The Value of Oil Extraction in Ecuador's Rainforests

A Cost-Benefit Analysis of the Yasuní ITT Exploitation Project

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1. Background and purpose

The Yasuní National Park in Ecuador has been hailed as one of the most biodiverse regions in the world (Bass et al. 2010). In one single hectare of the park, one can find a greater number of tree species - 655 - than in all of America and Canada combined (Nadal 2007), and it tops field counts for amphibian and reptile diversity compared to other sites within the Amazon, harboring around one-third of the Amazon Basin's reptile and amphibian species despite only representing 0.15% of its total area. Similar results are true for bird and fish richness, and 44% of Ecuador's mammal species can be found coexisting in the Yasuní Park (Bass et al. 2010). Furthermore, a great number of species on the brink of extinction call the park their home, many of which are mammals such as the White-Bellied Spider Monkey and the Great Otter, making Yasuní a "threatened mammals hot spot" (Bass et al. 2010, p. 9). Its large size and wilderness character, its exceptional status as a strictly protected area according to IUCN[1] criteria, and its potential to maintain wet, rainforest-like conditions even under drier, climate-change induced scenarios make it even more valuable as a conservation area to preserve (Bass et al. 2010). Finally, it is also culturally unique, since several indigenous tribes live in the park, including two which live in voluntary isolation from the outside world (Larrea et al., n.d.).

However, the recent discovery of Ecuador's second largest untapped oilfield lying directly under the park (in the three adjacent Ishpingo, Tambococha and Tiputini oil fields, giving the entire block the name "ITT") has placed the Ecuadorian government in a difficult decision-making position: should it continue to preserve this globally unique area and forego the opportunity cost of drilling, or take advantage of the windfall earnings that this discovery had led it to expect? Initially, in 2007, the Ecuadorian President Rafael Correa stepped before the United Nations with a surprising third suggestion, the so-called "Yasuní-ITT Initiative". In it, the country's government committed to assuming half of the opportunity costs of leaving the oil in the ground if the international community were to contribute the other half of the expected earnings, at the time an estimated 3.6 billion dollars. This money was supposed to compensate Ecuador both for avoided greenhouse gas emissions and for contributing to the preservation of global biodiversity (Larrea et al., n.d.).

Despite an initial spike of interest and support, the global community did not contribute to the fund to the extent that the country had hoped, and in 2013 President Correa announced the government's decision to initiate drilling operations (DW 2013). After months of protests, the indigenous population agreed to the proposal in September 2013 (Mallen 2013), and the parliament approved this decision in early October (Valencia 2013). Currently, however, there exist plans to submit the plan to start drilling to a public referendum, as many environmentalists claim that the overall costs outweigh the benefits of the Yasuní ITT oil extraction project (Dudenhoefer 2013).

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[1] International Union for the Conservation of Nature

The purpose of this study is to examine this claim, using the theoretical and practical tools provided by ex-ante Cost-Benefit Analysis (CBA), in order to come up with a recommendation to the Ecuadorian government on whether to pursue its plan or to abstain from action.

2. Specification, standing, counterfactual

The drilling proposal that will be examined concerns the extraction of an estimated 913 million barrels of heavy crude oil from block 43, the so-called ITT block, over a period of 25 years (Vallejo et al. 2011). This data follows the plans of PETROAMAZONAS (2010) and BEICIP FRANLAB (2004), respectively, and would involve the extraction of the majority of proven reserves in the ground. We chose this number over the more conservative estimate of 846 million barrels of recoverable oil chosen by Larrea (2010) to take into account the possibility of the additional discovery of recoverable heavy crude amongst the estimated total uncertain reserves of 1'530 million barrels (Larrea 2010). It has to be taken into account that this assumption might give a more optimistic picture of the benefits of oil extraction over its environmental and social cost.

To evaluate the costs due to environmental degradation and biodiversity loss, we chose the time horizon of 300 years, as is often done when considering climate-relevant policy proposals, despite the valid argument that ecosystems can theoretically continue to provide services incessantly if well maintained. Yet, if run until eternity, the value of those services would be infinite and thus it would be impossible to create an informative cost-benefit analysis. 300 years seemed a reasonable time horizon to take into consideration when making present-day political decisions concerning future uncertain scenarios, as it also considers the utility of future generations of humans, and it is significantly longer than the minimum time frame of 100 years that should be used in evaluating projects for their sustainability according to Pearce (1998).

We evaluate the Yasuní-ITT drilling proposal against the status-quo counterfactual of not drilling, but not being compensated by the global community for doing so (since this is the choice the Ecuadorian government has, now that the Yasuní-ITT Initiative failed), and use a global scope of analysis in order to take into account the fact that local decisions can have global consequences in terms of climate change and ecosystem service destruction. In the sensitivity analysis, however, we will also consider limiting our scope of analysis to the Ecuadorian state and its people to account for the fact that it is the Ecuadorian state and not the global community making the drilling decision and it thus may be more appropriate to take a national perspective.

Thus, parties with standing in this case include the following:

- the people living in and around Yasuní which will be affected by the extraction activity (through environmental impacts and, perhaps, displacement), including the tagaeri and taromenane peoples that have chosen to live in voluntary isolation in the park.
- the global (or, respectively, Ecuadorian) people that derive value from the park's richness in biodiversity and provision of ecosystem services (this includes direct and indirect use values,

option value and existence value), as well as being negatively affected by the CO_2 emissions resulting from the extraction.

- the Ecuadorian government as beneficiary from (parts of) the oil revenues, as well as the provider of some of the infrastructure necessary for extraction to commence.

- the oil partner companies benefitting from the extraction of oil, as well as bearing costs related to infrastructure, extraction and transport of the oil (in the national scenario, this only holds as long as the company is Ecuadorian in origin) (Vallejo et al. 2011).

3. Prediction, classification and quantification of impacts

3.1. Benefits

3.1.1. Oil extraction revenues

The Ishpingo, Tambococha and Tiputini (ITT) oil field contains around 20% of Ecuador's oil reserves (Larrea et al., n.d.). The first certain impact of the exploitation of this field would be obviously the extraction of oil, and the raising of revenues linked to its sale. According to the study by Vallejo et al., the project in the ITT field will lead to extraction of about 913 million barrels of proved and probable reserves of heavy crude oil over 25 years (2011). With an API gravity (a measurement of density) of 14.7, the oil in ITT is considered heavy crude and requires heating and potential cracking as an upgrade in order to transport it through pipelines (Larrea et al., n.d.). According to the production plan of PETROAMAZONAS (2010), operations are initiated after an installation period which can take up to three years. This means that the revenue from oil will be received with a delay; we assume that it will start in year 3 of the project, that is, 2016. The exploration will be based on the contractual agreement between the National Hydrocarbons Secretariat of Ecuador and foreign risk-bearing companies which will extract the oil for a specific fee for each barrel of net crude oil produced and delivered to the state at control point. Following Vallejo et al., once operations are initiated, the production can be maintained at an average of 100'000 barrels per day for 25 years, with a maximum of 190'000 barrels per day and a minimum of 50'000 barrels a day (2011, p. 69). Using the daily average amount extracted of 100 thousand barrels gives us the final amount of crude oil extracted over 25 years (some of which are leap years) of 913.2 million barrels of oil. However, as explained in section 3.1.2, 15% of the extracted oil will be consumed by the thermoelectric power generation and the synthetic crude conversion plant (Larrea 2010, p. 8). Thus, the commercially available daily amount of oil is 85'000 barrels a day bringing the total amount of oil sold to the market over 25 years at 776.22 million barrels using the average daily extracted amount of 100'000 barrels due to the absence of information on the precise distribution of extraction volumes over the whole time period. Revenues from this sold oil will be distributed between the government of Ecuador represented by the Ecuadorian national oil company Empresa Estatal Petroleos del Ecuador (Petroecuador)

and several foreign contracting companies: Petrobras, Chilean national oil company Empresa Nacional do Petróleo (Enap), and SIPC, a subsidiary of Chinese national oil company Sinopec, that signed the MoU with Petroecuador to develop the ITT field (Petrobras 2007), at a share of 65% of revenues flowing to the government and 35% to the international companies (Larrea et al., n.d.).

3.1.2. Avoided carbon emissions through use of gas

An additional indirect effect and a source of income stems from the use of gas released during the process of oil extraction. This gas can be used as fuel for thermal heaters that generate electricity further used in production instead of burning it. Several projects in other oil fields in Ecuador have used nearly half of released gas for this purpose, while burning the remaining half (Vallejo et al. 2011, p. 81). The emissions of CO_2 avoided by not burning this gas have been substantial. Vallejo et al. estimated that for ITT field the amount of emissions avoided this way would be 6.9 million tonnes of CO_2 (2011, p. 81). These emissions will be saved over the period of oil extraction - 25 years -, giving the annual amount of CO_2 saved of 6.9/25= 0.276 million tonnes of CO_2 equivalents. This annual values will need to be further discounted to obtain the present value of avoided carbon emissions, but since there are also CO_2 emissions caused through the extraction project (discussed under Section 3.2.2.), we can simply subtract the emissions avoided from the emissions caused to arrive at a net emissions caused estimate as done below.

