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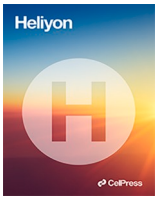

Research article

Extract or conserve? The Hartwick-rule and sustainable environmental governance

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A R T I C L E I N F O

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A B S T R A C T

The legal safeguards for sustainable environmental governance are often inadequate, inefficient, and amenable to political maneuverings. Australia recently approved the Carmichael coal mine, rail, and expansion of the Abbot Port projects. These projects, along with many others in the region, have dire consequences for the groundwater system (Currell et al., 2017) [5], the Great Barrier Reef (Kroon et al., 2016; Grech et al., 2016) [6,7], and climate change (Taylor and Meinshausen, 2014) [8]. Here we show that incorporating the Hartwick-rule in economic analysis renders many of these projects unviable with or without the opportunity and externality costs. The Hartwick-rule dictates that exhaustible resource extraction can ensure weak sustainability if resource rents can be invested in such a way that the produced capital outweighs the consumed natural capital (Hartwick, 1977) [9]. We put forward two main arguments; one, resource rents belong to the society and many projects are only viable when these rents are invested with a certain growth rate; second, economic analysis shall incorporate the Hartwick-rule and shall be applied prior to recourse to the legal safeguards. Our analysis can be applied to any non-renewable natural resource extraction decision making.

1. Introduction

Mining of non-renewable [1-4]natural resources in proximity of sensitive environmental assets presents a complex environmental governance challenge. The extraction of exhaustible natural resources often results in irreversible damage to the environment. The environmental legal framework in many countries requires identifying and evaluating the adverse environmental consequences of various development proposals prior to decision making [5]. However, the precise nature and cost of damage are often shrouded in mystery. Given the ecological complexities and difficulties of valuation, purely regulatory approaches to environmental governance often fail to achieve three main developmental goals recommended by OECD, *efficiency*, *sustainability*, and *equity* [1].

However, governments across the world are failing to meet these criteria. Firstly, the legal safeguards in the form of Environmental Impact Assessment (EIA) for preserving, protecting, or mitigating adverse environmental impacts of exhaustible resource extraction remain inadequate and inefficient [1–4,6,7]. Secondly, government departments responsible for project appraisals do not carry out rigorous scientific or economic analysis from a sustainability point of view and such decisions are often politically motivated [8–11]. Finally, various tax regimes fail to collect "reasonable" revenues from resource rents [12]. More importantly, resource rents belong to the resource owners, the society at large and not the mining firms [13–15]. While there is a rich literature on natural resources and property rights in political science and economics [16], the issue has not received sufficient attention in the environmental governance

