydney, past Nowra on the south coast, and east of Goulburn in New South Wales (NSW, Figure 1). There are eight underground coal mines currently operating in the Southern Coalfield. These mines are located in Sydney's drinking water catchment, which is an area recognised for its conservation values.

Underground coal mining in the Southern Coalfield has been undertaken for over 100 years. Most mines have been operating since before any requirement for development consent and environmental assessment under the *Environmental Planning and Assessment (EPA) Act, 1979* (NSW Government, 2009a). Under the *EPA Act 1979*, existing mines did not need consent if transitional provisions were adopted in the relevant local environmental plans. However, with the passage of the *State Environmental Planning Policy-Major Developments (SEPP) 2005* existing mines that did not yet have development consent, were required to obtain project approval by December 2010 to enable continuation of mining (NSW Government, 2009b). The project approval process included the submission of an environmental assessment that addressed the environmental, social, and economic impacts of continued mining (NSW Department of Planning, 2008).

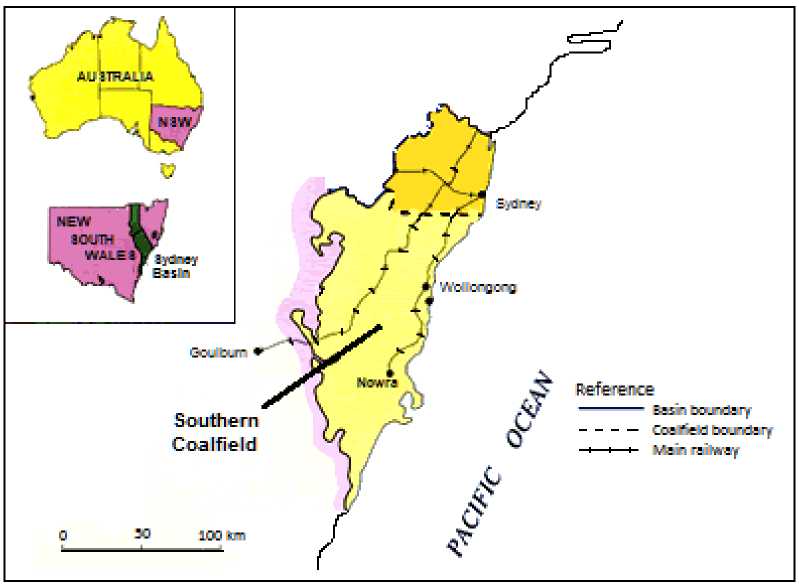

Figure 1. Location of the Southern Coalfield
(Source: NSW Department of Primary Industries)

NSW communities have raised concerns about the potential impacts of underground mines on drinking water and conservation values. Underground mining can cause subsidence, where the ground surface above the mine shifts downwards (and in some localised areas upwards) causing cracking of the land surface. In response to these concerns over impacts of mine subsidence in the Southern Coalfield, the NSW Government established an independent strategic inquiry to provide a sound technical foundation for the assessments of individual project applications that would be forthcoming under *SEPP 2005*. This inquiry examined the impacts of underground mining on significant natural features, such as rivers, swamps, and cliff lines, but also on Aboriginal heritage sites (NSW Department of Planning, 2008). The inquiry found that nonmarket valuation studies could "play an important role in assisting communities and the Government in their consideration of economic trade-offs", and recommended increased use of BCA by both mining proponents and regulatory agencies to assess individual project applications (NSW Department of Planning, 2008: 106).

3. METHODOLOGY

BCA provides a decision tool to evaluate regulatory proposals by comparing the economic efficiency of alternative policy investments. In a BCA, a proposal is considered to be welfare-improving if the aggregate incremental benefits of a proposal exceed the aggregate social costs. If applied correctly, a BCA will clearly lay out the trade-offs between the impacts of alternative policy decisions in a consistent and transparent way. This can encourage open discussions among stakeholder and decision-makers. The BCA of the mining proposal described in this paper incorporates nonmarket values estimated using a CE. In this section, we briefly describe the theoretical and econometric background to the CE method.

3.1 Choice experiments

CEs have their theoretical basis in random utility theory and Lancaster's 'characteristic theory of value' (Lancaster, 1966). It is assumed that individual i derives utility U_{ijt} from the attributes that describe alternative choice options. Respondents to a CE questionnaire are asked to choose their preferred alternative j from a set of choice options t, allowing the researcher to observe U_{ijt} as a latent variable through the choices made by respondents:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} = \beta' \mathbf{x}_{ijt} + \varepsilon_{ijt} \qquad j = 0,1,\ldots,J;\ \ t = 1,2,\ldots,T \tag{1}$$

where V_{ijt} is the observed component of utility, and ε_{ijt} is the unobserved component that is assumed to be independently and identically distributed (IID) across utilities, with a type I extreme value (Weibull) distribution. $\boldsymbol{x}_{ijt}$ is a vector of explanatory variables which can include the attributes of the alternatives, individual i's sociodemographic and behavioural characteristics and features of the choice task itself (Hensher and Greene, 2003). Alternative specific constants (ASC_j) can also be included in $\boldsymbol{x}_{ijt}$ to measure any systematic, but unobserved, differences in utilities between alternatives that are not explained by the other parameters in the utility specification. The probability that alternative j is chosen by individual i is equal to the probability that the utility derived from that option is greater than (or equal to) the utility derived from any other alternative z (Hensher et al., 2005: 82):