3.2. Costs

3.2.1. Building of infrastructure and oil purification facility

Commencing the project requires the construction of various types of new infrastructure. Despite the claims that modern technologies used for offshore drilling will be applied to minimize deforestation and road construction, a few technical aspects still require investment into new facilities. The field has oil of higher density and would require processing prior to transportation. PETROECUADOR proposed the installation of a conversion plant to improve the crude density up to 18 degrees API, and relatedly the construction of a thermoelectric power plant (Vallejo et al. 2011, p. 69). It also has to be considered that the new facility will use an estimated 15% of the energy found in the ITT block to convert the rest into the improved density crude variety (Larrea 2010, p. 8). Access to the Tambococha and Tiputini fields could be gained largely by using and upgrading the already existing production facility El Eden, though the pumping, heating and storage facilities would need to be expanded and modified (Vallejo et al. 2011, p. 87). One more platform and a number of pipelines would be necessary to connect the new facilities to the existing ones. For the Ishpingo field, additional oil wells and pipelines would also have to be installed to extract the oil and transport it to the conversion plant and to further processing facilities. According to plans provided by the oil companies PETROAMAZONAS and

PETROECUADOR, the exploitation of the full ITT field would require the construction of at least three additional platforms, 43 wells in cluster structures, and 20 km of additional pipelines and 'right-of-ways' (Larrea 2010, p. 11).

3.2.2. CO_2 emissions caused by oil combustion

The CO_2 emitted when the Yasuní-generated fossil fuel is burnt - enough to supply the entire world's demand for 10 days (Vallejo et al. 2011) - will have an impact on the global atmospheric balance and, in the long run, on global temperatures through the greenhouse effect. This can be seen as an environmental externality caused by the drilling project that should not be ignored. The CO_2 equivalents of the heavy crude extracted can be derived in a relatively straightforward manner and amount to 443 million tonnes of CO_2 under the assumption of the extraction of 920 million barrels of oil (Vallejo et al. 2011, p. 97), or via simple extrapolation (443 million/920 million*913.2 million/25) = 17'589'000 tonnes of CO_2 per year over the extraction period of 25 years, assuming that an average of 100'000 barrels per day is extracted.

Other impacts of oil combustion include, according to Vincente de Assuncao, the creation of pollutants such as ozone, sulfur and nitrates, as well as *"acid deposition, effects on vegetation, alteration of atmospheric visibility, increased turbidity of the atmosphere, and damage to materials"* (n.d., p. 1). However, it is difficult to quantify these effects properly, especially considering the fact that we have no knowledge where and to which purpose the oil extracted in Yasuní will be used. Thus, we chose to omit this effect from our analysis and trust that a higher-end value of carbon (as detailed below) might be able to catch some of the non-carbon related damages of oil combustion.

3.2.3. Environmental costs of presence of extraction facilities

The deforestation required for the TT portion of the project is rather minor according to the oil companies' plans: The El Eden facility takes up 1 hectare of land, to which the new platform and transportation lines would add another 17 hectares within the national park; an additional 96.90 ha would be added outside of the national park to account for access roads, camps and the installation of a port. However, to that one needs to add the area affected by seismic exploration and the establishment of heliports, which brings Vallejo et al. to estimate the entire area affected by deforestation in the TT field to 431.50 ha (2011, p. 89), and Covell extrapolates from a similar low-impact extraction process in an adjacent oilfield (block 16) that the best-case scenario for the full ITT project would incur the deforestation of around 1'000 hectares of rainforest, though his worst-case scenario is a full four times higher at 4'000 hectares (2009). To err on the side of caution, we here assume a middle-range scenario of 2'000 hectares of deforestation.

It is challenging however to attempt to quantify in which way the exceptional biodiversity of the park would be affected by drilling, since such activities can interrupt ecosystems in a multitude of ways above and beyond the destruction of habitat stemming from deforestation. Other adverse

impacts can include visual and noise disturbance, pollution, introduction of invasive species, soil erosion, and illegal hunting due to the increased access that are not linearly related to forest cover (Butt et al. 2013). Furthermore, it is unclear how the extraction operations will affect the lifestyle of the indigenous tribes that chose to live in the Yasuní in voluntary isolation. Any intrusion might very well represent the end of their lifestyle as they know it, which represents a basically invaluable loss of cultural diversity to the Ecuadorian inheritance. Due to this high level of uncertainty in impact quantification, it will be essential to conduct thorough sensitivity analyses in latter parts of this paper.

In any drilling operation, there is the potential of leakage and spills occurring, with potentially serious consequences for wildlife and human health and safety. To take account of this factor, but also the uncertainty surrounding it, it is convenient to use an expected value of potential spilling that incorporates different probabilities and different sizes of accidents. Here we follow Vallejo et al. (2011) in using Arteaga's (2003) estimate of 0.04 barrels spilled for each 1'000 barrels produced, which would result in an expected 36'800 barrels spilled over the entire ITT extraction operation. The clean-up and potential non-remedial consequences of such an expected spill should be included in a complete cost-benefit analysis, even if the real cost is likely to deviate from this estimate, as it is more likely that either no spill or a big spill would occur.

Furthermore, two additional environmental consequences are directly linked to a commencement of drilling activities: first, the production of formation water, which is water contaminated with oil, salt and grease that is a side-product of oil extraction, needs to be taken into consideration. PETROECUADOR estimated that in the ITT project, 8.1 barrels of formation water would accompany the extraction of each barrel of heavy crude. This amounts to a total amount of 6'548 million barrels of formation water that would need to be disposed of, most probably through reinjection into the ground (Vallejo et al. 2011, p. 97). Second, according to the SOS Yasuní website, well-drilling in the ITT fields would also lead to the creation of 65'000 cubic metres of solid waste and between 325'000 and 390'000 cubic metres of liquid waste that would be *"left beneath the drilling platform, a mechanism through which toxic elements are spread by the first rains"* (Sosyasuni, n.d.b). Such potential toxic spills might also need to be taken into consideration.

4. Methods used in impact valuation

There are several tools economists can use to estimate the societal costs or benefits of various projects. This next section will introduce the methodological framework that would ideally be used for the valuation of the diverse impacts of the Yasuní-ITT extraction project. Because of resource constraints, no primary data collection was possible, which is why Section 5 on the numerical monetization of impacts is mainly based on secondary data sources. Still, under ideal conditions the following would be the steps that would need to be followed for a comprehensive CBA.
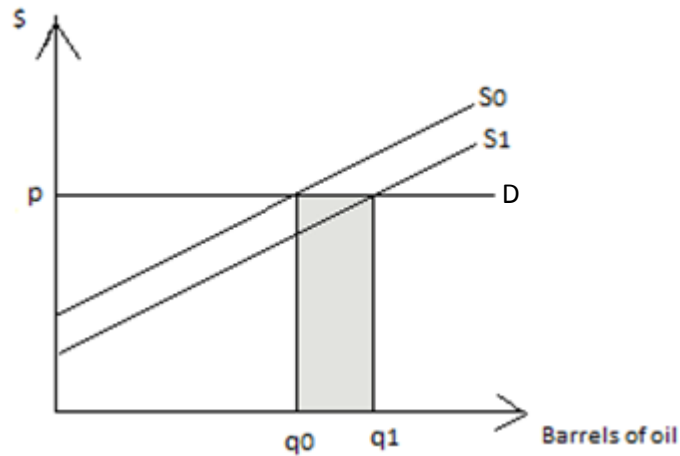
4.1. Benefits

4.1.1. Oil extraction revenues

Oil is a tradable commodity for which the market has been established long ago. The oil market is characterized by numerous actors, of which the role of the Organization of the Petroleum Exporting Countries (OPEC) has been widely examined in the literature. Particularly, Böckem came to the conclusion that *"OPEC appears to be a price-leader cartel and all non-OPEC countries are regarded as price-takers"* (2004, p. 1367). When Huppmann examined and compared various market structures for crude oil, he concluded a decline in market power of OPEC countries because of the high level of spare capacity since the oil price collapse in 2008 and the global recession that reduced the OPEC mark-up prices bringing the equilibrium close to a competitive benchmark (2013). These findings comply with conclusions of Huppmann and Holz (2012). Furthermore, in 2012 the total world production of crude oil was 74'141 million barrels a day of which OPEC contributed 42.9%; Ecuador, as the smallest oil producing member of OPEC that joined only in 2007, represented a mere 0.67% of the world production (EIA 2012a). We can thus assume that the country has minimal influence on the world price development and in practice faces an efficient market.

