Valuing the Non-Market Impacts of Underground Coal Mining

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Abstract

A strategic inquiry into underground coal mining in New South Wales, Australia, identified the need for non-market valuation studies and recommended increased use of benefit cost analysis in assessing individual mining proposals. This paper reports on the results of a choice experiment undertaken for a mine in the Southern Coalfield of New South Wales. Results from the study are used to aid the government decision by evaluating alternative proposals to continue underground coal mining operations. Results show that community wellbeing declines with increases in the kilometres of streams, the hectares of swamp, and the number of Aboriginal sites affected by mine subsidence. Community wellbeing increases with the length of time that the mine provides 320 jobs. Implicit price estimates from the choice experiment were incorporated into a benefit cost analysis of continued mining at the mine to assess the economic efficiency of a range of environmental restrictions on the proposed mining operations. Even though the mine generates negative environmental externalities, the continuation of mining was found to be economically efficient under a range of policy scenarios.

Key words: Australia, benefit cost analysis, coal mining, choice experiments, natural resource management, non-market valuation

JEL codes: D61, Q32, Q38, Q51

1. Introduction

Coal mining in Australia is under increasing scrutiny in response to community concerns about global warming and other potential environmental impacts of mining. This has manifested itself in a policy requirement for existing mines to obtain consent from Government to continue to operate. This consent process includes the submission of an environmental assessment that incorporates analysis of the environmental, economic and social impacts of mining operations.

An important element of robust assessment of mining projects is the consideration of economic efficiency using benefit cost analysis (BCA). The BCA framework aims to assess the trade-offs between all the benefits of a change in resource use and the costs, including impacts on community wellbeing (Hanley and Barbier, 2009). In the context of a coal mine, 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 intangible values that are not traded in markets, such as environmental, cultural and social features. Estimating the values of such impacts on the community requires the use of non-market valuation methods.

The study described in this paper, uses a non-market valuation technique known as discrete choice experiments (CEs) to assess community preferences for the impacts of underground coal mining in the Southern Coalfield of New South Wales. There are currently few studies that have estimated non-market value of the 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 measured impact on local house prices, the monetary environmental costs of opencast coal mining could substantially reduce mining's economic viability. While CEs have been used to evaluate people's preferences in vehicle choice, environmental, health and tourism contexts (see, for example, Axsen et al., 2009; Hanley et al., 2005; Hole, 2008; Scarpa et al., 2008), its application to mining appears limited to a study by Ivanova et. al. (2007) on the impacts of mining on migration, employment, town services and

medical facilities in a rural Queensland community. To the authors' best of knowledge, there are no previously published CE studies that have estimated community values for environmental, cultural and social impacts of underground coal mining.

A unique feature of the study described in this paper, is the application of a CE at the behest of the developer causing environmental externalities. In Australia, most CE applications to date have been commissioned by government agencies or research organisations that often have an interest in curtailing extractive resource uses. This is the first known example in Australia where a commercial developer has used CE to value the externalities of its business proposal.