$$\Pr_{ijt} = \Pr(U_{ijt} > U_{izt}) \tag{2}$$

It is expected that if the quantity or quality of a 'good' attribute in an alternative rises, the probability of choosing that alternative increases, *ceteris paribus*. The assumption of a type 1 (EV1) error distribution gives rise to the multinomial logit choice model, which is given by:

$$\Pr_{ijt} = \frac{\exp V_{ijt}}{\sum_{z=1}^{Z} \exp V_{izt}} \tag{3}$$

The model is estimated using maximum likelihood procedures. A monetary attribute (usually defined as a cost borne by the respondent, in the form of an annual or upfront payment, that would need to be incurred to obtain or prevent a change in the other attributes) is typically included to allow estimates of willingness to pay (WTP) for changes in the other, nonmonetary, attributes. If utility is specified as a linear, additive function of attributes, this WTP (also referred to as an implicit price) is estimated by dividing the parameter estimate by the parameter on the monetary attribute (Hanley et al., 1998):

$$WTP = \beta_{nonmarket\ attribute}/\beta_{monetary\ attribute} \tag{4}$$

3.2 Econometric modelling

A model that is increasingly used to account for unobserved variation in preferences across individuals is the mixed logit (ML) model. This model accounts for unobserved individual preference heterogeneity in the sampled population by estimating β′ as a vector of individual-specific random parameters β_i'. The random parameter for the *k*th attribute faced by individual *i* is:

$$\beta_{ik} = \beta_k + \sigma_k \cdot v_{ik} \qquad k = 1, \ldots., K \text{ attributes} \tag{5}$$

where β_k is the unconditional population parameter; and v_{ik} are the random, unobserved variations in individual preferences that are distributed around the population mean with standard deviation σ_k. (Hensher et al., 2005). The parameter distribution needs to be specified by the analyst. The model is estimated using simulated maximum likelihood methods (McFadden and Train, 2000).

In addition to random parameters to account for unobserved preference heterogeneity in the population, the ML model can include latent error components to capture unobserved heterogeneity that is alternative- rather than individual-specific (Greene and Hensher, 2007). Specifying a common error component term for multiple alternatives allows for cross-correlation between the stochastic components of the utilities derived from those alternatives. CE applications increasingly use ML models that specify random parameters to account for individual preference heterogeneity in the systematic component of utility. However, there are relatively few environmental valuation studies that exploit the full flexibility of the ML model by decomposing the stochastic component of utility using an error component model (Scarpa et al., 2007).

A final advantage of ML models is that they can include an individual specific error term that is correlated across the sequence of choices made by the same individual. Such a panel specification accounts for systematic, but unobserved correlations in an individual's unobserved utility over repeated choices (Revelt and Train, 1998).

4. QUESTIONNAIRE DEVELOPMENT

A CE questionnaire was developed to estimate the environmental, cultural, and social values potentially impacted by continued underground mining at a colliery in the Southern Coalfield (hereafter 'the Colliery'). The Colliery under consideration produces high value metallurgical coal for steel making and provides direct jobs for 320 people. At the time of this study, mining operations were planned to continue for another 25 years. The *status quo* option included in the questionnaire was therefore described as "mining continues as currently planned for a period of 25 years". Under this *status quo* scenario, the Colliery would continue to provide jobs, but could have adverse effects on environmental and cultural values.

One of the main potential impacts of continued underground mining at the Colliery is surface cracking from mine subsidence. This can affect the natural features of the land surface, such as streams and upland swamps, as well as Aboriginal heritage sites (HCPL, 2008). The questionnaire described several policy alternatives to the *status quo* of "mining continues as currently planned". These alternative options aim to reduce the environmental and cultural impacts of the Colliery and include: (i) mine cessation; (ii) limiting the geographical extent of mining; or (iii) requiring future mining to avoid areas that are located below or adjacent to significant natural features.

The potential environmental, cultural, and social impacts of each scenario needed to be described by their impacts on a set of attributes. Initial review of the literature on coal mining in the Southern Coalfield, meetings with the Colliery management, and interviews with environmental consultants elicited the following potential nonmarket impacts of continuation of mining:

- Loss of water from the catchment.
- Water quality impacts on surface water and groundwater systems.
- Cracking of stream beds in affected sections of streams.
- Draining of pools in affected sections of streams.
- Reduced water flow in sections of affected streams.
- Iron staining in affected sections of streams.
- Localised changes in stream ecological in affected sections of streams.
- Impacts on upland swamps above the underground mining area as a result of cracking, changes in drainage and erosion.
- Cracking and collapse of rock overhangs containing Aboriginal art.