In order to monetize the impact of Ecuadorian government acting as a producer extracting the ITT oil reserves (with a share of profits going to contractors) the observed oil price is an easy measure of benefits, although not necessarily the conceptually 'correct' one (Boardman et al. 2011). In CBA costs and benefits are based on the concept of willingness-to-pay and benefits are the sum of the maximum amounts that people would be willing to pay for a policy outcome, in our case elicited by the market prices. According to Boardman et al., the valuation of gross benefits in efficient markets relies on the rule that gross social benefits equal the net revenue plus the change in social surplus (2011). This approach also applies to the current project which will directly affect the quantity of the good available to consumers. The extraction of oil in the ITT field will increase the supply of oil in the world market gradually over the exploitation period although with varying intensity. However, the size of the project over the exploration period is small relative to the market capacity. The global demand for oil is projected to be on the current levels in 2030 as technological efficiency changes, recent high prices and the international crisis have already led to a reduction of 10% of oil demand in developed countries since 2005 which offsets the growth in emerging markets (Larrea 2010). Thus in the case of a long-run horizontal demand curve, shifting the supply curve faced by consumers right by the additional amount of oil supplied by Ecuador results in Ecuador following the world prices. The increase in social surplus is then equal to governmental revenue and producer surplus since no consumer surplus exists. Consumers purchasing more of the good increase governmental revenues and producer profits (as oil is supplied to the market by the government, which then shares 35% of its net revenues with the contractors) by the amount of price times the additional quantity as indicated in Figure 1 following Boardman et al. (2011).

However, regarding the specific levels of prices there has been substantial volatility in recent decades and long-term projections vary greatly as on the one hand, global agreements on climate may cut the demand for fossil fuels and on the other, new production methods and discoveries may increase the supply significantly. Thus, the uncertainty of world oil prices that Ecuador will face is central to measuring the benefits of extracting oil in the ITT field and will be further accounted for. The operational and transportation costs of extraction will have to be subtracted from the obtained gross benefits.

4.2. Costs

4.2.1. Building of infrastructure and oil purification facility

When valuing the inputs to a certain project, the conceptually correct measure to use is the sum of opportunity costs of the particular resource used. This is equivalent to *"the value of the goods and services that would have been produced had the resources used in carrying them out been used instead in the best alternative way"* (Boardman et al. 2011, p. 99). According to the literature, the opportunity cost can be approximated as the budgetary outlay for the resource as long as the market for the resource is efficient and the project is limited enough in scope to have no effective impact on the price of the particular input (ibid.) This assumption should hold in the case of the investment decisions related to the oil field, as they are relatively small operations. Thus, in this case we can assume a perfectly elastic supply curve where prices are constant for the purpose of the project, and equate the budgetary outlay to the social cost:

Figure 2: Small construction project with no impact on market prices
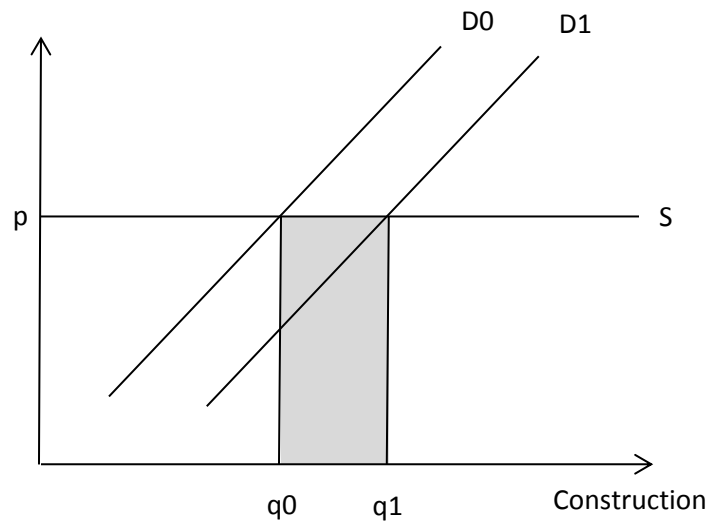
In addition, it is important to note that any already incurred investments, such as the existence of infrastructure close to the Yasuní field that can be repurposed, are treated as sunk costs and not included in the cost-benefit analysis.

4.2.2. CO$_2$ emissions caused by oil combustion

When extracting non-renewable carbon-based resources from the ground and burning them, CO$_2$ and other greenhouse gases are released into the atmosphere and contribute to global warming. Assessing how to value the environmental impacts of such emissions properly is a task fraught with contradictions. While on the one hand, cap-and-trade markets for carbon emission certificates exist, at least in Europe, which should reflect the shadow price for carbon emissions avoided and in (Pigouvian) theory should be equal to the social valuation of such carbon emissions, one could argue that these prices are based on total caps of emissions that have been set politically and are in addition highly dependent on the overall level of economic activity, which makes their accuracy in valuing the long-term social costs of emissions questionable (Ackerman & Stanton 2010).

Instead, it seems more appropriate to use the dose response (or damage function) approach, which estimates unit increases in a pollutant to various effects this pollution can cause and tries to give dollar values to these effects (Boardman et al. 2011, p. 429). While this approach is often used to quantify health impacts, one could easily draw the parallel to estimate the effects of unit increases in CO$_2$ emissions on global economic activity for a given time period - in our case, 300 years - in order to quantify the marginal social cost of a one unit increase in carbon emissions. This is widely done using modelling approaches, though the cost estimates are very sensitive to the assumed discount rate and other model assumptions (van den Bergen & Botzen 2013).

### 4.2.3. Environmental costs of presence of extraction facilities

Environmental costs provide a particular challenge in cost-benefit analysis because the goods and services affected are typically not traded in market environments. Thus, economists have to make use of shadow pricing and quasi-market methods to approximate a reasonable value for the goods in question.

Deforestation in rainforest areas can affect a multitude of different forest ecosystem services that would ideally all need to be valued separately. In general, one can differentiate between direct use values, indirect use values, option values and existence values. According to Andersen's valuation of Brazilian Amazon rainforest areas, these include, but are not limited to: "*sustainable timber harvesting, non-timber products (nuts, fruits, latex, etc.), tourism, and genetic material [direct use values], [...] soil and watershed protection, fire prevention, water recycling, carbon storage, and biodiversity protection [indirect use values], [...] the insurance premium we are willing to pay to secure that the forest, its biodiversity, and its ecological services are available in the future, in the case we find out that we need it [option value], [... and] the value we are willing to pay to secure the survival and well-being of other species [existence value]*" (1997, p. 3).

These values all seem to reasonably exist in the Yasuní National Park as well. Concerning direct use values, studies have found that around 3% of the total area is also used for logging and 31% for hunting (Naughton-Treves et al. 2006). Also, the Yasuní-ITT initiative spoke of the potential for moderate ecotourism development were the national park to stay untouched, which might be considered as a lost opportunity cost if drilling starts. As for the indirect use values, Amazon rainforests tend to have a similar composition and thus it is likely that the Ecuadorian forest yields similar ecosystem services as a Brazilian one. The same can be said for option and existence values.

Direct use values are easiest to estimate, since they can be approximated using market mechanisms, for example through examining the markets for sustainable logging or hunting products that exist around the Yasuní Park. The conceptually correct measure to use for the societal cost is the combined producer and consumer surplus lost through a reduction of the area available for those activities. If we are thus in the ideal position to estimate demand and supply curves for the renewable logging and hunting products, we can estimate the societal cost by measuring the change under the demand curve (but over the old/new prices) and over the supply curve (under the old/new prices) and summing the two. Since there is some redistribution from consumers to producers occurring, we find the net social cost as the remaining change in consumer surplus (blue) and producer surplus (mauve) as in Figure 3 below.

Figure 3: Shift of supply curve resulting in changes of consumer and producer surplus
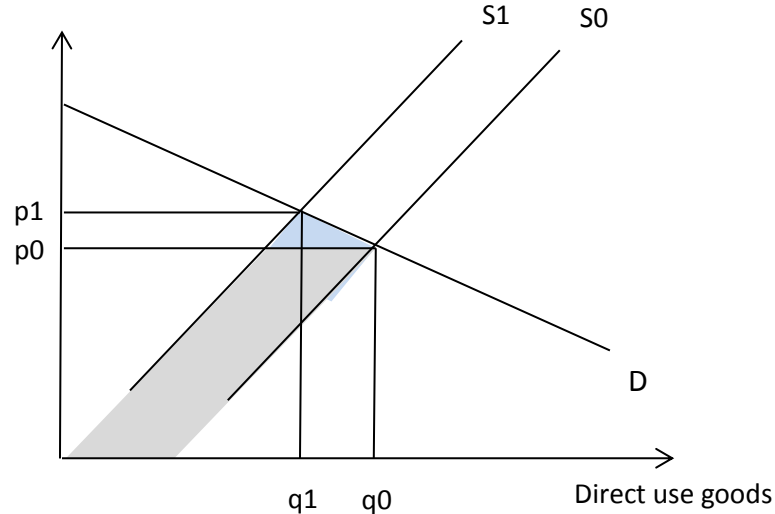
Since this use value assumes a regeneration and renewal of the resource thus harvested, it would also be necessary to sum the loss in social utility over the years in question - 300 - and discount them according to the correct discount rate.