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

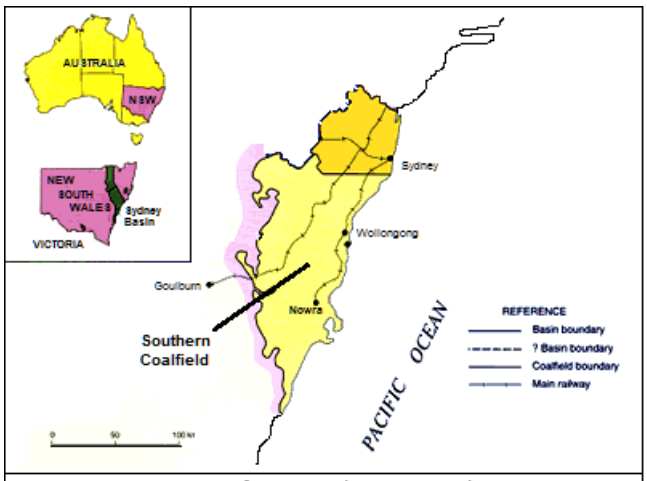
2. Policy context

The Southern Coalfield (15,000km^2) in New South Wales (NSW), Australia, extends from the south of Sydney, past Nowra on the south coast, and east of Goulburn (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). The *EPA Act 1979* stipulated that existing mines in the Southern Coalfield 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 have development consent under the *EPA Act 1979*, were required to obtain project approval by December 2010 to enable continuation of mining (NSW Government 2009b). The project approval process includes the submission of an environmental assessment that addresses the environmental, social and economic impacts of continued mining (NSW Department of Planning, 2008).

Figure 1 – Southern Coalfield of New South Wales, Australia



Source: NSW Department of Primary Industries, Mineral Resources Division

Concerns have been raised about the impacts of underground workings of the 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 concerns over past and potential future 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 projects that would be forthcoming under *SEPP 2005*. This inquiry focused on 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 stated that non-market 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, pg 106).

3. Methodology

3.1 Benefit Cost Analysis

Benefit Cost Analysis (BCA) provides a decision tool to evaluate regulatory proposals by comparing the economic efficiency of alternative policy investments. BCA is widely used to assist with choices involving public and private projects (Hanley and Barbier, 2009). BCA can help decision makers to make more efficient use of available resources and increase the well-being or welfare of the community.

In a BCA, all the marginal social costs and benefits of a proposed project and alternative actions are systematically assessed and compared. A proposal is considered to be economically efficient if the aggregate incremental benefits of a proposal exceed the aggregate social costs. Where a number of alternatives are examined, the alternative with the highest net benefits is the most desirable in terms of economic efficiency. 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.

A BCA of underground coal mining projects involves a comparison of the incremental producer surplus benefits of coal mining and the incremental environmental, cultural and social costs (reduced consumer surplus). The policy debate around mining proposals typically revolves around the restrictions that should be applied to reduce the environmental, cultural and social impacts of a mine. BCA can be used to assess the economic efficiency of imposing such environmental restrictions, as they inevitably involve a trade-off between the level of environmental, cultural and social costs of a mine and the quantity of coal recovered or costs of production.

The producer surplus impacts of mining restrictions can be readily estimated through market data on capital costs, operating costs and revenues. The estimation of environmental, cultural and social costs or benefits requires the use of non-market valuation methods, such as choice experiments.

3.2 Choice Experiments

Discrete choice experiments (CEs) are a form of conjoint analysis where respondents are asked to choose their preferred alternative from a set of choice options (Adamowicz et al., 1998). Consistent with Lancaster's 'characteristic theory of value' (Lancaster, 1966), it is assumed that individual *i* derives utility U_{ijt} from the attributes that describe each alternative option *j* in choice situation *t,* as a latent variable that is observed indirectly through the choices people make:

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

where ε_{ijt} is a normally distributed error term, and $\boldsymbol{x_{ijt}}$ is a vector of explanatory variables which can include the attributes of the alternatives, individual *i*'s socio-demographic and behavioural characteristics and features of the choice task itself (Hensher and Greene, 2003). By including cost as one of these attributes it is possible to estimate respondents' willingness to pay (implicit price) for changes in the levels of individual attributes (Hanley et al., 1998). 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. Alternative *j* will be chosen if, and only if, the utility derived from that option is greater than the utility derived from any other alternative *z*. 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*.

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 including a vector of individual-specific random parameters β_i'. The random parameter for the *k*th attribute faced by individual *i* is:

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

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).

As well as random parameters, the ML model can include latent error component terms that can capture unobserved heterogeneity that is alternative- rather than individual-specific (Greene and Hensher, 2007). Specifying a common error component term for different 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. But 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 control for unobserved heterogeneity across the choices made by the same individual, by including an individual specific error term that is correlated across the sequence of choices made by an individual. A panel specification accounts for systematic, but unobserved correlations in an individual's unobserved utility over repeated choices (Revelt and Train, 1998).