Loss of water from the catchment, via stream bed cracking, had been raised as an issue in some policy documents and in the media. However, a comprehensive analysis of stream flow data and yield behaviour of Woronora Reservoir indicated that past mining at the Colliery has had no discernible effect on the inflow to, or yield from, the reservoir (HCPL, 2008). This conclusion was supported by independent government surveys (NSW Department of Planning, 2008). Consequently, loss of water from the catchment was not included as an attribute in the CE questionnaire.[1]

It was expected that mining would impact surface water and groundwater quality. However, an extensive water quality monitoring program indicated limited impacts on water quality. Localised surface water quality impacts were observed in the form of nonpersistent changes in iron, manganese, and electrical conductivity. Water quality impacts predominantly emerged as localised iron flows – which can be seen as a discolouration of stream waters to an orange/brown colour. There were no measureable effects on water quality in the Woronora Reservoir downstream (Gilbert & Associates, 2008).

Therefore, the main impacts of underground coal mining considered were localised changes resulting from the cracking of stream beds due to mine subsidence (impacts 3 to 6). These impacts could not all be included in the questionnaire as individual attributes, because attribute definition in a CE questionnaire requires that the attributes presented can be evaluated independently from each other. Consequently, the impacts of mine subsidence on streams were amalgamated into a single attribute: ‘length of stream affected’. In the questionnaire, ‘length of stream affected’ was described as encompassing cracking, draining of pools, reduced water flow in streams, iron staining, and ecological impacts.

In addition to ‘length of stream affected’, ‘area of upland swamp affected’ was included as a potential environmental impact of mining at the Colliery.

[1] Note that this contrasts with the findings of Lambert and Shaw (2000).

Aboriginal heritage has been shown to contribute to social welfare in previous studies (see, e.g., Boxall et al., 2003) and therefore an attribute representing the 'number of significant Aboriginal sites impacted' was also included in the questionnaire.

The payment scenario and vehicle described in the questionnaire were extensively pretested during four focus group sessions[2], to assess respondents' understanding of the questionnaire and agreement with the payment scenario. The final payment scenario presented to respondents – developed based on the focus group discussions – was that the mine currently pays royalties and taxes to the NSW State Government that are used to pay for public services, such as schools, hospitals, parks, and roads. Policy alternatives that would limit the future environmental and cultural impacts of the Colliery would restrict the mining company's activities, and reduce the amount of royalties and taxes received by the State Government. This in turn would decrease the level of public services provided by the government. To limit future environmental and cultural impacts of the Colliery, but keep the current level of public services, respondents were told that every household in NSW would have to make additional annual payments to the State Government for 20 years. This annual payment for a period of 20 years was chosen to match previous CE studies in Australia (see, e.g., van Bueren and Bennett, 2000; Windle and Rolfe, 2004). Payments to secure environmental and cultural protection would be needed to replace the royalties and taxes otherwise paid by the mine. Payments would be in the form of increased taxes and/or paying higher prices for public services. This 'mixture' of payments has been used successfully in previous CE studies (see, e.g., Alvarez-Farizo et al., 2007). In our focus groups, participants accepted the need to make additional payments to reduce the impacts of the existing mine operation and did not raise objections against the presented payment scenario.

During the focus groups, participants confirmed the relevance of the environmental and cultural impacts that were represented by the questionnaire attributes. However, participants further stressed the importance of employment opportunities provided by the mine. Respondents derive welfare from the knowledge that the mine provides employment that goes beyond the labour costs, benefits, and transfers that are typically included in a BCA (see, e.g., Haveman and Farrow, 2011). It was therefore decided to include an additional attribute in the CE questionnaire that would capture the nonmarket social impacts of the Colliery. This social attribute was defined as the 'length of time that the mine provides 320 jobs'. This attribute measured the period (in number of years) that the mine would continue to provide employment opportunities. Under the *status quo* scenario, the Colliery would continue to provide its current employment for

[2]Two on 30 July 2008 in Sydney, and two on 31 July 2008 in Wollongong.

25 years – the planned life of the mine. But employment opportunities would be reduced under the alternative policy scenarios (mine cessation, limited geographical extent, mining avoiding areas with significant natural features). A number of previous studies have used nonmarket valuation methods to estimate community values for social changes. For example, Johnson and Desvouges (1997) estimated the nonmarket value of employment effects of energy programs in North Carolina, USA. Morrison et al. (1999) valued irrigation-related employment losses as a result of the protection of the Macquarie Marshes in NSW, while Bennett et al. (2004) estimated community values for the continued viability of rural communities in the context of wetland protection strategies in the Murrumbidgee River Floodplain of NSW. Othman et al. (2004) estimated the value impacts of changes in local employment from different conservation management strategies for mangrove wetlands in Perak State, Malaysia. These studies confirm that CE surveys can be applied to estimate social values.