A similar procedure could be applied to approximate the ecotourism revenues lost. However, this might only capture the expenses paid on-site and underestimate the total willingness-to-pay to visit the Yasuní on the whole. Alternatively, the travel cost method seems well-suited to capture the total value of the Yasuní for its visitors; here, ecotourists visiting the park would be polled on their origin and the money and time spent to arrive at the park and to visit it. Then, extrapolation procedures could be used to estimate the amount of visitors the park would receive at different hypothetical prices of entry to arrive at a more reliable demand curve for ecotourism in the region. One would then have to decide whether the loss in ecotourism potential is proportional to the loss in forest area or overproportional since the attraction of the Yasuní as a 'pristine rainforest' would be lost once drilling starts.

Indirect use values such as fire prevention, carbon storage or water recycling do not have a direct market price, but can be estimated using the defensive expenditure (or avoided cost) method. Here, ecosystem services are assumed to be replaceable by man-made alternatives and their value is equivalent to the costs avoided by not having to use the industrial alternatives. For example, one could estimate the costs of building and operating a water recycling plant for the Ecuadorians living close to the national park and value the ecosystem service the park provides for free at the same amount. This is also the ideal method used to estimate the cost of environmental degradation through drilling - for example, the potential cost of oil spills and the production of formation water can be estimated (at a minimum value) as their clean-up cost in case such degradation occurs. If oil spills also affect biodiversity or have other non-reversible effects, those would of course have to be valued separately. Furthermore, in case of uncertain consequences of a project (such as oil spills in the case of drilling), it is appropriate to use

probabilities to estimate the expected value of such uncertain events, rather than to make assumptions on their occurrence or non-occurrence.

Some non-market traded use values (such as the value of the Yasuní as ancestral homeland for the indigenous tribes living there at the moment), option and existence values are difficult to derive even from these indirect market methods (which use observed behavior and revealed preferences) and thus are best approximated by contingent valuation methods which survey individuals on their stated preferences and willingness-to-pay for certain goods. Thus, we could consider creating surveys asking the local indigenous tribes as well as Ecuadorians and global citizens for their willingness to pay to conserve the Yasuní rainforest. In designing the survey, one would have to be very careful to avoid common flaws such as hypotheticality (through making the description of the good and service in question and the payment vehicle as precise as possible), noncommitment bias and embedding effects (by putting the questions in context and using top-down disaggregation methods for example) (Boardman et al. 2011).

One can see that one simple consequence of the project - in this case, deforestation - might call for a number of methods used and studies conducted to fully appreciate its monetary impact. Since such thorough analysis falls outside of the scope of this paper, we will continue in Section 5 using the approximations used in previous studies and adapting them for our context.

4.3. Marginal excess tax burden

Finally, an ideal cost-benefit analysis would take the marginal excess tax burden (METB) into consideration that the government would save by raising funds through extraction activities rather than taxing its citizens or firms. The marginal excess tax burden stems from the inefficiencies and the deadweight loss associated with administrative activities and non-ideal expenditures of public funds and can reach a high proportion of the original tax dollar paid - in studies based in the US, it is as high as 20 to 40 cents on every dollar (Boardman et al. 2011). Unfortunately, accurate estimates of the METB do not currently seem to exist for Ecuador; additionally, it might be incorrect to assume that the money raised through the oil extraction would supplant taxation as source of government revenue. Rather, in its communications the government has treated this money as additional funds that could be invested in local development that would not necessarily be spent if the Yasuní were left untouched. Furthermore, its current economic situation makes it more dependent on external loans than on in-country taxation and it is likely that additional funds would rather be raised through this avenue as well in the case of non-exploitation (Dudenhoefer 2013); thus, we felt that pragmatically there was no need to multiply the government revenues by the METB in this case.

5. Monetization of impacts

5.1. Benefits

5.1.1. Oil extraction revenues

As indicated previously, the increase in social surplus from extracting and selling more oil equals the price of oil times the additional quantity of oil supplied to the market. As stated, the amount of crude oil expected to be sold is 776.22 million barrels over the 25 years. In the situation of uncertainty about the oil price development, obtaining the estimated projections of crude oil prices is possible due to data from different organizations like the World Bank, the International Monetary Fund or the Economist Intelligence Unit, which monitor commodity prices and make short- and long-term forecasts and projections. In the short run, there are various factors that influence oil prices, including factors that only have short-lived impacts. For the purpose of this analysis we require data on price development scenarios for the next 28 years. Such long-term prices are influenced by expectations about future demand of energy fuel and the production decisions of the main producers of crude oil. We will thus refer to estimates of crude oil prices provided by the US Energy Information Administration (2012b). For the projections as of 2013 they use the spot prices for light, sweet Intercontinental Exchange Brent crude oil instead of WTI crude oil traded on NYMEX in order to better reflect the price refineries pay for imported light, sweet crude oil and to take into account the divergence of WTI prices from those of globally traded benchmark crudes such as Brent (EIA, 2012b). They provide yearly price estimates until 2040 which is exactly our period of analysis. The data is given in the reference scenario accompanied by high and low price scenarios. We will use the reference scenario data for primary computations and high and low scenarios for the sensitivity analysis. The prices are given in 2011 US$ per barrel, which we transform into the real 2012 US$ by dividing by the deflator provided by the World Bank for the US in 2011 – 113.3 and multiplying the by most recent deflator for 2012 - 116 (2013). For the reference price scenario we use here the prices in 2012 US$ in the range from 99.31 US$ to 162.68 US$. Table 1 with all oil prices and revenue calculations is presented in the Appendix.

By multiplying the prices in 2012 US$ by the respective commercial amount of ITT oil in that year we obtained gross revenue from the sale of oil. In order to get the net revenues we need to subtract annual transportation and operational costs. According to Larrea et al. (n.d.) the operating cost is $12.32 per barrel and transportation costs are $2.60 per barrel in 2009 dollars. Thus we convert them using the GDP deflator for US in 2009 - 109.5 into total annual variable cost in 2012 US$ of 14.93/109.5*116 = 15.80 US$ per barrel. This annual variable cost is multiplied by the annual extraction to obtain the total annual variable costs. Overall, we calculated the total net revenues to be $86'298'345'560 over the 25 years. However, the yearly net revenues will need to be discounted in the following section to use the present value of net revenues for our analysis. This value will represent the global benefits from oil extraction.

5.2. Costs

5.2.1. Building of infrastructure and oil purification facility
Based on PETROECUADOR estimates from 2009, the total initial capital investment for the purification facility and the infrastructure used to access the Yasuní ITT fields amounts to 3.5 billion US$ (Larrea et al., n.d.) and would be borne by an international partner company such as Sinopec (from China) or Petrobras (from Brazil), both of which have signed Memoranda of Understanding with the state-owned company to explore the Yasuní-ITT reserves (Petrobras 2007). According to the World Bank's GDP deflator (2013), this is equivalent to 3.707 billion US$ in 2012 values. This capital investment would occur in the very beginning of the project period, which is why we attribute it to year 1 (2014) in the numerical cost-benefit analysis. In addition, transportation and operational costs will occur per barrel of oil produced, which as outlined in section 5.1.1. can however be accounted for by using net revenues rather than gross revenues in the analysis of benefits.

5.2.2. CO_2 emissions caused by oil combustion
Currently, there is a strong scientific debate concerning the accurate valuation of the social costs of carbon. One frequently cited meta-study (Tol 2009) placed the average certainty equivalent of the marginal social cost of carbon at 25 US$ per ton of carbon emitted; this number has subsequently also informed US policy makers which have set their social cost of carbon to roughly 21 US$/ton. However, Tol's study has been widely criticized for oversampling from some climate models rather than others and excluding alternative values without sufficient grounds to do so, biasing the median cost downward (Ackerman & Stanton 2010; van den Bergh & Botzen 2013). Furthermore, most models used in the meta-study ignore the potential catastrophic impacts of climate change or behave in other unrealistic ways (Ackerman & Stanton 2010).
An alternative valuation of the social cost of carbon that received much attention is that used in the Stern Review of 85 US$ (2000 values) per ton of carbon in a business-as-usual scenario without significant global efforts to contain atmospheric CO_2 concentration levels. This number takes into consideration *"the damage that the associated temperature rise causes includes economic and non-economic categories as well as the consequences of catastrophe risks for eight different regions"* (van den Bergh & Botzen 2013, p. 5) and is already presented as a net present cost of the entire future consequences of the emission of one additional ton of CO_2 equivalent today. Considering the current stalling of the Kyoto Protocol and subsequent negotiation rounds, a business-as-usual assumption seems more realistic than the optimistic assumption that *"the world will take substantial action towards an upper stabilisation goal limit of 550ppm CO_2e"* that, for example, the UK Department for Environment, Food and Rural Affairs took in 2007 (Price et al. 2007).