4. Survey development

A CE survey 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 currently provides direct jobs for 320 people. The status quo option included

in the survey was described as "mining continues as currently planned for a period of 25 years", in which case the Colliery will continue to provide jobs, but it may 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. The survey describes several policy alternatives to the status quo of 'mining continues as currently planned' that aim to reduce the environmental and cultural impacts of the Colliery. These include mine cessation; limiting the geographical extent of mining; or requiring future mining to avoid areas that are located below or adjacent to significant natural features.

After deciding on the policy scenarios, a set of attributes needed to be defined to describe the potential environmental, cultural, and social impacts of each scenario. Initial review of the literature on coal mining in the Southern Coalfield and meetings with the Colliery management and its environmental consultants elicited the following potential impacts of continued mining as a result of subsidence:

- 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;
- Loss of water from the catchment;
- 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;

The first five attributes are correlated, and result from the cracking of stream beds due to mine subsidence. An important requirement of attribute definition in CEs is that the attributes

presented in the survey 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'. The nature of effects were described as including cracking, draining of pools, reduced water flow in streams, iron staining and ecological impacts.

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 had had no discernable effect on the inflow to, or yield from, the reservoir (HCL, 2008). This conclusion was supported by the Southern Coalfields Panel Inquiry (NSW Department of Planning 2008). Consequently, loss of water from the catchment was not included as an attribute in the CE questionnaire. The potential impacts of mining on upland swamps and on Aboriginal heritage sites were considered as attributes in the survey development.

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 for another 25 years, while the lower bound represents the cumulative level of historical and future impacts if the mine would cease operations in two years time.

Four focus group sessions were held to refine the questionnaire designs; two on 30 July 2008 in Sydneys and two on 31 July 2008 in Wollongong. These confirmed the relevance of the environmental and cultural attributes but also stressed the importance of employment opportunities that may be impacted by alternative mining scenarios. The CE survey developed for this study therefore not only aimed to estimate values associated with environmental and cultural impacts of the Colliery, but also included a social attribute, namely the 'length of time that the mine provides 320 jobs'. A number of previous studies have used non-market valuation methods to estimate community values for social changes. For example, Johnson and Desvouges (1997) estimated the non-market 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***
Cost	Annual payment ($) 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 number of Aboriginal sites affected	Number of Aboriginal sites (No)	**270;** 220; 160; 100
Period of time that the mine will provide 320 jobs	Number of years (Years)	**25;** 18; 10; 2

* Attribute levels for the status quo of mining continues as currently planned in bold

A cost attribute was also added to the design. Various payment scenarios and vehicles were pretested during the focus group discussions. The final payment scenario presented to respondents 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 to limit the future environmental and cultural impacts of the Colliery would restrict coal production and the royalties and taxes received by the State Government. This in turn decreases the level of public services provided by government. To reduce environmental and cultural impacts of the Colliery and 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. Hence, the payments for policy alternatives to secure environmental

and cultural protection would 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. Focus group participants accepted the need to make additional payment to reduce the impacts of the existing mine operation and did not raise issue with the presented payment scenario. The final attributes and their levels 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 5 choice sets embedded into 5 blocks of the questionnaire. Each choice set comprised three choices:

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

The questionnaire was administered using a web-based survey, with a sample drawn from an existing panel of pre-stratified and registered respondents.[1] To test whether values differ between communities located inside and outside the region directly affected by a proposal, the sampling strategy targeted a sub-sample from the Illawarra Region, where the Southern Coalfield and the Colliery are located, and a sub-sample from the rest of NSW. The sampling strategy was aimed at obtaining 100 completed questionnaires per block for each of the sub-samples.

[1]The online panel of I-View, a market and social research data collection company, was used. As an aside, Nielsen (2011) recently showed that results are similar between face-to-face interviews and web-based survey modes.