Table 1. Attributes, their measurement units and levels

Attribute	**Unit of measurement**	**Levels[a]**
Cost	Payment ($/year) for 20 years	**0;** 10; 20; 50
Total length of stream affected	Length in kilometres (km)	**15;** 12; 8; 4
Total area of upland swamp affected	Area in hectares (ha)	**200;** 140;80; 20
Total Aboriginal sites affected	Number of sites (no.)	**270;** 220; 160; 100
Period of time that the mine will provide 320 jobs	Number of years (years)	**25;** 18; 10; 2

[a] Attribute levels for the *status quo* of mining continues as currently planned in bold font.

The range of the attribute levels was based on advice from environmental consultants and the mine manager. The upper limits represent the estimated maximum cumulative historical and future impacts if mining continues as currently planned, whereas the lower bound represents the cumulative level of historical and future impacts if the mine would cease operations in 2 years time. The environmental and cultural impacts were described to occur in 20 years time (i.e. during the lifetime of the mining operations). This period was chosen to match the length of the cost/payment attribute that was included in the CE questionnaire design. The attributes and levels that were used in the final questionnaire are outlined in Table 1.

A main effects orthogonal experimental design (Hanley et al., 1998) of 25 choice sets was constructed using the attributes described above, with five choice sets embedded into five blocks of the questionnaire (a fairly standard CE survey design). Each choice set comprised three choices:

- Option 1 – mining continues as currently planned. This option would result in maximum impacts on environmental and cultural attributes in 20 years time, and in a maximum number of years that the Colliery would provide 320 jobs. This option would come at no cost to respondents.
- Option 2 and option 3 – new policies for the mine. These options would limit the environmental and cultural impacts of the Colliery felt in 20 years time, but would also reduce the length of time that the mine would provide 320 jobs and come at a cost to respondents.

The questionnaire was administered using a web-based survey, with a random sample drawn from an existing panel of pre-stratified and registered respondents.[3] To test whether values differ between communities located inside and outside the region directly affected by a proposal, the sampling strategy targeted respondents from the local Illawarra Region – where the Southern Coalfield and the Colliery are located – and respondents from the rest of NSW, which coincides with the political boundary for decision-making about the Colliery. The sampling strategy was aimed at obtaining 100 completed questionnaires per block for each of the two subsamples.

5. RESULTS

The link to the CE questionnaires was distributed between the 2nd and 21st October, 2008. A total of 7553 questionnaires were distributed, of which 1028 completed questionnaires were returned[4] (Table 2). The questionnaire included a question to determine potential protest responses against the presented payment vehicle. 'Protest responses' express a zero WTP in protest against some aspect of the questionnaire, rather than a true expression of WTP. The protest rate was 2%

[3] The online panel of I-View, a market and social research data collection company, was used. The panel is representative of the internet population. I-view is able to balance samples from the panel to accurately represent the general population. As an aside, Olsen (2009) and Nielsen (2011) recently showed that results are similar between face-to-face interviews and web-based survey models.

[4] This represents a notional response rate of 14%, although it should be noted that with online surveys, once the quota of responses is obtained, the survey link is deactivated. Consequently, the ratio of survey responses to survey links distributed cannot be interpreted in the same way as for mail-out surveys. Similar response rates have been found for mail-out and face-to-face surveys (Windle and Rolfe, 2011).

of respondents, which is lower than protest rates found in other environmental valuation studies (see, e.g., Bateman et al., 2009; Czajkowski and Scasný, 2010; Hanley et al., 2003). The questionnaire also included a question to assess potential respondent burden associated with the choices sets. Respondents were asked to identify on a 5-point Likert scale, ranging from strongly disagree to strongly agree, how strongly they agreed or disagreed with the following statement, “I found the choice set questions confusing”. Of all respondents, 85% strongly disagreed, disagreed or neither agreed nor disagreed with the statement, suggesting that the respondents understood the choice task well. A total of 13% agreed with the statement and only 2% strongly agreed with “I found the choice set questions confusing”.

Table 2. Sample statistics

	Illawarra		**Rest of NSW**	
	Sample	**Popn.**	**Sample**	**Popn.**
n (completed questionnaires)	525		503	
Gender (% male ≥ 18)	25%	48%	50%	49%
χ^2 (5% critical value = 3.84)	116		1	
min–max (st.dev.)	0–1 (0.44)		0–1 (0.50)	
Household size	3.2	2.5	2.8	2.6
t-stat (5% critical value = 1.96)	10.5		3.1	
min–max (st.dev.)	1–9 (1.4)		1–8 (1.4)	
% Tertiary qualification	60%	56%	61%	57%
χ^2 (5% critical value = 3.84)	3.3		2.8	
Mean number of years (st.dev.)	13.5 (2.1)		13.6 (2.0)	
Mean age (years), 18+	45.8	48.7	47.4	46.5
t-stat (5% critical value = 1.96)	-4.95		1.46	
min–max (st.dev.)	18–81 (13.7)		18–77 (14.5)	
Proportion with income levels > median household income for the population	51%	55%	41%	49%
χ^2 (5% critical value = 3.84)	3.01		11.4	
Mean income (st.dev.)	$59,600 ($35,210)		$60,800 ($36,400)	

The socioeconomic characteristics of the samples were compared with their population characteristics (ABS, 2006). The Illawarra subsample had a higher proportion of females, a larger household size, and lower mean age than the average Illawarra population. The ‘rest of NSW’ subsample had a larger household size and higher income levels than the average NSW population. The pooled sample had a higher proportion of females and a higher household size than the NSW population. These features were taken into account in the subsequent BCA. Although not representative of the population in all aspects, the sample was considered a reasonable basis on which to draw inferences for the population.