It is also closer to the minimum value of van den Bergh and Botzen (2013), which they consider as 100 US$/ton, and falls into the confidence interval of the United Kingdom's new methodology related to mitigation costs of emitted carbon, which is 41 to 124 US$/ton with a central case of 83 US$/ton (van den Bergh & Botzen 2013). In this project, we decided to take a precautionary approach and use Stern's higher-end estimate in an effort to avoid the pitfalls of ignoring real social costs and consequences of global warming, including ecosystem changes that prove notoriously hard to put a dollar value on.

Transforming the 2000 nominal US$ values into real dollar values for our estimation in 2013 is possible using a GDP deflator such as provided by the World Bank (2013). Its value was 116.0 in 2012 and 88.7 in 2000, making the real value of Stern's estimate 85 US$/0.887*1.16 = 111.16 US$/ton of CO_2 equivalent.

Furthermore, staying consistent with the valuation of oil revenues requires us to start valuing the CO_2 emissions in the year that extraction begins, aka year 3 from the start of the project, and to value emissions annually taking into account the social discount rate.

This would mean that we estimate global yearly emission costs as the emissions caused due to extraction (the previously calculated 17'589'000 tonnes of CO_2 per year) over the extraction period of 25 years, but account for the avoided carbon emissions in-country due to the non-combustion of gas from oil extraction as described in section 3 b) with 0.276 million yearly tonnes of CO_2 to arrive at 17.313 million tonnes of CO_2e per year at 111.16 US$/ton = 1'924.513 million US$ per year over 25 years.

Sensitivity analyses will take the lower value of 25 US$/ton and upper bound of 124 US$/ton (transformed into 26.48 US$ and 129.58 US$/ton respectively in 2012 values) into consideration.

5.2.3. Environmental costs of presence of extraction facilities

The total cost of the partial deforestation and disturbance of a hitherto untouched nature reserve is difficult to predict accurately. Nevertheless, the think tank Earth Economics has made a valiant effort to value the Yasuní National Park, and the ITT portion of it, basing its estimates on an aggregation of the techniques described above (such as direct market pricing, replacement and avoided costs, and travel costs methods as well as contingent valuation), and utilizing *"geographic data and information systems on land cover vegetation cross-referenced with an extensive literature review of peer reviewed scientific journal articles on the economic value of ecosystem services"* (Batker, Kocian & De La Torre 2007, p. 4) to estimate the values of the 4 different forest types present in Yasuní directly. These forest types - a) evergreen forest of Low Lands of the Amazon; b) Forest of Low Lands of Palms and Black Water; c) Forest of Low Lands inundated by White Water; and d) Other (Natural forest, Pastures, Cultivated, Eroded) - all have slightly different contributions to ecosystem functioning and have different dollar values per acre attached to them, ranging from 0$ (for the 'Other' category) to 5'776.00 $/acre/year (for category c). Earth Economics then uses the overall surface area of the different forest covers found in the Yasuní ITT region and the low and high range per acre values to arrive at an overall value of the ITT between 300 million and 810 million US$ (in 2007 values) per year (Batker,

Kocian & De La Torre 2007). Using the GDP deflator again (World Bank 2013), this would correspond to a real value of 327 million to 885 million US$ in 2012 values.

It should be noted that throughout their analysis, the economists stress that the value ranges are underestimates, since it is likely that not all ecosystem services have been correctly identified and valued, that the values of ecosystem services have risen faster than inflation, and that *"the vast majority of renewable resource value is held in the distant future"* which the 300 year timeframe might not be able to capture (Batker, Kocian & De La Torre 2007, p. 9).

Even knowing an estimation of the total environmental value of the area leaves some uncertainty about how much of the total value would be destroyed if drilling began, however. The estimation of a deforestation of 2'000 hectares, which is only around 1.5% of the total area within the ITT of 129'000 hectares, seems insufficient to capture the entire effect on biodiversity and ecosystem services that can occur through a multitude of avenues, as explained above. Additionally, we have to take the costs of waste management and potential spillage into consideration as well, which could be incorporated directly in the environmental value lost. Finally, the analysts of Earth Economics also did not consider the cultural value of the Yasuní as the homeland of the tagaeri and taromenane peoples in their analysis, which would ideally need to be included. To start our analysis, we thus decided to use a destruction rate of two-thirds (67%) of total value due to drilling to incorporate some of the latent values that would otherwise be unaccounted for, and will go back to this number later during our sensitivity analyses. This first estimate would lead us to an annual loss value of 218 million to 580 million US$ over a period of 300 years, starting with the drilling operations in year 1.

6. Discounting of impacts

Following Boardman et al. (2011, p. 261), we use a time-declining discount rate to take into consideration individuals' time inconsistency, uncertainty in the far future about market developments, and to eschew the ethical dilemma of effectively not valuing the utility of future generations at all we would run into if we used a constant discount rate. Thus, we used a discount rate of 3.5% for years 1 to 50, 2.5% for years 51 to 100, 1.5% for years 100 to 200 and 0.5% for years 200 to 300. These values are suggested by Boardman et al. (2011) following the research of Richard Newell and William Pizer (2003), which is based on the historical behavior of interest rates as evaluated through the U.S. government's real, long-term bond rate. This leads to the stylized discount table on the following page:

Year	Discount rate (r)	Benefits: Oil revenues	Costs: construction	Costs: Carbon emissions	Costs: ecosystem lost
Welfare change		65% Δ GR, 35% Δ PS	Δ PS	Δ Third party	Δ Third party
1 - 2	3.5%		3'707 million (year 1)		218 - 580 million/year
3 - 28	3.5%	3'451 million net benefits (on average)/year		1'924 million/year (already with B from avoided emissions)	218 - 580 million/year
29 - 50	3.5%				218 - 580 million/year
51 - 100	2.5%				218 - 580 million/year
101 - 200	1.5%				218 - 580 million/year
201 - 300	0.5%				218 - 580 million/year

Using the formula (following Boardman et al. 2011):

$$NPV = \sum_{t=1}^{300} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{300} \frac{C_t}{(1+r)^t}$$

We arrive at the following values:

PV (Benefits) = 50'788'862'205 US$
PV (Costs) = 40'199'714'176 US$ to 52'158'220'035 US$
PV (Net Benefits) = + **10'589'148'029 US$ to -1'369'357'830 US$**

over the 300 year time horizon that we considered the project under. To restate the original baseline assumptions, this value is based on a moderate estimate of oil extraction and oil price development (refer to Table 1 in the Appendix for the exact oil prices), a social cost of carbon of 111.16 US$/ton CO_2 following Stern (2006), an assumption of low and high rainforest value following Batker, Kocian, and De La Torre (2007) and an assumed destruction of this value by two-thirds due to drilling. We can see that whether the project yields net benefits or net costs is very dependent on the final value we place on the rainforest destroyed in the process. This result points toward a relative sensitivity of our results based on the assumptions we make that warrants further analysis. This is done in the next section on sensitivity analyses.

7. Sensitivity analysis

The sensitivity analysis that follows will first estimate the net present value of best- and worst-case scenarios, and then identify break-even values of some of the variables that pose the greatest problems to estimate correctly: the ecosystem value of the Yasuní and the development of oil prices. Finally, we also consider the possibility that Ecuador's government would prefer to take a national approach and again look into the break-even valuation of its national park it would have to assume to decide whether to drill or not.

7.1. Best-case scenario

For this sensitivity analysis we vary the following uncertain parameters in the benefit-favourable way. We use the high oil prices scenario (EIA 2012b) and larger proven, probable and possible reserves totalling 1'531 billion barrels assumed to be evenly daily distributed (Sosyasuni, n.d.a), of which again 85% are brought to market. Table 2 in the Appendix illustrates the yearly values of oil revenues in 2012 US$. 100% of the extraction values were subsequently used to recalculate the amount of carbon emissions avoided and caused. For the costs, we assumed that only one-tenth of the original rainforest destruction rate occurs (6.7% rather than 67%), because the main damage stems from the 1.5% of the territory that is deforested (with trickle-down effects), but the overall ecosystem manages to recover and find a new balance that lets it continue to offer most of its services. We also use the lower-value estimate of Batker, Kocian and De La Torre's valuation (2007), which yields a yearly cost of 21.8 million US$ of ecosystem loss. Furthermore, we follow Tol (2009) to use a lower social cost of carbon of 26.48 US$ (corresponding to 25 US$ 2009 adjusted to 2012 values).

These assumptions led us to the total present value benefits of 164'004'304'827 US$, costs of 18'194'774'657 US$, and a net present benefit of **145'809'530'170 US$**.