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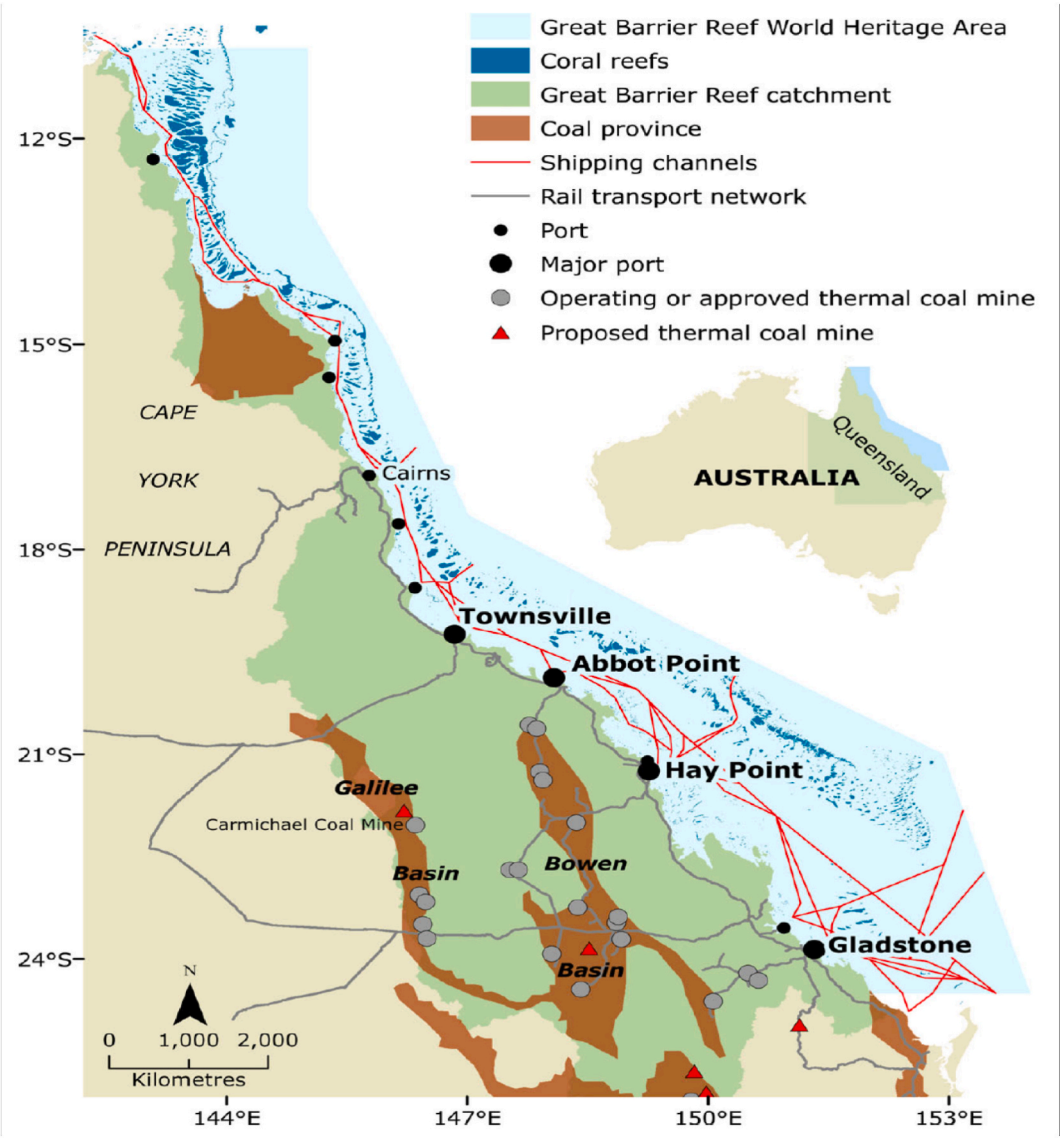

Fig. 1. The Galilee Basin and the GBRWHA. Source: Grech, A., Pressey, R. L. & Day, J. C. Coal, Cumulative impacts, and the Great Barrier reef. *Conserv Lett* **9**, 200–207, (2016).

literature [17,18].

The Carmichael Mine and Rail Project (CCMRP) in the Galilee Basin of Queensland (Australia) is a representative case of several others in Australia and across the world. The project has serious damaging consequences for climate change, the Great Barrier Reef World Heritage Area (GBRWHA), the Great Artesian Basin (Australia's largest groundwater aquifer), endangered species, and socio-economic impact on the rights of indigenous landowners [19]. Despite a near consensus among the scientific community about the irreversible environmental damage that this and other projects in the region would cause [12,20,21,22–28], the developer and the government managed to overcome the legal challenges and sidelined various scientific assessments [4].

Our analysis shows that incorporating the Hartwick-rule [29,30], applied through the Resource Rent Tax (RRT) [31], not only offers an efficient, sustainable, and equitable development path, but also serves as a default safeguard against environmental damage. In that, when opportunity costs, resource depreciation, and discount rates are taken into consideration, many of such mining projects become economically unviable with or without costs of environmental externalities. Nevertheless, for the successful projects, the revenues generated through the RRT must be reinvested for the development of natural or produced capital to ensure a sustainable path of development.

2. The CCMRP and the failure of legal safeguards

The CCMRP was proposed in 2010 with an estimated investment of USD 12.3 billion, making it among the largest in the world. It includes coal processing facilities, waste water treatment dams, water supply infrastructure, and a 200 km railway line corridor that connects the mine to the existing railway network leading to the Abbot Point port on the northeast coast of Australia within the GBRWHA (Fig. 1). The project includes six open-cut pits and five underground mines with coal production capacity of 40 million tons per annum (mtpa). The CCRMP is expected to extract some 2.3 billion tons of coal over a 60-year period.