5.1 Mixed logit model results

A variety of models were estimated using NLOGIT4.0 (Econometric Software, 2007). The variables included in the final choice model are shown in Table 3.

Table 3. Variables used in the choice models

Variable code	Description
ASC	Alternative specific constant (1 for new policies alternatives)
Cost	Cost of choice alternative ($/year over 20 years)
Years	Period of time that the mine will provide 320 jobs (years)
Km	Total length of stream affected (km)
Ha	Total area of upland swamp affected (ha)
No.	Total number of Aboriginal sites affected (number)
Education	Respondent education (years)
Gender	Respondent gender (1 for female)

Tests for differences in parameter estimates and scale[5] between the Illawarra and rest of NSW subsamples revealed no significant difference between subsamples. Therefore, only the pooled model results are reported in this paper. Initially, multinomial logit models were estimated specifying linear additive utility functions. However, results from a Hausman specification test (Cameron and Trivedi, 2005) indicated that the independence of irrelevant alternatives (IIA) assumption of the multinomial logit model was rejected. Additional models were therefore specified, such as nested logit and mixed logit (ML) models. Of the tested models, the ML model that included random parameters and an error component term provided the best model fit (Table 4).[6]

In the ML model, the four nonmarket choice attributes (length of stream affected, area of upland swamp affected, number of Aboriginal sites affected, and period of time that the mine will provide 320 jobs) were defined as random

[5]Nesting of the two samples in a nested logit (NL) model resulted in an IV parameter (the ratio of the scale factors) that was not significantly different from one, indicating a nonsignificant difference in the scale parameter for each data set (Hensher et al., 2005). Likelihood ratio tests and Poe test (Poe et al., 2005) on the implicit price estimates between the pooled and subsample models also showed no significant differences.

[6] Results of these models are available upon request from the authors.

variables. Numerous distributional assumptions were tested (normal, lognormal, uniform, and triangular), of which a normal distribution performed best statistically. Similar to many other CE studies (e.g. Hanley et al., 2005; Hensher and Greene, 2003; Rigby et al., 2009), the cost attribute was specified as a fixed parameter.

The model includes a common error term for the two choices associated with 'new policies for the mine'. This shared error component term accounts for unobserved correlations between the errors of the 'new policies' options (Scarpa et al., 2007). The model specification further accounted for the repeated choices made by individual respondents by estimating the model in a panel data format. The model was estimated by simulated maximum likelihood using Halton draws with 1000 replications (Train, 2003).

Results of the best fitting model are reported in Table 4. This model includes all choice attributes, respondents' gender, and education level as explanatory variables in the utility function. Gender and education were interacted with the ASC to avoid singularity of the matrix. Including a range of additional sociodemographic variables (such as previous visitation to the area, income, household size, and being a member of an environmental organisation) were not consistently significant across models and did not significantly improve model fit (χ^2 value of 0.1 against a critical value of 9.49). These variables were therefore not included in the final model specification.[7]

The estimated attribute parameters are all significant at the 1% level with the *a priori* expected signs. The positive sign on the 'years' attribute indicates that the wellbeing of respondents increases with the length of time that the mine provides 320 jobs. The negative sign on the other choice attributes indicates that respondents' wellbeing declines with increases in the annual payment, kilometres of stream affected, hectares of swamp affected, and the number of Aboriginal sites affected. The significant standard deviations on the random parameters reflect the considerable heterogeneity in preferences towards the choice attributes.

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[7]Including additional sociodemographic variables also did not alter the implicit price estimates reported in Section 5.2 or the CBA reported in Section 6. Following recent developments in CE (see, e.g., Kragt and Bennett, 2012), a more parsimonious model was therefore specified.

Table 4.Mixed logit model results

Variable	Coefficient Mean	Standard error
Random parameters		
Years	0.1471***	0.0098
Km	–0.0927***	0.0125
Ha	–0.0084***	0.0008
No.	–0.0067***	0.0009
Standard deviations of random parameters		
Years	0.1670***	0.0113
Km	0.1123***	0.0254
Ha	0.0080***	0.0014
No.	0.0118***	0.0016
Non-random parameters		
Cost	–0.0248***	0.0020
Gender	1.7192***	0.4051
Education	1.5051***	0.3987
ASC	–1.5313***	0.4309
Standard deviation of latent random effects	4.9081***	0.3147
Log likelihood	–3478.4	
McFadden Pseudo R^2	0.326[a]	
No.[b]	4695	

[a] Compared to a constant-only base model.
[b] The total number of observations in the model estimates is less than the total number of respondents because not all respondents answered the education question.
Significance level ***: $p = 0.01$

Having more years of education and being female increase the probability of respondents choosing one of the ‘new policies for the mine’. The ASC is negative and significant at the 1% level, indicating a systematic preference for continuing mining as currently planned. The significance of the latent error component indicates considerable heterogeneity in the way that individual respondents compared the *status quo* option against the alternative policy options for the Colliery.