5. Results

The link to the CE questionnaires was distributed between the 2nd and 21st October 2008. A total of 7,553 questionnaires were distributed, of which 1,028 completed questionnaires were returned (Table 2). The questionnaire included a question to determine potential protest responses against the presented payment vehicle.[2] The protest rate was 2% of respondents, which is lower than protest rates found in other environmental valuation studies (see, for example, Bateman et al., 2009; Czajkowski, 2010; or Hanley et al., 2003).

Table 2 – Sample Statistics

	Illawarra		**Rest of NSW**	
	Sample	**Population**	**Sample**	**Population**
N (completed questionnaires)	525		503	
Gender (% male ≥ 18)	25%	48%	50%	49%
X^2 (5% critical value =3.84)	116		1	
Household Size	3.2	2.5	2.8	2.6
t-stat (5% critical value = 1.96)	10.5		3.1	
% Tertiary qualification	60%	56%	61%	57%
X^2 (5% critical value =3.84)	3.3		2.8	
Mean age 18+	45.8	48.7	47.4	46.5
t-stat (5% critical value = 1.96)	-4.95		1.46	
Proportion with income levels greater than the median household income for the population	51%	55%	41%	49%
X^2 (5% critical value =3.84)	3.01		11.4	

[2] Protest responses express a zero willingness to pay in protests against some aspect of the questionnaire, rather than a true expression of willingness to pay. Such responses are excluded from the analysis.

The socioeconomic characteristics of the samples were compared with their population characteristics (ABS, 2006). The Illawarra sub-sample had a higher proportion of females, a larger household size and lower mean age than the average Illawarra population. The rest of NSW sub-sample had a larger household size and higher income levels than the average NSW population.

5.1 Mixed logit model results

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

Table 3 – Variables used in the Choice Models

Variable code	Description
ASC	Alternative Specific Constant (1 = new policies alternatives)
Cost	Cost of choice alternative ($ pa 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 = female)

Tests for differences in scale between the Illawarra and rest of NSW sub-samples indicated that the scale parameters were not significantly different between sub-samples.[3] Therefore, only the pooled model results are reported in this paper. Initially, conditional 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 conditional logit model was rejected. Additional models

[3] 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 an insignificant 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 sub-sample models also showed no significant differences.

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.[4]

In the ML model, the four non-market 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 variables. A number of 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), the cost attribute was specified as a fixed parameter.

The error component term accounts for unobserved correlation between the errors associated with the new resource use options for the Colliery (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 1,000 replications (Train, 2003).

A range of socio-demographic variables were initially included in the model (such as previous visitation to the area, income, having children and being a member of an environmental organisation). Variables that were not significant are not included in the final model specification. Results of the best fitting model are reported in Table 4. This model includes all choice attributes, except cost, as random variables, and includes respondents' gender and education level as explanatory variables in the utility function for the 'new policies' options.

The estimated attribute parameters are all significant at the 1% level with the *a priori* expected sign. 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 the wellbeing of respondents 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.

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

Table 4 – Mixed Logit model results

Variable	Coefficient Mean	Standard Deviations of Random Parameters
Random Parameters		
Years	0.15***	0.17***
Km	-0.09***	0.11***
Ha	-0.01***	0.01***
No	-0.01***	0.01***
Non-random Parameters		
Cost	-0.02***	
Gender	1.72***	
Education	1.51***	
ASC	-1.53***	
Standard Deviation of Latent Random Effects	4.91***	
Log likelihood	-3796	
McFadden Pseudo R^2 [(a)]	0.33	

Significance levels: *p = 0.1, **p = 0.05, ***p = 0.01; [(a)] Compared to a constants only base model

Having more years of education and being female increase the probability of respondents choosing one of the 'new government decisions for the mine'. The ASC is negative and significant at the 5% level, indicating a systematic preference for continuing mining as currently planned. However, the significance of the latent error component indicates individual heterogeneity in the way respondents evaluate the status quo option, compared to the alternative resource use 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 non-market attributes (Table 5).