The CCMRP was declared a "significant project" therefore requiring an EIA. After a four years long process, the federal Minister for Environment approved the CCMRP as a "controlled action" subject to 36 conditions under the Australian federal Environmental Protection and Biodiversity Conservation Act 1999 (EPBCA) in July 2014. The project was challenged in courts on various grounds but eventually was approved in June 2019. The Labour government support for the project was so strong that it called lawsuits "vigilante litigation", "political vendetta", and "campaign of harassment" [32]. The government even proposed to amend the EPBCA 1999 to prevent the lawsuits once projects have been approved. On the other hand many concerned scientists, economists, and environmental activists have alleged the government and the developer to have used pressure tactics to silence or sideline economic and environmental concerns [4].

Various court proceedings and scientific reviews have expressed the following environmental concerns.

- The extreme use of some 12 billion liters of water per year from both surface and ground water sources, this amounts to a total ground water depletion of some 300 billion liters [33].
- Australia's largest groundwater aquifer, the Great Artesian Basin and Doongmabulla Springs face degradation [20,33].
- The deposition of dredging spoils are a potential damage to the GBRWHA into the Pacific Ocean [34,35].
- The loss of endangered species [36].
- The min also conflicts with the rights of traditional land owners and Native Title
- Greenhouse gas emissions [37].

The Minister in his approval played down the damage to the Great Barrier Reef, groundwater, and climate. There is ample scientific evidence from within the Australian and international scientific community on the damage to the underground water system and to the GBRWHA [12,20,21,22–28].

Despite having won the environmental and Native Titles court cases, the Adani group faced serious financial challenges and the economic analysis of the project was questioned[13]. The presiding judge concluded that "the applicant has overstated certain elements of the benefit of the mine in the EIA" (p. 129) [19]. The two party joint expert report highlighted that the economic analysis was "deficient because … it did not provide any insight into the financial viability, economic efficiency or wider social implications of the project … ignored the opportunity costs" (p.116) [e.d.]. Furthermore, the company failed to secure investments and insurance as close to thirty international investment banks backed down from the Galilee Basin projects citing financial unviability of projects and corporate strategy to divest from coal [11].

As a result, the project has been significantly scaled down (now approximately USD 3.7 billion, 30 year time frame with 27 mtpa output) and solely financed by the parent Adani group with substantial subsidies and loans from the Australian government [1]. The Adani group applied close to AUD 1 billion government funding to build the railway line. Through special legislation, the group was allowed deferred royalty payments amounting to AUD 900 million on low interest for seven years along with billions of dollars in subsidies that include free and unlimited access to water, fuel tax credits, road construction to the mine, and end of mine life rehabilitation[15].

3. Methods and modeling

For simplification purposes, we employ the Hotelling [29,38] assumptions of uniform resource quality/extraction-effort and constant prices such that marginal costs (MC) are equated with average costs (AC). The marginal cost function remains constant over time or increases stepwise in discrete time periods due to low quality of resource or high extraction-effort with increasing variable costs. The net benefit (NB) to resource owners is defined [13] in Eq. (1) below under the assumption that a fully foreign owned firm is likely to repatriate all profits and for the host society the net benefit is only corporate tax (τ) and Royalty payments (RP).

$$NB = \tau * (PQ - AC - OC - NP) + RP - OP \quad (1)$$

Where,

τ = Corporate tax rate.
PQ = Revenue.
AC = Annualized capital.
OC = Operating costs.
NP = Normal profit.
RP = Royalty payments.
OP = Opportunity cost of other uses (including preservation, alternative uses, or cost of externalities, we discuss this in the analysis)

We calculate the AC by standard accounting method using discount rate (δ) and time-period (T) in equation (2):

Table-1
Baseline and alternative inputs for economic analysis.