5.2 Implicit price estimates

The parameter estimates reported above were used to estimate implicit prices (in 2008 A$) for each of the nonmarket attributes (Table 5). The implicit prices were calculated using parametric bootstrapping techniques (Krinsky and Robb, 1986) with 10,000 replications from the unconditional parameter estimates.

These implicit prices represent respondents' household marginal willingness to pay (WTP) for a unit change in attribute levels. The results show that respondents are, on average, WTP $3.74 per household for one additional kilometre of stream remaining unharmed by mining impacts, compared to the base case scenario. Respondents are, on average, WTP $0.34 per hectare of upland swamps protected; $0.27 per Aboriginal site protected; and $5.94 for every additional year that the mine provides 320 jobs.

Table 5. Mean estimated implicit prices (A$/household/year)

Attribute	Time mine provides 320 jobs (/year)	Streams (/km)	Upland swamp (/ha)	Aboriginal sites (/site)
Population average	$5.94	$3.74	$0.34	$0.27
95% CI [a]	($4.96–$7.22)	($2.73–$4.96)	($0.27–$0.43)	($0.19–$0.36)
Illawarra subsample	$6.26	$3.01	$0.33	$0.26
95% CI [a]	($4.59–$7.92)	($1.47–$4.54)	($0.22–$0.44)	($0.16–$0.37)
Rest of NSW subsample	$5.12	$4.37	$0.36	$0.29
95% CI [a]	($3.45–$6.79)	($2.61–$6.13)	($0.24–$0.49)	($0.15–$0.42)

[a] Confidence interval

The 95% confidence intervals are in parentheses and were calculated using a Krinsky and Robb procedure with 1000 draws. The estimated willingness to pay is expressed as Australian $ are per annum per household for a 20-year period.

It may appear from the results in Table 5 that 'length of streams affected' and 'time the mine provides 320 jobs' are the most valuable attributes to respondents. However, it is important to note that the attributes are measured in different units and described in the specific context of the Colliery. Therefore, one cannot simply compare implicit price estimates either within or across studies. It is only when implicit price estimates are combined with estimates of physical impacts in the subsequent BCA that welfare impacts can be compared.

Implicit prices were also estimated for the two separate subsample populations (Table 5). Results show that – conforming to *a priori* expectations – local respondents derive more wellbeing from the knowledge that the mine will provide employment than the rest of NSW respondents. The implicit price estimates for environmental impacts is higher for the rest of NSW compared to the local subsample. However, the differences between the average value estimates of the two subsamples are not statistically significant. Therefore, population averaged implicit price estimates were used in the subsequent BCA calculations.

6. BENEFIT COST ANALYSIS

As the implicit price estimates are welfare measures that are consistent with the principles of BCA (Bennett, 2008), they can be used directly in a BCA of the mining proposal to account for nonmarket impacts. First, a BCA was undertaken without taking the impacts of subsidence on streams, swamps, and Aboriginal heritage sites into account (HCPL, 2008). In this BCA, continued mining for 25 years was compared with mine cessation in 2010 (i.e. mine cessation 2 years after the CE study). This first BCA study estimated the Net Present Value (NPV) of the producer surplus benefits of mining = revenues less capital and operating costs and opportunity costs of capital and land. Using the discount rate of 7% recommended by Government guidelines (NSW Treasury, 2007), the producer surplus was estimated at $995M. The estimate was subsequently adjusted for some environmental impacts: noise impacts (estimated using a property valuation approach), greenhouse gas impacts (using an estimated social cost of carbon), and impacts of subsidence on roads and bridges (using a repair cost approach). These externalities were shown to reduce the Colliery's net benefits to $839M (HCPL, 2008). In what follows, 'producer surplus' will refer to the producer benefits net of these environmental impacts.

During the independent strategic inquiry into continued mining at the Colliery, the results from the CE study became available. These results were used to incorporate – previously unquantified – nonmarket values into a second BCA. This extended BCA involved four steps: (1) Predicting the incremental attribute level impacts of continued mining relative to mine cessation in 2010; (2) converting the annual implicit prices per respondent household into a present value estimate; (3) estimating the WTP for the total incremental attribute level changes into a present value per household; and (4) extrapolating these values across the relevant population to estimate the community's WTP for the predicted attribute level changes.

https://doi.org/10.1515/2152-2812.1101 Published online by Cambridge University Press

(1) Predicting the incremental attribute impacts of continued mining relative to mine cessation in 2010 was undertaken by environmental consultants based on subsidence and environmental assessments of continued mining at the Colliery (HCPL, 2008). These experts predicted that 3 km of streams and 10 Aboriginal sites would be affected. The final mining project under consideration was designed in such a way that no incremental impacts on swamps would occur.