7.2. Worst-case scenario

This analysis uses cost-favourable values of same uncertain parameters as previously. Low oil prices are used (EIA 2012b) as well as lower amount of oil "in situ" that can almost certainly be commercially produced - totalling 412 million barrels of oil (Sosyasuni, n.d.a). For yearly values please refer to Table 3 in the Appendix. Again, carbon emissions avoided and caused are calculated using the 100% estimates of the oil brought to the surface.

It was now assumed that the entire (higher estimate) value of the Yasuní ITT region would be destroyed due to extraction, leading to a yearly loss of 885 million US$ (Batker, Kocian & De La Torre 2007). Finally, we used an upper-bound estimate of the social cost of carbon of 129.58 US$, following UK methodology (van den Bergh & Botzen 2013).

Thusly estimated, the total discounted benefits equal 9'606'224'718 US$, while the present value costs amount to 50'352'016'946 US$, yielding a total net present loss of **-40'745'792'228 US$**.

7.3. Break-even values of ecosystem valuation

We modeled yearly ecosystem values of 100 million US$ to 1'000 million US$ with the baseline oil extraction assumptions, but under different scenarios of oil prices and carbon emission costs, to find break-even points for the project that could aid the government in deciding what valuation of the environment would be reasonable. The results can be extracted from the graphs below:

Figure 1: Breakeven analysis of rainforest value (SCC $111,16)

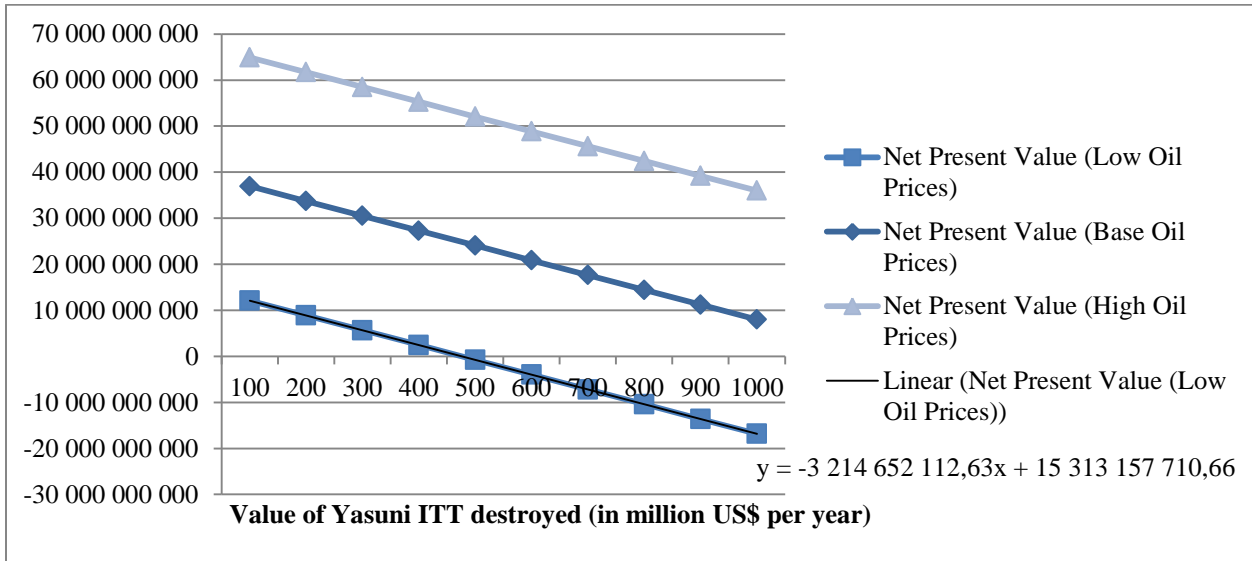$$y = -3\ 214\ 652\ 112{,}63x + 17\ 597\ 089\ 634{,}13$$
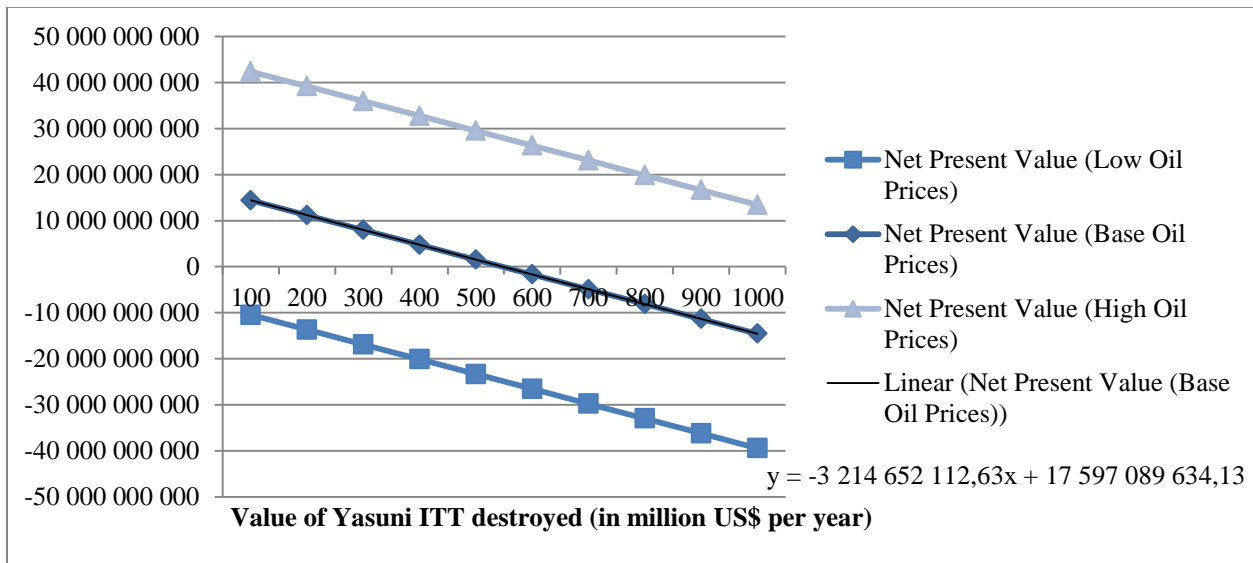
As can be read from the analysis, under social costs of carbon of 111.16 US$ and baseline oil prices, a break-even point occurs at a yearly valuation of the rainforest destruction of 547.40 million US$, which is rather close to our initial higher-end estimate of 580 million US$. Yet, we find that this conclusion is also highly sensitive to oil price estimates, as the project would yield net losses even at a yearly ecosystem valuation of only 100 million US$ if oil prices follow the low-range estimate, and would be a net benefit even at a rainforest valuation of 1'000 million $ if prices follow the high-range projections.

Similarly, it can be noted that the rather subjective valuation of the social cost of carbon can equally make a large impact on the final conclusion. Repeating the analysis with the low carbon costs of 26.48 $ per ton of CO_2e emitted makes the baseline oil price scenario beneficial even at very high values of ecosystem services, and brings us a break-even point with low oil prices at around 476.36 million US$ per year. Alternatively, using a price of 129.58$ per ton of carbon emitted lowers the breakeven point of the baseline oil price scenario to 394.77 million US$ per year, as is illustrated in Figures 2 and 3 on the following page.

Figure 2: Breakeven analysis of rainforest value (SCC $26,48)

Legend:
- Net Present Value (Low Oil Prices)
- Net Present Value (Base Oil Prices)
- Net Present Value (High Oil Prices)
- Linear (Net Present Value (Low Oil Prices))

$y = -3\ 214\ 652\ 112{,}63x + 15\ 313\ 157\ 710{,}66$

X-axis: **Value of Yasuni ITT destroyed (in million US$ per year)**

Figure 3: Breakeven analysis of rainforest value (SCC $129,58)

Legend:
- Net Present Value (Low Oil Prices)
- Net Present Value (Base Oil Prices)
- Net Present Value (High Oil Prices)
- Linear (Net Present Value (Base Oil Prices))