Features	Baseline	Sensitivity analysis
Exchange rate AUD/USD	0.75 (10 year average)	0.75
Mine life	60 years	30 years
Total output	2.3 billion tons	810 million tons
Annual Output	40 million tons	27 million tons
Average coal price	USD 75/t[a]	USD 90/t
Capital	USD 12.3 billion	USD 3.75 billion
Corporate tax rate	30 %	30 %
Royalty Payment	7 %	7 %
Discount rate	7 %	4 %
Normal Profit	15 %	15 %
Estimated costs of environmental externalities		
Carbon emissions CO_2	Annual 1.437 million tons (operations) 78.833 million tons (including burning of coal)[8]	
Carbon price	USD 94.5/t Adani estimates[41]	
Opportunity Cost of Agriculture	Assumed to be [a]20 Million/year[18]	
Opportunity Cost of rehabilitation (exemption provided to the Adani)	USD 1.07 billion Queensland government estimates	
Opportunity Cost of water	USD 0.10/million liter (1/200th of the current Queensland river water price)	
The potential damage to the GBRWH, groundwater, endangered species, water contamination and flood risk, etc.	Not estimated, nevertheless the expected value of damage to the GBRWH alone = 4.2 USD billion Adani estimates[41]	

[a] Past (2010–20) and futures' (06/2020-12/2026) average Newcastle coal price, a figure used by the Treasury and the Adani. We do not include a low-quality discount rate included by experts from both parties in the court.

$$AC = (CC * \delta) \,/\, \left(1\text{-}(1+\delta)^{-T}\right) \tag{2}$$

Given the production cost estimates by the Adani of USD 52/t, we can calculate the operating costs without adjusting for inflation and capital depreciation by multiplying it with annual output. The term normal profit (NP) includes payments to management, dividends to shareholders, and the cost of capital such that revenue – cost = 0. Abnormal profits emerge when prices are higher than marginal cost (MC). Two sets of MC as break-even prices would be that (a) removes any abnormal profit and (b) removes normal profit rendering the firm unable to meet its obligations.

The net benefits (NB) to the host state would be primarily fiscal revenue (see equation (3)). This is because the foreign firm is assumed to remit the relevant share of income back. Hence the net income accruing to the host state (NB) is defined as:

$$NB = [\alpha\tau(PQ - AC - OC - NP)] + [(1\text{-}\alpha)(PQ–AC–OC–NP)] + RP \tag{3}$$

Herein, the we assume that the new capital is generated by investing entirety of NB each year. That is, $[I_t = (NB_t)]$. As equation (4) shows the perpetual inventory method to estimate the accumulated capital stock, K_T (valued at constant resource price P), as follows:

$$K_T = K_{(t-1)}(1+\rho) + I_t - \delta K_{(t-1)} \tag{4}$$

In equation (3), investments grow at a rate of ρ over time and accumulating investment depreciates at the rate of δ. We assume as per custom that δ is 1/30 assuming a 30 year life span of the project. The newly created capital stock (K_T) is estimated for discrete values of ρ (e.g. 1, 2, 3 … n).

Since the society is consuming natural stock, for this consumption to be weakly sustainable, K_T shall offset the depreciation of the natural resource. Hartwick (1977, 1978, 1990), and Solow (1986), argue that the economic rents from mining operations must be invested in the creation of new assets. Only then, the newly created asset can offset the depreciation of mineral asset. If the initial size of a mineral reserve is Q, and its unit price is P, then, initial value of the resource stock is (PQ). As per equation (5), if NB is progressively invested then a new capital stock K_T is generated. In this case the depreciation of the mine is defined as:

$$D = (PQ\text{-}K_T) \;/\; T \tag{5}$$

The earnings (E) from the extraction of a natural resource from its stock then needs to be adjusted for depreciation (D) of the stock. In that NB = (E − D).

For the argument that natural resources are only valuable when extracted and they have no value when left underground. We set PQ = 0 and K_T equals the total of all externalities and opportunity costs. The quantitative accumulation of externalities may result in qualitatively different natural catastrophe, however, that is beyond the scope of analysis offered in this paper.

Table-2
Economic analysis of 60 year project.