(2) The payment mechanism used in the CE questionnaire was an annual payment for 20 years. This payment mechanism matches the context of the issue, which was the potential loss of annual royalties from ongoing mining over an extended period. For use in a BCA, the stream of payments had to be converted to a present value per household, which required selection of a discount rate. There are many discussions about what discount rate should be used in BCA (Burgess and Zerbe, 2011). Individual discount rates for environmental impacts estimated in CEs have been estimated at over 30% (Windle and Rolfe, 2004), whereas Burgess and Zerbe (2011) estimated a social discount rate for the United States of between 6% and 8%. NSW Treasury (2007) recommends a social discount rate of 7%. A compromise position was initially adopted in this study for the results of the CE-based implicit prices, using the private borrowing rate for unsecured personal loans. At the time of the analysis, this rate ranged between 14.75% and 16.75%. Therefore, a discount rate of 15% was used to convert annual payments to a lump sum. A sensitivity analysis around this assumption is reported in the next section.

(3) The lump sum values of the implicit price estimates were multiplied by the predicted attribute level changes, to estimate household WTP for each attribute level change.

(4) These household-level estimates then needed to be extrapolated to the affected population[8]. This necessitates assumptions about whether nonrespondents hold the same values as those of respondents included in the sample. Some studies recommend conservative aggregation, by only aggregating WTP values to the proportion of the population given by the questionnaire response rate (see, e.g., Bennett, 2008). However, this may understate community WTP as it assumes that all nonrespondents have a zero WTP. An alternative method has been suggested by Morrison (2000), who found that approximately one-third of nonrespondents

[8] Although the pooled sample exhibited a higher proportion of females and larger household sizes compared to the NSW population, only gender was found to be a significant determinant of relative utility in the econometric models, with females having a higher WTP for attributes. Aggregation of the sample mean WTP to the population is therefore likely to overstate aggregate values, all other things being equal.

https://doi.org/10.1515/2152-2812.1101 Published online by Cambridge University Press

hold values similar to questionnaire respondents. van Bueren and Bennett (2000) support these findings in a follow-up telephone interview with nonrespondents in a CE.

The analysis in this study focused on the NSW population as the relevant community. Taking the questionnaire response rate plus one-third of the nonresponse rate equals 42% of the NSW population. In the BCA, the aggregation level was rounded up to 50% of the NSW households to ensure a precautionary approach in protecting the environmental and cultural values.

Using this approach, the environmental and cultural costs of ‘mining continuing as currently planned’ were estimated to be nearly $110M (Table 6). Thus, there are considerable costs associated with degradation of streams and Aboriginal heritage if mining continues. Nevertheless, the producer surplus benefits of continued mining at the Colliery, adjusted for noise impacts, greenhouse gas impacts and impacts of subsidence on roads and buildings, were found to outweigh the costs associated with impacts on streams and Aboriginal heritage. This indicates that – even though mining would have significant negative impacts on nonmarket values – continued mining would improve economic efficiency. The CE questionnaire also included an employment attribute that aimed to assess the nonmarket values associated with the knowledge that the mine provides employment. Despite its significance to focus groups and in econometric models, this attribute invoked some discussion during the inquiry. This discussion centred around prospects for technological change over the mine life to alter the pattern of employment both in the mine and in the region more broadly, as well as difficulties associated with disentangling nonmarket and market values associated with employment and issues of potential nonlinearity of this attribute. These concerns are being tested in a follow-up study. Conservatively, the nonmarket value of employment has been omitted from the BCA.

Table 6. Using the CE results in a benefit cost analysis

Attribute	Incremental physical impacts[a]	Conversion of annual implicit prices to present value per respondent		Present value of physical impacts per respondent	Extrapolation to the affected population[b]($M[c])
Benefits		Implicit price/year for 20 years	Lump sum value (at 15% discount rate)		
Producer surplus (net environmental impacts, 7% discount rate)					$839
Total benefit					***$839***
Environmental and cultural costs					
Streams (km)	3	$3.74	$23.42	$70.27	$89
Swamps (ha)	0	$0.34	$2.13	$0.00	$0.00
Aboriginal sites (no.)	10	$0.27	$1.70	$16.95	$21
Total cost					***$110***
Net benefit					***$729***

[a] This is the incremental physical impact of continued mining relative to the mine ceasing in 2010 – 2 years after the CE survey.
[b] 50% of the estimated 2.5 million households in NSW.
[c] The extrapolated values of estimated physical impacts were included in year 1 of the BCA calculations.

6.1 Sensitivity analysis

The sensitivity of the results was tested against a range of parameter values: using different discount rates, using lower and upper bounds of the 95% confidence intervals for implicit prices, and alternative aggregation assumptions.