$y = -3\ 214\ 652\ 112{,}63x + 12\ 690\ 481\ 180{,}70$

X-axis: **Value of Yasuni ITT destroyed (in million US$ per year)**
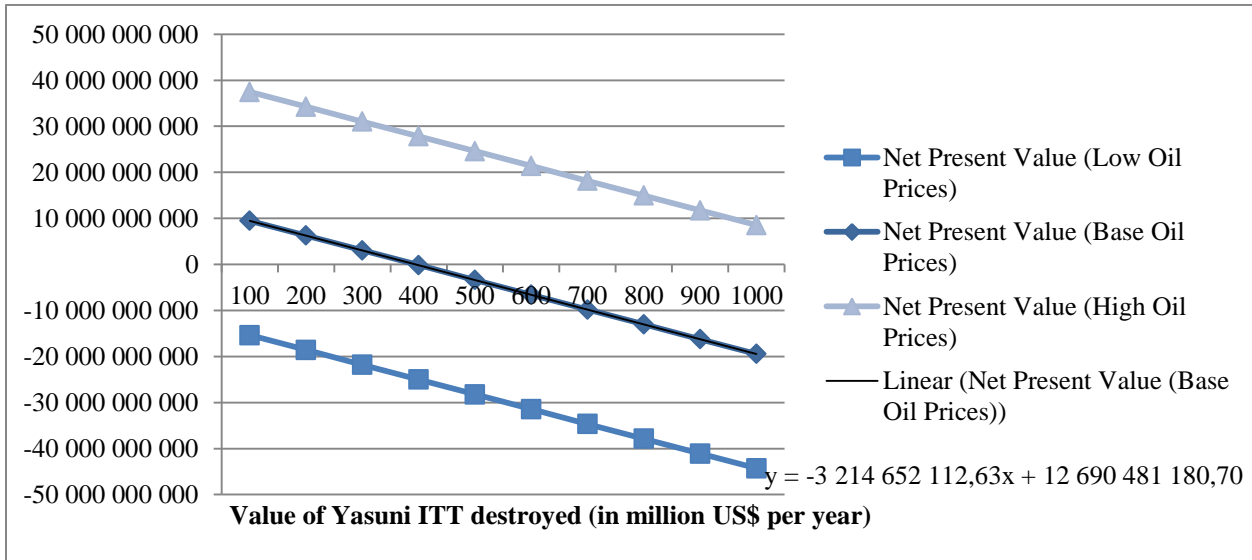
7.4. Break-even values of oil prices

For this sensitivity analysis we were interested to see which average oil price over the 25 years of exploitation would equate the present value of benefits to that of costs under the baseline assumptions for all values except oil prices. We compared the present value of benefits under different oil prices constant over the 25 years for simplicity and due to lack of forecasted data for various average prices for this period. In the case of lower bound present value of costs under the

reference scenario (40'199'714'176 US$) the break-even price of oil in 2012 US$ is 102.74 US$. For the upper bound of present value of costs (52'158'220'035 US$), the break-even price of oil in 2012 US$ is 127.78 US$. Both of these break-even prices are smaller than the average of our reference scenario – 129.77US$, thus if the values used for monetizing the costs and amount of reserves in the baseline accurately represent reality it is likely that benefits will indeed exceed the costs. Here again, we need to recognize the importance of the discount rate in influencing our final results – as we see, if we had an average price of 127.78 US$ over the entire period, our project would break even with the higher assumed costs, but because the higher prices in later periods are discounted versus the lower prices in earlier periods, we found a negative net present value at the prices of the reference scenario.

7.5. National scope of costs and benefits

Finally, since the decision ultimately lies in the hands of the Ecuadorian government, we could consider carrying out a cost-benefit analysis that is national rather than global in scope, in which we only consider the part of the global costs and benefits that Ecuadorian citizens bear. In order to do so on a schematic level, we make the simplifying assumption that the economic impacts of climate change are equally distributed across all global citizens, which is probably an underestimation of Ecuador's costs, seeing as low-income countries are those that in tendency will be affected more strongly (van den Bergh & Botzen 2013). This would signify that the total annual cost stemming from emissions affecting Ecuadorians are 1'969.755 million US$/ 7'095'217'980*15'439'429 (CIA 2013) = 4'286 million US$/year. In addition, since international companies would assume most of the 3'770 million US$ in up-front capital investment costs, we could exclude these from the national analysis. According to sample contracts, the government and national companies however would still bear half of the transportation and operational costs and would only receive 65% of the revenues from the commercially proven and probable reserves. Using these assumptions, we again examine break-even points for the valuation of the Yasuní from a national perspective.

Figure 4: National breakeven analysis of rainforest value (SCC $111,16)
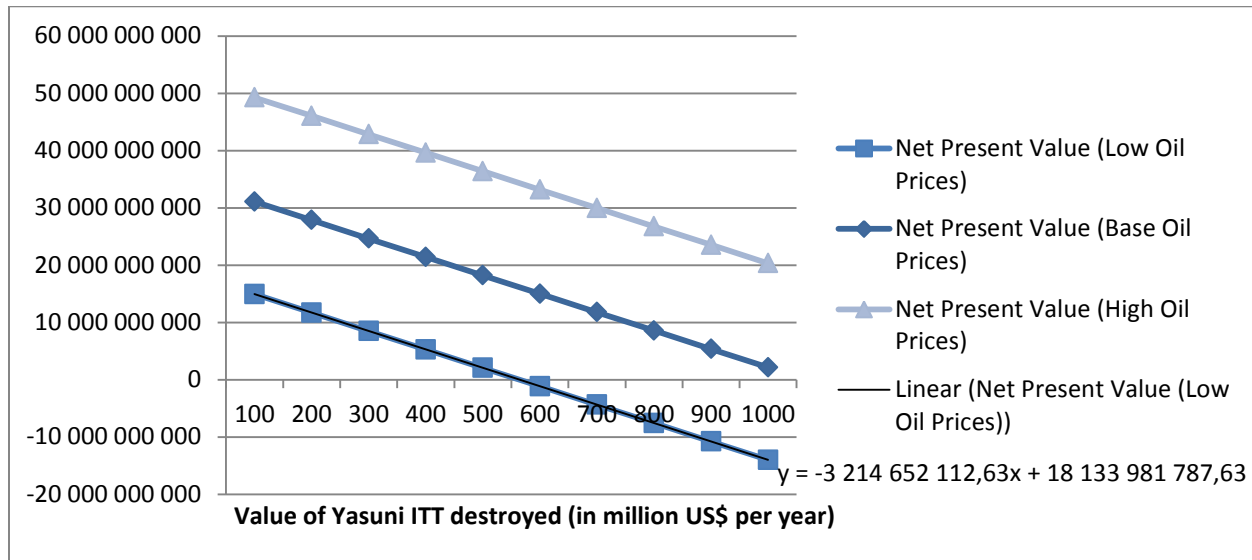
We find that from a national perspective, the benefits mostly outweigh the costs in the high and mid-range oil price scenarios, unless one let the ecological value of the Yasuní ITT region go over 1'000 million US$. Under the low-oil price scenario, we find a break-even point for the ecosystem service costs at around 564.10 million US$ per year, which is close to the break-even point in our original scenario with normal oil prices. This is intuitive if one considers that Ecuador covers less of the initial costs and a much smaller percentage of the climate change consequences from its oil exports than the share of the revenues from those exports. Thus, one can understand the governmental decision-making process in terms of the oil extraction allowance that has gone forward; to the extent that it is relying on median-range estimates of both oil extraction levels and prices, it is making a decision that seems to be yielding a net benefit for the country as such, even if on a global level it is more difficult to draw such a conclusion.

8. Conclusion and recommendation

This CBA of the oil extraction project in the Yasuní Park in Ecuador, unique in its biodiversity, has proved to be a rather complex but socially and economically relevant task due to the vast predictable and uncertain environmental impacts of the oil drilling operations on the park flora and fauna, the ecosystem services it provides as well as the climate implications for all of humanity. It must be noted that in order to obtain our results, we have referred to previously conducted estimations to value these diverse effects; thus, our baseline results hinge very much on the accuracy of our secondary data and extensive sensitivity analysis was carried out to check the robustness of our findings.

Firstly, examining the issue from a global perspective, we used the higher average amount of oil revenues among alternatives for the reference scenario, moderate oil price growth as well as also higher moderate values for social costs of carbon and both upper and lower value bounds for ecosystem destruction. This brought us to witness that the sign of net benefits depends on the value of ecosystem destruction chosen: we obtain net benefits of 10.6 billion US$ with a lower value of ecosystem and a net loss of -1.4 billion US$ if the upper bound of the ecosystem value is applied.

Testing this by the worst- and best-case sensitivity analysis reveals that uncertainty over the oil prices, reserves exploited, actual social and environmental cost of destroying the Ecuadorian rainforest ecosystem effects the change in social surplus from the project with an immense magnitude: our calculations result in 40.7 billion US$ of net loss (worst-case) versus 145.8 billion US$ of net gain (best-case scenario). Therefore, searching for the break-even value of ecosystem valuation under different varying parameters was insightful to provide any valid recommendation. The 547.4 million US$ break-even cost of ecosystem services seemed to justify sticking to the initial higher-end estimate. However, it could be seen that even high-range rainforest valuation leads to a net benefit from oil extraction if the prices of oil follow their higher estimated trajectory. Speaking of oil prices, interestingly break-even values under both high and low value of ecosystem are smaller than the average of reference oil price projections thus pushing towards overall net benefits if the initial moderate level assumptions hold true. Analysis from the Ecuadorian perspective only seems to confirm the government's decision to reap most of oil revenues at the expense of the smaller share Ecuador has in the total global costs induced.