Coal price	$75	$90	$75	$90
Discount rate	**7 %**	**7 %**	**4 %**	**4 %**
	USD in millions			
Annual Revenue (PQ)	3000	3600	3000	3600
Annualized capital (AC)	881	881	547	547
Annual Operating cost (OC)	1199	1199	1533	1533
Annual Royalty payments (RP)	210	252	210	252
Annual Normal profit (NP)	132	132	82	82
Annual Abnormal profit (RRT)	578	1136	628	1186
Firms' after tax earnings	404	795	440	830
Government earnings (without RRT)	383	593	398	608
Government earnings (with RRT)	751	1477	816	1542
Net Benefit without RRT @6 % growth	(1180)	(182)	(1040)	(42)
Net Benefit without RRT @7 % growth	(517)	**1120**	(320)	**1317**
Net Benefit with RRT @6 % growth	(812)	**702**	(622)	**892**
Net Benefit with RRT @7 % growth	(149)	**2004**	**98**	**2251**

Table-3
Economic analysis of 30 year project.

Coal price	$75	$90	$75	$90
Discount rate	**7 %**	**7 %**	**4 %**	**4 %**
	USD in millions			
Annual Revenue (PQ)	2025	2430	2025	2430
Annualized capital (AC)	302	302	217	217
Annual Operating cost (OC)	1102	1102	1187	1187
Annual Royalty payments (RP)	142	170	142	170
Annual Normal profit (NP)	45	45	33	33
Annual Abnormal profit (RRT)	434	811	447	823
Firms' after tax earnings	304	567	313	576
Government earnings (without RRT)	272	413	276	417
Government earnings (with RRT)	564	1054	581	1070
Net Benefit without RRT @6 % growth	(1069)	(739)	(1045)	(715)
Net Benefit without RRT @7 % growth	(943)	(503)	(915)	(476)
Net Benefit with RRT @6 % growth	(777)	(99)	(740)	(62)
Net Benefit with RRT @7 % growth	(651)	**137**	(610)	**178**

4. Economic analysis and conclusion

The primary aim of economic analysis is to maximize social welfare. While mining firms are entitled to normal profits (NP), the society owns natural resources. NP include payments to management, dividends to shareholders, and the cost of capital such that revenue – cost = 0. The New South Wales Treasury deems this to range between 10 and 15% of investment [39]. For this reason, some governments pay fees to mining companies for their services, engage in production sharing agreements, or tax resource rents (RRT) [31]. The RRT is revenue minus all costs including NP but excluding royalty payments. If the RRT is absent, the mining firms reap abnormal profits, which essentially is a transfer of ownership from the society to the mining firm while the society bears the cost of externalities. This point becomes particularly important when a foreign mining firm repatriates all profits and the net benefit to the host society is only corporate tax and royalty payments.

The fundamental premise of environmental accounting is the fact that the resource is exhaustible. Therefore, the Hartwick-rule suggests a weak sustainable path where produced capital substitutes depletion of natural capital [29,30]. Therefore, key concerns include, the rate of depreciation of natural capital and accumulation of produced capital, acceptable social discount rate, and opportunity and externality costs. For example, the mining site can be used for agriculture, solar, or wind farms. The withdrawal of huge amounts of river and underground water has its consequences for underground water level and the GBRWHA. For these reasons, economic analysis offers a good starting point even before legal safeguards are invoked. Table-1 below presents the salient features of the project along with alternatives for sensitivity analysis. The Australian government recommends a discount rate of seven percent for large infrastructure projects with moderate risk and four percent for minimum risk projects [40]. We calculate the operating costs using the production cost estimates by the Adani (USD 52/t). It is important to note that these are only production costs and do not include selling/transportation costs, which are estimated by experts close to USD 10–20/t.

Table-4
The applied Hartwik-rule economic analysis with opportunity and externality costs.

Project life	60 years		30 years	
Coal price	$90	$90	$90	$90
Discount rate	7 %	4 %	7 %	4 %
	USD in millions Annually			
Government earnings (without RRT)	593	608	413	417
Government earnings (with RRT)	1477	1542	1054	1070
Annual opportunity & externality costs				
Carbon emissions	136	136	136	136
GBRWHA	301	187	340	244
Mine rehabilitation	76	47	86	62
Water	1200	1200	1200	1200
Agriculture	20	20	20	20
Total	1733	1590	1782	1662
Net Benefit without RRT @1 % growth	(521)	(336)	(768)	(634)
Net Benefit without RRT @2 % growth	(347)	(153)	(679)	(544)
Net Benefit without RRT @3 % growth	(94)	**111**	(572)	(435)
Net Benefit without RRT @4 % growth	**279**	**500**	(442)	(303)
Net Benefit with RRT @1 % growth	363	598	(128)	19
Net Benefit with RRT @2 % growth	537	781	(39)	109
Net Benefit with RRT @3 % growth	790	1044	68	218
Net Benefit with RRT @4 % growth	1163	1434	198	350