The proposal was found to increase economic efficiency under a wide range of tested scenarios (Table 7). Sensitivity scenario A represents the results described in the previous section using discount rates of 4%, 7%, and 10% to estimate producer surplus benefits (these rates follow guidelines of the NSW Treasury, 2007). In scenarios B and C, we use lower discount rates of 4% and 7% for the implicit price estimates of the environmental and cultural impacts. Although the environmental and cultural cost increased to $239M under a 4%

discount rate, producer surplus benefits outweighed these cost under all discount rate scenarios. Using the upper bound of the 95% confidence intervals for implicit prices, and a 15% discount rate, resulted in environmental and cultural costs of $146M ($247M if discounted at 7%), still outweighed by producer surplus benefits. A precautionary approach to protecting environmental and cultural values could follow from the assumption that 100% of the population would hold positive values (scenario F). Aggregation of implicit prices to 100% of the population resulted in environmental and cultural costs of $220M, or $372M under a 7% discount rate assumption. Although we did not find significant differences between the subsample implicit price estimates, we analysed the sensitivity of the BCA results to distinguishing between local and rest of NSW respondents. The final scenario reported in Table 7 shows the results of aggregating the separate subsample implicit prices to their respective subpopulations. This results in environmental and cultural costs of $123M. Thus, under all of the tested sensitivity scenarios, the environmental and cultural costs of continued mining at the Colliery did not outweigh the producer surplus benefits (adjusted for greenhouse gas, noise impacts, and subsidence impacts on road and bridges). Inclusion of the nonmarket employment benefits of the Colliery would further reinforce this result.

In addition to the sensitivity analysis described here, numerous other policy scenarios were examined as part of the strategic inquiry into continued mining at the Colliery. The examined scenarios encompassed environmental restrictions on mining, to limit the mine's impacts on environmental features and cultural heritage sites. In all cases, the costs of environmental restrictions on mining (in terms of reduced producer surplus) were found to outweigh the environmental and cultural benefits. Inclusion of the nonmarket employment costs from a reduction in mine life as a result of the environmental restrictions would further reinforce this result.

Table 7. Sensitivity testing for benefit cost analysis results (in $M)

Sensitivity scenario	Costs and benefits	Discount rate for producer surplus estimates 4%	7%	10%
A. Core analysis (15% discount rate used to calculate NPV of implicit prices; IPs)	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$110	–$110	–$110
	Net benefits	$1134	$729	$479
B. 4% discount rate for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$239	–$239	–$239
	Net benefits	$1005	$600	$350
C. 7% discount rate for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$186	–$186	–$186
	Net benefits	$1058	$653	$403
D. Upper 95% CI for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$146	–$146	–$146
	Net benefits	$1098	$693	$443
E. Upper 95% and 7% discount rate for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$247	–$247	–$247
	Net benefits	$997	$592	$342
F. 100% aggregation for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$220	–$220	–$220
	Net benefits	$1024	$619	$369
G. 100% aggregation and 7%discount rate for IPs	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$372	–$372	–$372
	Net benefits	$872	$467	$217
H. Aggregation of split-sample IPs to individual sub-populations	Producer surplus benefits	$1244	$839	$589
	Environmental and cultural impacts	–$123	–$123	–$123
	Net benefits	$1121	$716	$466

7. CONCLUSION

The study described in this paper demonstrates how nonmarket value estimates can be incorporated in an extended BCA of underground coal mining in the Southern Coalfield of NSW, Australia. Results from a CE survey were used to estimate nonmarket values for environmental, cultural, and social attributes impacted by continued coal mining in the Southern Coalfield. The study was commissioned by a private sector company to assess the impacts of their continued mining operations. The results indicate that community wellbeing declines with increases in the kilometres of stream affected, hectares of swamp affected, and the number of Aboriginal sites affected by the mine. Community wellbeing increases with the knowledge that the mine provides continued employment.

CE involves directly surveying representatives of the community and can hence provide robust quantitative estimates of community values to support decision-making. CE allows an estimation of nonmarket values in monetary terms, which can be directly incorporated into BCA, such as the proposal to continue mining at the Colliery. CE can therefore enhance the role of BCA as a decision support tool for policy makers, to examine the social welfare impacts of alternative policy proposals. Results of the BCA for the Colliery in the Southern Coalfield indicate that the present value of the benefits of continued mining (in terms of producer surplus) outweigh the costs of mining damages to environmental attributes and cultural heritage. This result is robust to a range in parameter values. The BCA framework was also used to analyse the impacts of imposing a range of environmental restrictions on mining activities in the Southern Coalfield. Incorporating nonmarket values, we found that the costs of imposing environmental restrictions on the continued operation of the Colliery outweigh the environmental and cultural benefits. Notwithstanding this finding, a move from a potential Pareto improvement to an actual Pareto improvement can be obtained if the Colliery takes steps to internalise the environmental and cultural costs through impact remediation as well as environmental and cultural offsets.

There are currently no published studies that have estimated the environmental, cultural, and social impacts of underground coal mining. The results of the study presented here are therefore not only useful to specific consideration of underground mining in the Southern Coalfield but can also help governments to evaluate other underground mining proposals in Australia and beyond. Although site-specific studies will generally yield more accurate estimates, the nonmarket values reported in this paper can be used for future benefit transfer exercises of underground coal mining provided that sites, population, and policy scenarios are similar (Colombo et al., 2007).

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