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

Attribute	Mean	95% Confidence Interval
Streams (km)	$3.74	($2.48 - $5.41)
Upland swamp (ha)	$0.34	($0.25 - $0.45)
Aboriginal sites (no)	$0.27	($0.17 - $0.39)
Time mine provides 320 jobs (yrs)	$5.94	($4.67 - $7.84)

The 95% confidence intervals are in brackets and were calculated using a Krinsky & Robb procedure (Krinsky and Robb, 1986) with 1,000 draws.

The results show that respondents are, on average, willing to pay $3.74 per km of stream protected; $0.34 per hectare of upland swamps protected; $0.27 per Aboriginal site protected; and $5.94 per year that the mine provides 320 jobs (all estimates 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 defined in different units so a simple comparison of implicit price estimates is not possible (Bennett and Adamowicz, 2001).

6. Benefit Cost Analysis

Initially, a BCA was undertaken to compare continued mining for 25 years, versus mine cessation in 2010 (HCL, 2008). This initial BCA study estimated the producer surplus benefits of mining (revenues less capital and operating costs and opportunity costs of capital and land) at $995M. This estimate was subsequently adjusted for noise impacts (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), resulting in a net benefit estimate of the project at $839M (HCL, 2008). However, this value did not include the impact of subsidence on streams, swamps and Aboriginal heritage sites. The Government's Planning Assessment Commission (PAC) inquiry into continued mining at the Colliery made use of the implicit price estimates from the CE study. The implicit price estimates reported in Table 5 are welfare measures that are consistent with the principles of BCA (Bennett, 2008). They can be incorporated in the analysis, to extend the BCA of mining proposals at the Colliery to incorporate previously unquantified environmental, cultural and social impacts. The BCA of the Colliery involves: (1) Predicting the incremental attribute level impacts of continued mining relative to mine cessation in 2010; (2) Converting the annual implicit price estimates into present values; (3) Estimating household willingness to pay for the total attribute level changes in present value terms; and (4) Extrapolating across the relevant population to estimate the community's willingness to pay for the predicted attribute level changes.

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 (HCL, 2008). These experts predicted that three kilometres of streams and ten Aboriginal sites would be affected. Contrary to assessments of previous proposals, the final mining project under consideration was designed to have no incremental impacts on swamps.

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 must be discounted to a present value, requiring selection of a discount rate.

There are many discussions about what discount rate should be used in BCA (Boadway, 2006). Individual discount rates for environmental impacts have been estimated at over 30% (Windle and Rolfe, 2004), well above those recommended by State agencies. For example, the NSW Treasury (2007) recommends a social discount rate of 7%. A compromise position was initially adopted in this study, based on 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.

The present values of the implicit price estimates were multiplied by the predicted attribute level changes, to estimate the respondent household willingness to pay for each attribute level change. These household-level estimates then need to be extrapolated to the affected population. Extrapolation presents a number of challenges since household willingness to pay estimates are based on a sample, without information about the entire population from which the sample is drawn. This necessitates assumptions about whether non-respondents hold the same values as those of respondents included in the sample. Some studies recommend conservative aggregation, by only aggregating willingness to pay values to the proportion of the population given by the survey response rate (see, for example, Bennett 2008). However, this may understate community willingness to pay as it assumes that all non-respondents have a zero willingness to pay. An alternative method has been suggested by Morrison (2000), who found that about one-third of non-respondents hold values similar to survey respondents. Van Bueren and Bennett (2000) support these findings in a follow-up telephone interview with non-respondents in a CE.

In this study, the survey response rate plus one third of the non-response rate is equivalent to 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 valuing the environmental, cultural and social values.