Our analysis shows (Table-2) that the 60 year project is not viable under any scenario if average coal prices remain below USD 90/t. The past and future's ten year average coal price is USD 75/t. Given the fact that China and India are moving away from coal, the seaborne coal prices are unlikely to cross the USD 100/t profitability threshold for any sustained period over the next 30 years [8,10,11]. Secondly, in the absence of the RRT, the annual government revenues are not even weakly sustainable unless invested in their entirety with seven percent growth rate. This is an extremely unviable given that the long-term Australian bond rates hover below two percent. Even when the government imposes a 100% RRT, the project offers net benefits only when entire earnings are invested with a growth rate of six percent, again extremely unrealistic. Finally, the scaled down 30 year project does not offer any net benefits to Australia in most scenarios (Table-3). Therefore, the project is economically not viable and year's long legal battles were mere waste of resources. The project was not even financially viable if the Australian government had not provided enormous amounts of subsidies.

One may argue that using a market price to value the stock of a resource is a misplaced approach because the resource is only valuable when extracted not when underground. Therefore, the Hartwick-rule may not be applied. Although this criticism can be rebutted from a strong sustainability perspective, we address this argument by assigning a zero value to coal stock underground. However, we introduce opportunity and externality costs. We use the most conservative estimates possible and the data is offered by either the Adani group or the Australian government (Table-1) [41]. For example, we use only 1/200th of the river water price and price of carbon emissions only from mine operations (excluding the burning of coal). It is worth noting that the cost-benefit analysis, submitted to the Court by the Adani group, extends benefits (firm profits) of the project beyond Australian borders, however, it argues that the costs of burning coal shall not be included in the analysis [41].

Furthermore, the Adani group argued that for an environmental damage to offset the benefits of the project, an "unlikely" event to the magnitude of USD 16–43 billion would have to happen depending on the year of event. The group only considered low probability high impact catastrophe but ignored high probability low impact gradual damage accumulating over the years. We calculate the expected value of damage to the GBRWH = (0.02*43 + 0.30*43/4) billion USD. This translates into annualized damage from USD 190 to 347 million. These estimates are in line with the estimated USD 56 billion value of the GBRWH [42], assuming that seven percent (official discount rate) of that value will be eroded over a thirty year time period.

The most controversial aspect of the CCRMP project was the water license that allows the Adani group to withdraw 12.3 billion liters of water per year besides extracting unlimited groundwater. The impact of such huge amounts of water withdrawal was ignored despite warnings from the government scientific research agencies [4,33]. In order to factor in opportunity and/or externality cost of water, we take a fraction (1/200) of the water price that the Queensland government charges for river water (USD20/million-liter). Our analysis shows (Table-4) that without the RRT, the project offers net benefit only when the coal price is USD 90/t or above and the invested earnings grow at four percent over 60 years. It is only with the RRT that the project offers net benefits in most scenarios, yet any substantial benefits are only associated with a 60 year time frame with coal prices above USD 90/t.

In conclusion, the current legal safeguard fail to meet efficiency, sustainability, and equity criteria. The economic analysis conducted by the Australian government only calculated fiscal revenue ignoring the sustainability and equity issues. Our economic analysis which incorporates the Hartwick-rule, with or without opportunity/externality costs, shows that the project is not recommendable under any realistic scenario. It may become viable only when full resource rents are collected by the government and reinvested in their entirety for the development of natural or produced capital.

Competing interests' statement.

The authors state no conflict of interest with any individual or entity.

Data availability statement

- Supplementary MS Excel file with data, codes, and calculations is available.
- Correspondence and requests for materials should be addressed to I. Lodhi (iftikhar.lodhi@aucegypt.edu; ialodhi@gmail.com)

CRediT authorship contribution statement

Iftikhar Lodhi: Writing – review & editing, Writing – original draft.

Declaration of competing interest

The author does not have any conflict of interest. The research is presented entirely for public interest and from the publicly available data.

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