However, the government should bear in mind that the project's environmental impacts could greatly contribute to the destabilization of critical biophysical systems and trigger abrupt or irreversible global and local environmental changes potentially effecting Ecuador overproportionally. Furthermore, as previously stated, it is close to impossible to accurately estimate the total costs of ecosystem destruction accurately; for one, there might be values linked to a functioning ecosystem that we do not know of yet, and furthermore, it is difficult to place dollar values on services provided in theory until eternity because then the issue of valuation of future generation's welfare becomes central to the analysis. In this analysis, due to the existing large number of uncertain parameters, we have not carried out sensitivity analyses with respect to the discount rate used; however, it should be noted that this is an additional factor that could dramatically change the conclusion reached.

Therefore, as illustrated previously, before concluding either net benefits or net costs of this project we must highlight that it is subject to great sensitivity of the main uncertain parameters and, guided by the precautionary approach, it is advisable to support the environmentalist-driven call for a national referendum with the purpose to delay the carrying-out of the project until more certain information about future prices and environmental valuations is at hand. In this regard, the avenues for further analysis are numerous: adopting alternative manners of time-declining discounting, deriving the quasi-option-value for the decision to not undertake full development at

present, assessing the implications of the climate change for Ecuador, evaluating the rainforest ecosystem resilience to partial destruction, and incorporating into CBA the effects from pollution by ozone, sulfur and nitrates released from oil combustion are only some of the ways forward that would shine even greater light on this difficult decision.

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10. Appendix

Table 1: Benefits in reference scenario

Year	Annual amount of oil sold (barrels)	Price of oil in 2012$/b	Annual Transportation and Operational Cost	Global Net Revenues	Discounted at 3.5% Global Net Revenues
2016	31110000	99.31	578280000	2511302701	2265051153
2017	31025000	101.44	576700000	2570511050	2240051876
2018	31025000	103.61	576700000	2637851456	2221000144
2019	31025000	105.82	576700000	2706462436	2201708935
2020	31110000	108.09	578280000	2784268925	2188410207
2021	31025000	110.40	576700000	2848449047	2163145123
2022	31025000	112.76	576700000	2921824678	2143833261
2023	31025000	115.18	576700000	2996788526	2124479767
2024	31110000	117.65	578280000	3081760703	2110838784
2025	31025000	120.16	576700000	3151163230	2085387196
2026	31025000	122.74	576700000	3231209373	2066048692
2027	31025000	125.36	576700000	3312526090	2046418298
2028	31110000	128.04	578280000	3405052088	2032443647
2029	31025000	130.78	576700000	3480877105	2007442404
2030	31025000	133.58	576700000	3567593760	1987876727
2031	31025000	136.44	576700000	3656216275	1968364760
2032	31110000	139.36	578280000	3757328219	1954395654
2033	31025000	142.34	576700000	3839496531	1929599970
2034	31025000	145.57	576700000	3939554210	1912932895
2035	31025000	148.88	576700000	4042153036	1896378647
2036	31110000	152.25	578280000	4158336943	1884914396
2037	31025000	155.71	576700000	4254338844	1863218047
2038	31025000	159.25	576700000	4363925825	1846582074
2039	31025000	162.86	576700000	4476053954	1829979473
2040	31110000	166.56	578280000	4603300554	1818360074
Total	776220000		14428560000	86298345560	50788862205

Table 2: Benefits in worst-case scenario

Year	Annual amount of oil sold	Price of oil in 2012$/b	Annual Transportation and Operational Cost	Global Net Revenues	Discounted at 3.5% Global Net

	(barrels)				Revenues
2016	16512484	75.43	578280000	667183911	601761662
2017	16467367	70.64	576700000	586625768	511210466
2018	16467367	70.44	576700000	583253809	491084056
2019	16467367	70.34	576700000	581567829	473105804
2020	16512484	70.54	578280000	586542363	461016995
2021	16467367	70.85	576700000	589997726	448051091
2022	16467367	71.16	576700000	595055664	436610771
2023	16467367	71.46	576700000	600113603	425431823
2024	16512484	71.77	578280000	606829545	415645296
2025	16467367	72.08	576700000	610229479	403839677
2026	16467367	72.38	576700000	615287417	393417330
2027	16467367	72.69	576700000	620345355	383238064
2028	16512484	73.00	578280000	627116727	374320091
2029	16467367	73.31	576700000	630461231	363590719
2030	16467367	73.61	576700000	635519169	354113683
2031	16467367	73.92	576700000	640577107	344861822
2032	16512484	74.23	578280000	647403909	336750827
2033	16467367	74.53	576700000	650692984	327016095
2034	16467367	74.84	576700000	655750922	318413567
2035	16467367	75.15	576700000	660808860	310018893
2036	16512484	75.46	578280000	667691091	302654779
2037	16467367	75.76	576700000	670924736	293836275
2038	16467367	76.07	576700000	675982674	286040033
2039	16467367	76.38	576700000	681040612	278435058
2040	16512484	76.68	578280000	687978273	271759840
Total	412000000		14428560000		9606224718

Table 3: Benefits in best-case scenario

Year	Annual amount of oil sold (barrels)	Price of oil in 2012$/b	Annual Transportation and Operational Cost	Global Net Revenues	Discounted at 3.5% Global Net Revenues
2016	61360710	146.07	578280000	8384672893	7562494555
2017	61193057	149.19	576700000	8552850479	7453315075
2018	61193057	152.39	576700000	8748322600	7365852885
2019	61193057	155.65	576700000	8948180314	7279350451
2020	61360710	158.98	578280000	9176870524	7212937279
2021	61193057	162.38	576700000	9359799492	7107939898
2022	61193057	165.86	576700000	9572813983	7023870110
2023	61193057	169.40	576700000	9789587553	6940022795
2024	61360710	173.03	578280000	10038801649	6876034161
2025	61193057	176.73	576700000	10238171011	6775450580

Year	Annual amount of oil sold (barrels)	Price of oil in 2012$/b	Annual Transportation and Operational Cost	Net Revenues	Discounted at
2026	61193057	180.52	576700000	10469980898	6694549268
2027	61193057	184.38	576700000	10706176378	6614080810
2028	61360710	188.32	578280000	10977376796	6552293227
2029	61193057	192.36	576700000	11194230168	6455778715
2030	61193057	196.47	576700000	11446088478	6377803759
2031	61193057	200.68	576700000	11703585406	6300755576
2032	61360710	204.97	578280000	11998878261	6241284806
2033	61193057	209.36	576700000	12234868608	6148827563
2034	61193057	213.84	576700000	12508654880	6073838843
2035	61193057	218.41	576700000	12788706284	5999829620
2036	61360710	223.09	578280000	13110844801	5942957592
2037	61193057	227.86	576700000	13366977976	5854163363
2038	61193057	232.74	576700000	13665198263	5782387503
2039	61193057	237.72	576700000	13970310196	5711589081
2040	61360710	242.81	578280000	14320815171	5656897312
Total	1531000000		14428560000		164004304827

Table 4: Benefits from national perspective in reference scenario

Year	Annual amount of oil sold (barrels)	Price of oil in 2012$/b	Annual Transportation and Operational Cost (50% of global)	Net Revenues (65% of global)	Discounted at 3.5% Net Revenues
2016	31110000	99.31	289140000	1719088756	1550519563
2017	31025000	101.44	288350000	1757337183	1531417829
2018	31025000	103.61	288350000	1801108447	1516484983
2019	31025000	105.82	288350000	1845705583	1501482681
2020	31110000	108.09	289140000	1896516801	1490645063
2021	31025000	110.40	288350000	1937996880	1471737227
2022	31025000	112.76	288350000	1985691041	1456963018
2023	31025000	115.18	288350000	2034417542	1442236870
2024	31110000	117.65	289140000	2089886457	1431458771
2025	31025000	120.16	288350000	2134761100	1412749242
2026	31025000	122.74	288350000	2186791093	1398243306
2027	31025000	125.36	288350000	2239646959	1383613108
2028	31110000	128.04	289140000	2300025857	1372863857
2029	31025000	130.78	288350000	2349075118	1354725508
2030	31025000	133.58	288350000	2405440944	1340320785
2031	31025000	136.44	288350000	2463045579	1326008025
2032	31110000	139.36	289140000	2529005342	1315476520
2033	31025000	142.34	288350000	2582177745	1297714442
2034	31025000	145.57	288350000	2647215237	1285410692
2035	31025000	148.88	288350000	2713904474	1273229996

2036	31110000	152.25	289140000	2789661013	1264513260
2037	31025000	155.71	288350000	2851825248	1248977212
2038	31025000	159.25	288350000	2923056786	1236882679
2039	31025000	162.86	288350000	2995940070	1224853160
2040	31110000	166.56	289140000	3078887360	1216198200
Total	776220000		7214280000		34344725996