Using this approach, the environmental and cultural costs of 'mining continuing as currently planned' are estimated to be $110M. The social values of employment provided by continuation of the Colliery are estimated to have an economic value of $1.1B (Table 6). The benefits of continued mining at the Colliery were found to outweigh the costs, indicating that the continuation of mining is economically efficient.

Table 6 – Application of CE results in a Benefit Cost Analysis

Attribute	Incremental physical impacts[(a)]	Conversion of annual implicit prices to Present Values		Present value of physical impacts	Extrapolation to the affected population[(b)] ($M)
		Implicit price/yr for 20 yrs	Present value (at 15% discount rate)		
Streams (km)	3	$3.74	$23.42	$70.27	$88.50
Swamps (ha)	0	$0.34	$2.13	$0.00	$0.00
Aboriginal sites (no)	10	$0.27	$1.70	$16.95	$21.35
Years of mine life (yrs)	23	$5.94	$37.18	$855.22	$1,077.11

[(a)]This is the incremental physical impact of continued mining relative to the mine ceasing in 2010; [(b)]50% of the estimated 2.5 million households in NSW.

6.1 Sensitivity Analysis

The sensitivity of the results was tested against a range of parameter values. The proposal was found to be economically efficient under a wide range of scenarios. Using a discount rate of 7% results in environmental and cultural costs of $186M and employment benefits of $1.8B. Using the upper bound of the 95% confidence intervals for implicit prices results in environmental and cultural costs of $159M ($269M if discounted at 7%) and employment benefits of $1.4B ($2.4B if discounted at 7%). Aggregation of implicit prices to 100% of the population gave environmental and cultural impacts of $220M and employment benefits of $2.1B. Even with omission of the social values of employment[5], the environmental and cultural costs under these sensitivity scenarios do not outweigh the estimated producer surplus benefits (adjusted for greenhouse gas, noise impacts and subsidence impacts on roads and bridges) of $839M.

The CE implicit prices were further used to examine the economic efficiency of environmental restrictions on mining to limit minig impacts on environmental features and cultural heritage sites. These restrictions would come at the expense of producer surplus benefits of mining and

5 The inclusion of this attribute invoked some discussion from the PAC despite its significance to focus groups and in econometric models. 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 issues of potential non-linearity of this attribute. These concerns have been tested in a subsequent study. For this study, sensitivity testing included omission of this value.

would reduce the length of time that the mine provides employment. Numerous environmental restriction scenarios were examined as part of the PAC inquiry into the continuation of mining at the Colliery. In all cases, the costs of environmental restrictions on mining (in terms of reduced producer surplus benefits) were found to outweigh the environmental and cultural benefits.

7. Conclusion

This study described in this paper uses a CE survey to estimate the values for environmental, cultural and social attributes impacted by underground coal mining in Australia. The study was commissioned by a private sector company to assess the impacts of continued mining operations in the Southern Coalfield, NSW. 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. Community wellbeing increases with the length of time that the mine provides 320 jobs.

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 community values in monetary terms, which can be directly incorporated into benefit cost analyses, such as the proposal to continue mining at the Colliery. CE can therefore enhance the role of BCA as a useful aid to decision-makers, helping decision-makers to examine the economic efficiency of management proposals and the economic efficiency of alternative policies. Results of the BCA indicate that the present value of the benefits of continued mining outweighs the costs. This result is robust to a range in parameter values. BCA was further used to analyse the impacts of imposing environmental restrictions on mining activities. Incorporating the CE implicit prices, we found that the costs of imposing environmental restrictions on the continued operation of the Colliery outweigh the environmental and cultural benefits.

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 also for benefit transfer exercises to other underground mining proposals in Australia and beyond.

The study presented in this paper considers the context of one coal mining proposal in the Southern Coalfield. Future non-market valuations of mining proposals are required to assess the cumulative environmental and cultural impacts on community values of all mining activity in the region, rather just the impacts of a single mine. Other avenues for future research involve the implication of using different temporal payment mechanisms; and further discussions regarding the significance and relevance of including social attributes such as employment.

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